3 Citrus

The large citrus fruits of today evolved originally from small, edible berries over millions of years. Citrus plants are native to subtropical and tropical regions of Asia and the Malay Archipelago, and they were initially domesticated in these areas. The generic name “citrus”, originated from Latin and it is referred to the plant now known as Citron (C. medica). These plants are large shrubs or small to moderate-sized trees, reaching 5–15 m (16–49 ft) tall. They have spiny shoots and alternately arranged evergreen leaves with an entire margin. The world’s largest citrus-producing countries are Brazil, China, the United States, Mexico, India, and Spain.

Citrus plants are prone to infestation by aphids, whitefly, and scale insects. Also, the viral infections of citrus are a major concern for which some of these ectoparasites serve as vectors. The newest threat to citrus groves in the United States is the Asian citrus psyllid. In this chapter, detailed information about citrus diseases and their preventive measures is discussed.

3.1 **ALTERNARIA BROWN SPOT OF CITRUS**

*Alternaria alternata* is an opportunistic pathogen on over 380 hosts. In citrus, it especially affects mandarins. Alternaria brown spot first appeared in Florida 30 years ago. Currently, brown spot is also known to occur in South Africa, Turkey, Israel, Spain, and Colombia. It has become a severe problem on some varieties in recent years. Grapefruit can also be affected, although it is not a common commercial problem in that species.

### 3.1.1 Causal Organism

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. alternata</em></td>
<td>Rot of Leaves, Twigs, and Fruits</td>
<td>Severe</td>
</tr>
</tbody>
</table>

### 3.1.2 Symptoms

Alternaria brown spot attacks leaves, twigs, and young fruit. On young leaves, lesions first appear as small brown to black spots, which soon become surrounded by yellow halos (Figure 3.1). A fungal-specific toxin that is responsible for much of the necrosis produces the halo. The spots on young leaves can appear as early as 36–48 hours after infection. The toxin is sometimes translocated in the vascular system, producing chlorosis and necrosis that extend out along the veins from the lesions. Spots enlarge as the leaves mature and if the disease is severe the leaves may drop, or the entire shoot may die. Young shoots are also attacked, usually producing lesions 1–10 mm in diameter. Shoot infection and abscission of infected, young leaves produce dieback of twigs.

Fruitlets may be infected soon after petal fall, and even a small lesion causes immediate abscission. The lesion is then surrounded by yellow halo (Figure 3.2).

On more mature fruit, symptoms vary from small, dark specks to large, black lesions on the peel. Fruits are susceptible for at least three months after petal fall. Even after that time, some fruits may fall as the result of earlier infections. Symptoms of this disease are sometimes confused with those of anthracnose.

### 3.1.3 Favorable Conditions for Disease Development

Spore production is greatest at relative humidity of above 85%. Spores are airborne and release into the air is triggered by rainfall or by a sharp change in relative humidity. Once the spores
are released, they are moved by the wind to susceptible tissue where they can infect. When temperatures are favorable (20°C–29°C (68°F–83°F)), the length of the wetting period required for infection is about eight to ten hours. When temperatures drop below 17°C or above 32°C (63°F and 90°F, respectively), the fungus requires extended leaf wetness duration (>24 hours) to cause significant infections.

**FIGURE 3.1** Small brown to black spot surrounded by yellow halo.

**FIGURE 3.2** Lesions on fruit surrounded by yellow halo.
3.1.4 Disease Cycle

Spores of the fungus are thick-walled, multicellular, and pigmented and thus tolerate adverse conditions well.

Spores are produced primarily on old lesions on mature leaves that remain on the tree as well as those which have fallen to the ground, but they are not produced on fruit. Spores are airborne and carried by winds. Rain events or sudden changes in relative humidity trigger spore release.

The length of the wetting period required for infection is about eight to ten hours when the temperature is favorable (20°C–29°C). At temperatures of less than 17°C, extended periods of leaf wetness (greater than 24 hours) are needed before much infection occurs. Most of the infection probably follows rains, but dew is often sufficient for infection (Figure 3.3).

3.1.5 Management

There are many management practices that are helpful in reducing disease severity.

- In new planting of susceptible varieties, use disease-free nursery stock.
- Trees grown in greenhouses without overhead irrigation are usually free of Alternaria. If foliage remains dry, the disease never develops.
- Selection of appropriate planting sites: Choose a location with good air circulation and wind movement. Avoid foggy areas.
- Increase the spacing between trees and pruning tree skirts.
- Avoid excessive vegetative growth: Control over-fertilization and over-watering (Table 3.1).

3.2 Citrus Black Spot

Citrus black spot is one of the most important diseases in major citrus production areas of the world, such as Asia, South America, South Africa, and Australia. This disease is primarily important as a pre-harvest disease and causes severe lesions on the rind which significantly decreases the fruit quality and its marketability.

Late maturing acid lime, mandarins, and grapefruit are the most susceptible varieties.

FIGURE 3.3 Disease cycle of A. alternata causing alternaria brown spot.
3.2.1 **CAUSAL ORGANISM**

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Phylllosticta citricarpa</em> (Asexual Stage)</td>
<td>Lesions on Rind</td>
<td>Severe</td>
</tr>
<tr>
<td><em>Guignardia citricarpa</em> (Sexual Stage)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.2 **SYMPTOMS**

There are four main fruit symptom types:

3.2.2.1 **Hard Spot**
- This is the most common diagnostic symptom (Figure 3.4).
- The lesions are small, round, sunken with tan centers and with a brick-red to chocolate brown margin.
- Green halos are often seen around the hard spot lesions.
- Fungal structures appear as slightly elevated black dots.
- Lesions are most prevalent on the side of fruit that receives the most exposure to sunlight.

3.2.2.2 **False Melanose**
- Also known as Speckled Blotch.
- These are observed as numerous small, slightly raised lesions that can be tan to dark brown (Figure 3.5).
- The slightly raised lesions are 1–3 mm in diameter.

### TABLE 3.1
**Recommended Chemical Controls**

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOA</th>
<th>Mature Trees Rate/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper fungicide</td>
<td>M1</td>
<td>Use label rate.</td>
</tr>
<tr>
<td>Ferbam Granulfo</td>
<td>M3</td>
<td>5.0–7.5 lb.</td>
</tr>
<tr>
<td>Abound 2.08 Fc</td>
<td>11</td>
<td>12.0–15.5 fl oz. Do not apply more than 92.3 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem 25 WGc</td>
<td>11</td>
<td>4.0–8.0 oz. Do not apply more than 32 oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem 500 SCc</td>
<td>11</td>
<td>1.9–3.8 fl oz. Do not apply more than 15.2 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Headlinec</td>
<td>11</td>
<td>12–15 fl oz. Do not apply more than 54 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Pristinec</td>
<td>7/11</td>
<td>16–18.5 oz Do not apply more than 74 oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Quadris Topd</td>
<td>11/3</td>
<td>15.4 fl oz. Do not apply more than 61.5 fl oz/acre/season for all uses. Do not apply more than 0.5 lb ai/acre/season of difenconazole. Do not apply more than 1.5 lb ai/acre/season of azoxystrobin.</td>
</tr>
</tbody>
</table>

**Note:** This table is from PP-147, one of a series of the Plant Pathology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 1995. Revised February 2012.

- **Rate/Acre**: Lower rates can be used on smaller trees. Do not use less than minimum label rate.
- **C**: Do not use more than 4 applications of strobilurin fungicides/season. Do not make more than 2 sequential applications of strobilurin fungicides.
- **D**: Do not make more than 4 applications of Pristine or Quadris Top/season. Do not make more than 2 sequential applications of Pristine or Quadris Top before alternating to a non-strobilurin, SDHI or DMI fungicide.
• It may occur on green fruit and does not have pycnidia (fungal structures).
• False melanose may become hard spot later in the season.

3.2.2.3 Cracked Spot
• Cracked spot has large, flat, dark brown lesions with raised cracks on their surface.
• It is thought to be caused by an interaction between the pathogen and rust mites.
• It occurs on green as well as mature fruit and can become hard spot later in the season.

3.2.2.4 Virulent Spot
• Lesions are sunken and irregular in shape and occur on heavily infected, mature fruit toward the end of the season.
• In high humidity, large numbers of pycnidia may develop.
• The lesions can turn brown to black with a leathery texture that eventually covers the entire fruit (Figure 3.6).
• Virulent spot may cause premature fruit to drop and serious post-harvest losses since the symptoms may extend into the fleshy part of the fruit.

3.2.2.5 Symptoms on Leaves and Stem
• Leaf and stem symptoms although not as common as fruit symptoms can occur when there is insufficient disease control on any cultivar.
• They are most commonly found on acid lime, a very susceptible species.
• Lesions begin as small reddish-brown lesions that are slightly raised.
• With age, they become round sunken necrotic spots with gray centers and prominent margins that are brick-red to chocolate brown.

3.2.3 **CAUSE AND DISEASE DEVELOPMENT**

Wind-borne ascospores are forcibly ejected from fungal fruiting bodies embedded in leaves in the leaf litter under trees and are carried by air currents, approximately 75 ft (25 m) from the leaf litter. Rain splash may also move spores from fruit infected with conidia and/or leaf litter (conidia and ascospores), but only moves the spores a few inches. Live leaves that have latent infections (infections that are not visible) are common means of long-distance spread. These often are moved as trash in loads of fruit. Infected nursery stock is another potential means of spread. This can occur very easily since these latent infections cannot be seen in otherwise healthy looking trees. Leaf litter movement may be either by wind or human activities. Humans are the main form of long-distance movement.²

3.2.4 **FAVORABLE CONDITIONS OF DISEASE DEVELOPMENT**

Moist climate favors the development of the disease. Spores are released only when the leaf litter is wetted by heavy dew, rainfall, or irrigation.

3.2.5 **DISEASE CYCLE**

As with many diseases, timing is important for black spot to occur. Inoculum in the leaf litter needs to be available during the period when the host is susceptible, and the environment is favorable for infection. Fruits are susceptible from fruit set until five to six months later when they become age resistant. Both the ascospores (sexual spores) and the conidia (asexual spores) of *G. citricarpa* are able to infect susceptible tissues. Ascospores are found in microscopic fungal structures embedded in the leaf litter. They are the most important source of inoculum, in some regions causing nearly all infections. Ascospores have never been found in fruit lesions or lesions on attached leaves. Spores are released when the leaf litter is wetted by heavy dew, rainfall, or irrigation and can be carried...
by air currents over long distances. Dark brown or black pycnidia, structures that produce conidia, are formed on fruit, fruit pedicles, and leaf lesions. They are also abundant on dead leaves. Conidia are not wind-borne but may reach susceptible fruit by rain splash. These spores are not considered a significant source of inoculum in climates with dry summers; however, in climates with frequent summer rains, conidia play a larger role in the epidemic when there are multiple fruit ages present on trees simultaneously. Often late hanging fruit with lesions remain on the tree and spores can be washed onto young susceptible fruit.

Infections are latent until the fruit becomes fully grown or mature. At this point the fungus may grow further into the rind producing black spot symptoms months after infection, often near or after harvest. Symptom development is increased in high light intensity, intensifying temperatures, drought, and low tree vigor (Figure 3.7).

### 3.2.6 Management

- Always plant clean, certified nursery stock. Keeping nursery stock clean is much easier with the new covered nursery regulations but black spot is still a threat. This will help prevent movement of black spot and other diseases into newly established grove plantings.

- Increase airflow in the grove to reduce leaf wetness where possible. *G. citricarpa* needs 24–48 hours of leaf wetness for spore germination and infection as do many other fungal diseases.

- Reduce leaf litter on grove floor to decrease ascospore load through enhanced microsprinkler irrigation.

- Fungicides registered for citrus in Florida that have been found effective in other countries: Copper products (all formulations have been found to be equivalent).

- The best fungicide application method is with an airblast sprayer. Aerial applications are not likely to get adequate canopy penetration for control. It is important that the leaves and fruit are covered with fungicide.

- For enhanced coverage, increase the gallons used to 250 gal/A for applications to ensure full coverage (Table 3.2).

![FIGURE 3.7 Disease cycle of *G. citricarpa*.](image)
3.3 GREASY SPOT OF CITRUS

Greasy spot is a major foliar and fruit disease on citrus. It causes premature leaf drop beginning in the fall and continues through winter and spring. As a result, yields of the following crop are reduced. Furthermore, cold damage has been observed to be more severe on severely defoliated trees. Rind blemish from this disease causes a downgrading of fruit intended for the fresh fruit market and this can be particularly severe on grapefruit.

3.3.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mycosphaerella citri</td>
<td>Greasy Spot on Leaves and Rind Blotch on Fruit</td>
<td>Severe</td>
</tr>
</tbody>
</table>

3.3.2 SYMPTOMS

The first symptom to appear is a small yellowish blister on the underside of the leaf. This is matched by a yellow mottle on the upper surface of the leaf. Later, infected areas of the leaf turn dark brown and become greasy in appearance (Figure 3.8). Leaf drop of infected leaves is common.

On the fruit, symptoms may take several months to appear after infection. They take the form of brown specks in the skin, where cells have died (Figure 3.9).

On most cultivars, the specks are too small to cause a significant blemish, but coloring may be delayed in areas around them. This results in unsightly patches of green on the ripe fruit. In grapefruit, the lesions are larger and often form large, speckled patches. The lesions are pink at first, and later turn brown.

3.3.3 CAUSE AND DISEASE DEVELOPMENT

Spores are produced in decomposing fallen leaves and are released when the leaves become wet. Germination of the spores requires high temperatures and high humidity.

### TABLE 3.2

**Recommended Chemical Controls for Citrus Black Spot**

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOA</th>
<th>Mature Trees Rate/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper fungicide</td>
<td>M1</td>
<td>Use label rate.</td>
</tr>
<tr>
<td>Abound 2.08F&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11</td>
<td>12.4–15.4 fl oz. Do not apply more than 92.3 fl oz/acre/season for all uses. Best applied with petroleum oil.</td>
</tr>
<tr>
<td>Gem 25WG&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11</td>
<td>4.0–8.0 oz. Do not apply more than 32 oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem 500 SC&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11</td>
<td>1.9–3.8 fl oz. Do not apply more than 15.2 fl oz/acre/season for all uses. Best applied with petroleum oil.</td>
</tr>
<tr>
<td>Headline&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11</td>
<td>9–12 fl oz. Do not apply more than 54 fl oz/acre/season for all uses. Best applied with petroleum oil.</td>
</tr>
</tbody>
</table>

---


<sup>b</sup> Lower rates can be used on smaller trees. Do not use less than minimum label rate.

<sup>c</sup> Do not use more than 4 applications of strobilurin fungicides/season. Do not make more than 2 sequential applications of strobilurin fungicides.
3.3.4 Favorable Conditions of Disease Development

High relative humidity and high temperatures are required for spore germination and the subsequent fungal growth on the leaf surface. Optimum germination and growth occur between 25°C (77°F) to 30°C (86°F) in the presence of free water or near 100% relative humidity.

3.3.5 Disease Cycle

No sexual fruiting structures are produced in greasy spot lesions on living leaves. Pseudothecia on decomposing leaves are aggregated, have papillate ostioles, and measure up to 90 μm in diameter. Ascospores are slightly fusiform, have a single septum, and often contain two oil globules in each cell. They are hyaline and measure 2 to 3 × 6 to 12 μm. Ascospores of *M. citri* are produced in pseudothecia in decomposing leaf litter on the grove floor (Figure 3.10). Once mature, ascospores are forcibly ejected following wetting of the litter and subsequently dispersed by air currents. Ascospores

FIGURE 3.8 Typical leaf symptoms of greasy spot infection.

FIGURE 3.9 Greasy spot: Rind blotch on grapefruit.
deposited on the underside of the leaf germinate and form epiphytic mycelia. Development of the epiphytic growth requires high temperatures and extended periods of high humidity or free moisture. Appressoria form over stomata, and the fungus penetrates into the mesophyll of the leaf. Nearly all infections occur through the lower leaf surface since citrus leaves have stomata only on the abaxial side. Numerous penetrations are required for the development of macroscopic symptoms. Colonization of the leaf is very slow, and symptoms appear only after 45–60 days, even on highly susceptible species under optimal conditions. Undergrove conditions, infection of leaves occurs mostly in the summer rainy season and symptoms develop in late fall or winter. Symptoms develop more rapidly when winter temperatures are warm. Symptomatic leaves abscise prematurely, and most of the greasy spot—induced leaf drop—occurs in late winter and early spring. The conidial stage *Stenella citri-grisea*, is found in nature only on epiphytic mycelium in late summer. Conidia are not believed to play an important role in disease development.

### 3.3.6 Management

Greasy spot is relatively easy to control with well-timed sprays of many products. The epiphytic growth on the leaf surface is exposed and readily killed by many materials.

The products that have been traditionally used for control of greasy spot are copper fungicides and petroleum oils.

- Copper fungicides directly kill germinating ascospores and epiphytic mycelium and prevent infections. The activity of oil for control of greasy spot has been investigated but is still not well understood. Oil does not appear to inhibit ascospore germination or germ tube growth but does prevent leaf penetration. It also slows fungal development in the mesophyll and symptom development.

- Petroleum oils are widely used for control of diseases caused by *Mycosphaerella* spp., such as yellow Sigatoka disease of banana, but their activity is not well understood in those cases either. Petroleum oil controls foliar infection but has not been highly effective for rind blotch control. However, we have found that the higher viscosity oils used in more recent years also effectively control rind blotch.
• Dithiocarbamate fungicides have also been used in the past, but they have a relatively short residual activity and are not highly effective.
• When benomyl was introduced, it was widely used and very effective for foliar and fruit symptoms. However, resistance developed quickly, and none of the Benzimidazole fungicides are currently recommended for greasy spot control.
• Fenbuconazole and the strobilurin fungicides are quite effective for control of foliar disease and rind blotch and are currently recommended in Florida, along with petroleum oils and/or copper fungicides.
• Foliar fertilizers, especially those containing heavy metals such as zinc, manganese, and iron, are quite effective for greasy spot control if applied at sufficiently high rates. Other nutritional products, fish oils, and biocontrol agents have all shown at least some activity against greasy spot.
• Acaricides are also active on greasy spot. It appears that they act directly rather than indirectly through action on mites that aggravate disease since acaricides are effective in the absence of mites. It appears that any product that is toxic to epiphytic mycelium will reduce greasy spot severity if applied at the proper time.
• Most fungicides have no effect, but benzimidazoles delay the formation of pseudothecia. Benomyl substantially reduces inoculum production, but only for four to six weeks (Table 3.3).

3.4 ALTERNARIA ROT OF CITRUS

Alternaria rot, also called black rot or navel rot, is caused by the fungus *Alternaria* spp. It is most common in navel oranges, Minneola and Orlando tangelos, and occasionally in lemons and limes. The fungus grows on dead citrus tissue during wet weather. It produces airborne spores which can land and grow on the blossom end of the fruit. Premature fruit coloring and fruit drop are commonly associated with infection.

3.4.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alternaria citri</em></td>
<td>Stem-End Rot on Fruit</td>
<td>Minor</td>
</tr>
</tbody>
</table>

3.4.2 SYMPTOMS

Alternaria rot occurs primarily as a stem-end rot on fruit stored for a long time, but sometimes the decay develops at the stylar end of fruit in the orchard where it may cause premature fruit drop. Fruits infected with *A. citri* change color prematurely and may develop a light brown to black firm spot on the rind at or near the stylar end (Figure 3.11). Some fruits, however, show no external evidence of infection and must be cut to reveal center rot.

3.4.3 FAVORABLE CONDITIONS FOR DISEASE DEVELOPMENT

Alternaria rot is often associated with cold damage. Frost damaged tissue is more likely to be infected (Figure 3.12). The rot inside the fruit may not be evident from the outside.

3.4.4 DISEASE CYCLE

*A. citri* grows saprophytically on dead citrus tissue and produces airborne conidia. Initially, it establishes a quiescent infection in the button or stylar end of the fruit. Entrance to the fruit is facilitated
**TABLE 3.3**

**Recommended Chemical Controls for Greasy Spot**

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mature Trees Rate/Acre&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Oil 97+% (FC 435-66, FC 455-88, or 470 oil)</td>
<td>NR&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5–10 gal. Do not apply when temperatures exceed 34°C. 470 weight oil has not been evaluated for effects on fruit coloring or ripening. These oils are more likely to be phytotoxic than lighter oils.</td>
</tr>
<tr>
<td>Copper Fungicide</td>
<td>M1</td>
<td>Use label rate.</td>
</tr>
<tr>
<td>Copper Fungicide + Petroleum Oil 97+% (FC 435-66, FC 455-88, or 470 oil)</td>
<td>M1 and NR</td>
<td>Use label rate + 5 gal. Do not apply when temperatures exceed 34°C. 470 weight oil has not been evaluated for effects on fruit coloring or ripening. These oils are more likely to be phytotoxic than lighter oils.</td>
</tr>
<tr>
<td>Abound 2.08F&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11</td>
<td>12.40–15.45 fl oz. Do not apply more than 92.3 fl oz/acre/season for all uses. Best applied with petroleum oil.</td>
</tr>
<tr>
<td>Enable 2F</td>
<td>3</td>
<td>8 fl oz. Do not apply more than 3 times per year; no more than 24 fl oz./acre. Minimum retreatment interval is 21 days.</td>
</tr>
<tr>
<td>Gem 25WG&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11</td>
<td>4.0–8.0 oz. Do not apply more than 32 oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem 500 SC&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11</td>
<td>1.9–3.8 fl oz. Do not apply more than 15.2 fl oz/acre/season for all uses. Best applied with petroleum oil.</td>
</tr>
<tr>
<td>Headline&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11</td>
<td>9–12 fl oz. Do not apply more than 54 fl oz/acre/season for all uses. Best applied with petroleum oil.</td>
</tr>
<tr>
<td>Quadris Top&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11/3</td>
<td>10–15.4 fl oz. Do not apply more than 61.5 fl oz/acre/season for all uses. Do not apply more than 0.5 lb ai/acre/season difenconazole. Do not apply more than 1.5 lb ai/acre/season azoxystrobin.</td>
</tr>
</tbody>
</table>

*Note:* This document is PP-144, one of a series of the Plant Pathology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 1995. Revised February 2012.


<sup>b</sup> Lower rates can be used on smaller trees. Do not use less than minimum label rate.

<sup>c</sup> No resistance potential exists for these products.

<sup>d</sup> Do not use more than 4 applications of strobilurin-containing fungicides/season. Do not make more than 2 sequential applications of strobilurin fungicides.

---

**FIGURE 3.11** Alternaria infection causes rotten spots that may eventually cover as much as 1/4 of the fruit.
if growth cracks form at the stylar end. The fungus does not grow from the button into the fruit until the button becomes senescent.

Alternaria rot is more likely to occur if the fruit has been weakened by adverse conditions in the field, during storage, or is overmature.

3.4.5 MANAGEMENT

Healthy, excellent quality fruit are more resistant to Alternaria rot than stressed or damaged fruits, especially oranges with split navels. Preventing stress can reduce the incidence of splitting and Alternaria rot.

Postharvest treatments with imazalil, 2,4-D, or both have provided some control. The growth regulator 2,4-D delays senescence and thereby restricts colonization of the host.3

3.5 CITRUS BROWN ROT

Citrus brown rot (CBR) is one of the most common diseases of Citrus. Brown rot is the most common fruit rot observed in the orchard.

3.5.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytophthora spp.</td>
<td>Decay of the Fruit</td>
<td>Severe</td>
</tr>
<tr>
<td>• P. citrophthora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• P. nicotianae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• P. syringae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• P. hibernalis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5.2 SYMPTOMS

Symptoms appear primarily on mature or nearly mature fruit. Initially, the firm, leathery lesions have a water-soaked appearance, but they soon turn soft and have a tan to olive-brown color (Figure 3.13) and a pungent odor. Infected fruit eventually drops. Occasionally, twigs, leaves, and blossoms are

FIGURE 3.12 Alternaria rot inside the fruit after freeze damage.
infected, turning brown and dying. At a high humidity, fruit becomes covered by a delicate white growth of the fungus (Figure 3.14).

The most serious aspect: Fruit infected before harvest may not show symptoms. If infected fruit gets mixed with healthy fruit, the disease may spread quickly from fruit to fruit in storage and during transit.

3.5.3 **Cause and Disease Development**

Brown rot is caused multiple species of *Phytophthora* when conditions are cool and wet. Brown rot develops mainly on fruit growing near the ground when *Phytophthora* spores from the soil are splashed onto the tree skirts during rainstorms. Infections develop under continued wet conditions. Fruit in the early stage of the disease may go unnoticed at harvest and infect other fruit during storage.

**FIGURE 3.13** Tan to olive-brown lesion on citrus.

**FIGURE 3.14** Fruit covered with delicate white fungus.
3.5.4 Favorable Conditions of Disease Development

Phytophthora brown rot is a problem usually associated with restricted air and/or water drainage. It commonly appears from mid-August through October following periods of extended high rainfall. It can be confused with fruit drop from other causes at that time of the year. If caused by *P. nicotianae*, brown rot is limited to the lower third of the canopy because the fungus is splashed onto fruit from the soil. *P. palmivora* produces airborne sporangia and can affect fruit throughout the canopy.

3.5.5 Disease Cycle

For the disease to develop, 18 hours of wetness is required for sporangia production and zoospore release. Three hours of wetness is required for infection. The length of the continuous rainy period is the most important predictor of brown rot epidemics. Zoospores produced in sporangia on the ground may be splashed up onto low-hanging fruit. Thus, brown rot mainly develops on fruit growing near the ground (Figure 3.15).

3.5.6 Management

3.5.6.1 Cultural Practices

- Pruning tree skirts can significantly reduce brown rot.
- Sprinkler irrigation: Water should be directed away from the tree canopy.

3.5.6.2 Fungicidal Protection

Rates for pesticides are given as the maximum amount required to treat mature citrus trees unless otherwise noted. To treat smaller trees with commercial application equipment including handguns, mix the per acre rate for mature trees in 250 gallons of water. Calibrate and arrange nozzles to deliver thorough distribution and treat as many acres as this volume of spray allows (Table 3.4).

---

**FIGURE 3.15** Disease cycle of *Phytophthora* spp. On citrus causing citrus brown rot.
3.6 PHYTOPHTHORA FOOT ROT AND ROOT ROT OF CITRUS

Foot rot results from scion infection near the ground level, producing bark lesions that extend down to the bud union on resistant rootstocks. Crown rot results from bark infection below the soil line when susceptible rootstocks are used. Root rot occurs when the cortex of fibrous roots is infected, turns soft, and appears water-soaked. Phytophthora foot rot is also known as gummosis.

3.6.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. nicotianae</em> or <em>P. palmivora</em></td>
<td>Foot Rot and Root Rot</td>
<td>Severe</td>
</tr>
</tbody>
</table>

3.6.2 SYMPTOMS

3.6.2.1 Foot Rot/Gummosis

An early symptom of phytophthora foot rot or phytophthora gummosis is sap oozing from small cracks in the infected bark, giving the tree a bleeding appearance. The gumming may be washed off during heavy rain. The bark stays firm, dries, and eventually cracks and sloughs off. Lesions spread around the circumference of the trunk, slowly girdling the tree. Decline may occur rapidly within a year, especially under conditions favorable for disease development, or may occur over several years (Figure 3.16).

3.6.2.2 Root Rot

Phytophthora root rot causes a slow decline of the tree. The leaves turn light green or yellow and may drop, depending on the amount of infection. The disease destroys the feeder roots of susceptible rootstocks. The pathogen infects the root cortex, which turns soft and separates from the stele, becomes somewhat discolored, and appears water-soaked. If the destruction of feeder roots occurs faster than their regeneration, the uptake of water and nutrients will be severely limited (Figure 3.17).
The fibrous roots slough their cortex leaving only the white threadlike stele, which gives the root system a stringy appearance. The tree will grow poorly, stored energy reserves will be depleted, and production will decline. In advanced stages of decline, the production of new fibrous roots cannot keep pace with root death. The tree is unable to maintain adequate water and mineral uptake, and nutrient reserves in the root are depleted by the repeated fungal attacks. This results in the reduction of fruit size and production, loss of leaves, and twig dieback of the canopy.

Disease symptoms are often difficult to distinguish from nematode, salt, or flooding damage; only a laboratory analysis can provide positive identification (Figure 3.18).
3.6.3 Cause and Disease Development

Phytophthora fungi are present in almost all citrus orchards. Under moist conditions, the fungi produce large numbers of motile zoospores, which are splashed onto the tree trunks. The Phytophthora species cause gummosis to develop rapidly under moist, cool conditions. Hot summer weather slows disease spread and helps drying and healing of the lesions. Secondary infections often occur through lesions created by Phytophthora. Phytophthora citrophthora is a winter root rot that also causes brown fruit rot and gummosis. P. citrophthora is active during cool seasons when citrus roots are inactive and their resistance to infection is low. Phytophthora parasitica is active during warm weather when roots are growing.

3.6.4 Disease Cycle

The disease cycle of P. nicotianae and P. citrophthora begins with the production of sporangia which release large numbers of zoospores. P. nicotianae produces chlamydospores in abundance while most isolates of P. citrophthora do not. P. citrophthora rarely produces oospores, whereas P. nicotianae commonly produces oospores. With time and appropriate conditions zoospores encyst and germinate to form mycelia. The optimum temperature for mycelial growth is 30°C–32°C for P. nicotianae and 24°C–28°C for P. citrophthora.

Sporangial production by P. nicotianae and P. citrophthora is favored by small deficits in matric water potential, but not by saturated conditions unless sporangia are produced on citrus root pieces. The optimal for sporangium formation probably represents a compromise between requirements for free water and aeration. Nutrition depletion and light also stimulate sporangial production from mycelium.

Indirect germination of sporangia to produce zoospores requires free water and is stimulated by a drop in temperature. Under moist conditions sporangia may also germinate directly by the growth of germ tubes, but the correlation between soil saturation and severity of phytophthora root rot suggests that indirect germination is more important in the root disease cycle.
Citrus

Chlamydomspore production by *P. nicotianae* occurs under unfavorable conditions for fungal growth, i.e., nutrient depletion, and low oxygen levels and temperatures (15°C–18°C). Water requirements for germination of chlamydospores are similar to those for sporangia. Chlamydospores of *P. nicotianae* appear to become dormant below 15°C, so exposure to temperatures of 28°C–32°C is used to stimulate germination. Nutrients that are acquired from soil extracts and excised citrus roots are known to stimulate chlamydospore germination.

The requirements for oospore germination are thought to be nearly identical to those of chlamydospores. Oospore maturation appears to be an important factor in germinability of *Phytophthora* spp. Periods of alternating high and low temperatures may also be a prerequisite for uniform germination (Tables 3.5 and 3.6).

### 3.6.5 Management

#### 3.7 ANTHRACNOSE OF CITRUS

Anthracnose is a decay that develops primarily on fruit subjected to ethylene during commercial de-greening. The fungus is a common symptomless inhabitant of citrus rind and only manifests itself when the rind is weakened. In some instances, ethylene treatment causes sufficient weakening to induce the disease.

### 3.7.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Colletotrichum gloeosporioides</em> (Asexual Stage)</td>
<td>Bruised and Injured Rind with Lesions</td>
<td>Severe</td>
</tr>
<tr>
<td><em>Glomerella cingulate</em> (Sexual Stage)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.7.2 SYMPTOMS

##### 3.7.2.1 Leaf

Common symptoms are a more or less circular, flat area, light tan in color with a prominent purple margin that at a later phase of infection will show the fruiting bodies of the fungus (tiny dispersed black flecks). Tissues injured by various environmental factors (such as mesophyll collapse or heavy infestations of spider mites) are more susceptible to anthracnose colonization (Figure 3.19).

##### 3.7.2.2 Fruit

Anthracnose usually only occurs on fruit that have been injured by other agents, such as sunburn, chemical burn, pest damage, bruising, or extended storage periods. The lesions are brown to black spots of 1.5 mm or greater diameter. The decay is usually firm and dry but if deep enough, can soften the fruit. If kept under humid conditions, the spore masses are pink to salmon, but if kept dry, the spores appear brown to black. On ethylene de-greened fruit, lesions are flat and silver in color with a leathery texture. On de-greened fruit, much of the rind is affected (Figure 3.20). The lesions will eventually become brown to gray-black leading to soft rot (Figure 3.21).

It should be noted that leaves and fruit infected with other diseases (*Alternaria*, citrus canker) may also be colonized by the fruiting bodies of *C. gloeosporioides*. The fruiting bodies (black flecks) can be seen over the disease of concern.

### 3.7.3 CAUSE AND DISEASE DEVELOPMENT

The fungus, *C. gloeosporioides*, which causes anthracnose, is very common in citrus orchards. It grows in the deadwood of the tree canopy and produces spores that are carried in water to
### TABLE 3.5

**Recommended Chemical Controls for Phytophthora Foot Rot and Root Rot—Fosetyl-AL and Phosphite Salts Products**

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mature Trees Rate/Acre&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Method of Application</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aliette WDG&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>33</td>
<td>5 lb/100 gal, 2.5–5 lb/5 gals</td>
<td>Foliar spray</td>
<td>Protectant and curative systemic. Buffering to pH 6 or higher is recommended to avoid phytotoxicity when copper has been used prior to, with, or following Aliette.</td>
</tr>
<tr>
<td>Nonbearing</td>
<td></td>
<td>5 lb/100 gal or 1 lb/100 gal</td>
<td>Foliar spray</td>
<td>Adjust rate according to tree size.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Up to 5 lb/acre</td>
<td>Microsprinkler</td>
<td>Apply up to 4 times/year (e.g., March, May, July, and September) for fibrous root rot control.</td>
</tr>
<tr>
<td>Bearing</td>
<td></td>
<td>5 lb/10 gal/acre</td>
<td>Aerial</td>
<td>Fly every middle. Do not apply in less than 10 gal/acre.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 lb/acre</td>
<td>Surface spray on weed-free area followed by 0.5 inch irrigation or by microsprinkler in 0.1–0.3 inch of water.</td>
<td>Apply up to 4 times/year (e.g., March, May, July, and September) for fibrous root rot control.</td>
</tr>
<tr>
<td>Phostrol</td>
<td>33</td>
<td>4.5 pt/acre</td>
<td>Foliar spray</td>
<td>Protectant and curative systemic. Do not apply when trees are under water stress or high temperature conditions.</td>
</tr>
<tr>
<td>Bearing or Nonbearing</td>
<td></td>
<td></td>
<td></td>
<td>Apply up to 4 times/year (e.g. March, May, July, and September).</td>
</tr>
<tr>
<td>ProPhyt</td>
<td>33</td>
<td>2–5 pt/5 gal</td>
<td>Trunk paint or spray.</td>
<td>Trunk paint or spray.</td>
</tr>
</tbody>
</table>

* This information is from SL127, one of a series of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.


<sup>b</sup> Lower rates may be used on smaller trees. Do not use less than the minimum label rate.

<sup>c</sup> For combinations of application methods, do not exceed 4 applications or 20 lb/acre/year.

<sup>d</sup> Fungicide treatments control fibrous root rot on highly susceptible sweet orange rootstock, but are not effective against structural root rot and will not reverse tree decline.

<sup>e</sup> Apply in May prior to summer rains and/or in the fall prior to wrapping trees for freeze protection.
### TABLE 3.6
Recommended Chemical Controls for Phytophthora Foot Rot and Root Rot—Mefenoxam and Copper Products

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRACMOA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mature Trees Rate/Acre&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Method of Application</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridomil Gold SL&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>4</td>
<td>Protectant and curative systemic. Do not apply tank mixes of Ridomil and residual herbicides to trees less than 3 years old. Apply herbicide first, then wait 3–4 weeks to apply Ridomil. Do not apply to bare roots. Do not apply rates higher than 1 qt./A to citrus resets or new plantings (less than 5 years old) to prevent potential phytotoxicity. Do not make trunk gummnosis sprays and soil applications to the same tree in the same cropping season. Time applications to coincide with root flushes. Make the 1st application at time of planting. Make up to 2 additional applications per year at 3-month intervals for maximum control; in most cases a late spring and late summer application should be sufficient.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing</td>
<td>1 qt/acre of treated soil surface</td>
<td>Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or by microsprinkler in 0.1–0.3 inch of water.</td>
<td>Through irrigation injection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0–1.5 fl. oz/20 trees</td>
<td>Individual Tree Treatment for Resets/New Plantings: Mix desired amount of Ridomil Gold SL in a water solution. Apply as a directed spray to individual trees (generally 8–12 fl.oz./tree) around the base of the tree and outward to cover the fibrous root system. Follow with sprinkler irrigation to move product into root zone. Make 1st application at time of planting. Make up to 2 additional applications per year at 3-month intervals for maximum control; in most cases a late spring and late summer application should be sufficient.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bearing</td>
<td>1 pt/acre of treated soil surface if propagule counts are 10–20 propagules/cm³ soil</td>
<td>Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or microsprinkler in 0.1–0.3 inch of water.</td>
<td>Begin applications during the spring root flush period. Apply up to 3 times/year on 3-month intervals (late spring, summer, early fall).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 qt/acre of treated soil surface if propagule counts are &gt;20 propagules/cm³ soil</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> FRACMOA: Fetigation Association of Commodity Manufacturers of Agricultural Chemicals

<sup>b</sup> Rate/Acre: Application rate per acre

<sup>c</sup> Mefenoxam

<sup>d</sup> Copper products
### TABLE 3.6 (CONTINUED)

**Recommended Chemical Controls for Phytophthora Foot Rot and Root Rot—Mefenoxam and Copper Products**

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mature Trees Rate/Acre&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Method of Application</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1/2 pt/grove acre if propagule counts are 10–20 propagules/cm³ soil</td>
<td>Through irrigation injection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 pt/grove acre if propagule counts are &gt;20 propagules/cm³ soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bearing</td>
<td></td>
<td>1 qt/10 gal</td>
<td>Trunk Spray for Gummosis: Spray the trunks to thoroughly wet the cankers.</td>
<td>May be applied up to 3 times/yr.</td>
</tr>
<tr>
<td>Ridomil Gold GR&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4</td>
<td>40–80 lb/acre of treated soil surface</td>
<td>Apply as banded application under the canopy. For banded applications, use a band wide enough to cover the root system. If rain is not expected for 3 days, follow by 0.5–1.0 inch of irrigation.</td>
<td>Do not apply Ridomil Gold GR and residual herbicides to trees less than 3 years old simultaneously. Apply herbicide first, then wait 3–4 weeks to apply Ridomil. Do not apply more than 240 lb of Ridomil Gold GR/acre/year. Time applications to coincide with root flushes. Make 1st application at time of planting. Make up to 2 additional applications per year at 3-month intervals for maximum control; in most cases a late spring and late summer application should be sufficient.</td>
</tr>
<tr>
<td>Nonbearing</td>
<td></td>
<td>40–80 lb/acre of treated soil surface</td>
<td>Banded application under the canopy. If rain not expected for 3 days, follow by 0.5–1.0 inch of irrigation.</td>
<td>Begin applications during the spring rot flush period. Apply up to 3 times/year on 3-month intervals (late spring, summer, early fall). Protectant and curative systemic. Do not apply tank mixes of UltraFlourish and residual herbicides to trees less than 3 years old. Apply herbicide first, then wait 3–4 weeks to apply UltraFlourish. Apply every 3 months for maximum control; in most cases a late spring and late summer application should be sufficient.</td>
</tr>
<tr>
<td>UltraFlourish&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>4</td>
<td>2–4 qt/acre of treated soil surface</td>
<td>Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or by microsprinkler in 0.1–0.3 inches of water.</td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRACMOA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mature Trees Rate/Acre&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Method of Application</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2–3 oz/100 gal</td>
<td>Soil drench; apply 5 gal of mix in water ring.</td>
<td>Apply every 3 months for maximum control; in most cases a late spring and late summer application should be sufficient.</td>
</tr>
<tr>
<td>Bearing</td>
<td></td>
<td>1 qt/acre of treated soil surface &lt;20 propagules/cm³ soil &amp; 2 qt/grove acre &gt;20 propagules/cm³ soil</td>
<td>Surface spray on weed-free area, followed immediately by 0.5 inch irrigation or microsprinkler in 0.1–0.3 inch of water.</td>
<td>Apply 3 times/year (late spring, summer, early fall).</td>
</tr>
<tr>
<td>Copper-Wettable Powder</td>
<td>M1</td>
<td>1 qt in 3 qt water</td>
<td>Through irrigation injection</td>
<td></td>
</tr>
<tr>
<td>Copper-Count-N</td>
<td>M1</td>
<td></td>
<td>Trunk paint&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Protectant. Do not apply to green bark; may cause gumming.</td>
</tr>
</tbody>
</table>


<sup>b</sup> Lower rates may be used on smaller trees. Do not use less than the minimum label rate.

<sup>c</sup> Do not exceed the equivalent of 6 lb a.i./acre/year of mefenoxam-containing products.

<sup>d</sup> Do not apply to bare roots or higher than 1 qt/acre of treated soil surface to citrus resets or trees less than 5 years old to avoid potential phytotoxicity.

<sup>e</sup> Apply in May prior to summer rains and/or in the fall prior to wrapping trees for freeze protection.

Note: This Table is from PP-156, one of a series of the Plant Pathology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 1999. Revised February 2012.
the surface of leaves and immature fruit during the growing season. During periods of high moisture, such as after rainfall, heavy dew, or overhead irrigation, the spores germinate to form microscopic “appressoria”, which are very hard and resistant to some commonly used fungicides. The appressoria remain dormant for many weeks and months until the fruit is susceptible. The fungus is a very weak pathogen and anthracnose usually only appears on fruit injured by other factors, such as sunburn, chemical treatments or pests, and on fruit that is very mature or held too long in storage.

However, the disorder may develop in certain mandarin varieties without apparent injury. Ethylene de-greening stimulates the appressoria to germinate and increases the susceptibility of the rind to further invasion. Ethylene concentrations, more than those required for optimal de-greening, can significantly increase the incidence of anthracnose.

3.7.4 Favorable Conditions of Disease Development

The anthracnose fungus usually infects weakened twigs. The disease is most common during springs with prolonged wet periods and when significant rains occur later in the season than normal. During wet or foggy weather, anthracnose spores drip onto fruit, where they infect the rind and leave dull, reddish-to-green streaks on immature fruit and brown-to-black streaks on mature fruit (tear stains). Certain conditions, however, such as applications of insecticidal soaps, which damage the protective wax on the fruit peel, can increase the severity of this disease.
Anthracnose is a primary colonizer of injured and senescent tissue. The organism grows on dead wood in the canopy, and it spreads short distances by rain splash, heavy dew, and overhead irrigation. Such movement deposits the spores on susceptible tissues of young leaves or immature fruit. Sexual spores, although less numerous, are significant for long-distance dispersal because of their ability to become airborne. Once the spores germinate, they form a resting structure that allows them to remain dormant until an injury occurs or until de-greening. The disease is especially troublesome on fruit that are harvested early and de-greened for over 24 hours because ethylene stimulates the growth of the fungus.

Best control of anthracnose can be achieved by a combination of in-field and postharvest treatments.

- The fungus responsible for anthracnose harbors in deadwood. Good cultural practices to reduce deadwood should be encouraged.
- Field sprays of copper-based fungicides or Mancozeb® may inhibit spore germination. Heavy rain may wash off a copper application and allow infection.
- Ethylene stimulates anthracnose development. Delayed harvesting or selective picking for better color will minimize the amount of time in de-greening.
- Ethylene de-greening should not be above optimal concentrations (5ppm trickle method).
- Harvested fruit should be washed on revolving brushes to remove appressoria or dipped in a benzimidazole fungicide (carbendimizim or TBZ) to control anthracnose before de-greening.
- Dipping in guazatine alone will not control anthracnose. Fruit treated with guazatine and a benzimidazole will control molds, sour rot, and anthracnose.
- Immediate cold storage of fruit after packing may assist in reducing the expression of anthracnose.
- Benzimidazole fungicides, such as Tecto®, Spinflo®, or Bavistin®, should be used for dipping or drenching field bins to provide protection from anthracnose. Chlorine alone will not control fungal spores or appressoria on the surface of the fruit. Inappropriately high levels of chlorine and/or by-products may induce weakness in the rind and increase the susceptibility of fruit to anthracnose.
3.8 CITRUS CANKER

Citrus Canker is one of the most feared of citrus diseases, affecting all types of important citrus crops. The disease causes extensive damage to citrus and severity of this infection varies with different species and varieties and the prevailing climatic conditions. The disease is endemic in India, Japan, and other South-East Asian countries, from where it has spread to all other citrus-producing continents except Europe. Generally, canker does not occur in arid citrus growing areas and has been eradicated from some areas. However, widespread occurrence of the disease in many areas is a continuous threat to citiculture, especially in canker-free areas.²

Citrus canker is most severe in grapefruit, acid lime, and sweet orange.

3.8.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xanthomonas campestris pv. Citri</td>
<td>Raised Necrotic Lesions on Fruits, Leaves, and Twigs.</td>
<td>Severe</td>
</tr>
</tbody>
</table>

3.8.2 SYMPTOMS

3.8.2.1 Leaf

Typical citrus canker lesions on leaves will range from 2 to 10 mm in size and will have raised concentric circles on the underside of the leaf. Frequently, lesions will be surrounded by a water-soaked margin (Figure 3.22) and a yellow halo (Figure 3.23). As a canker lesion ages, it may lose it palpable roughness, but the concentric circles will still be visible with a hand lens (on the underside of the leaf). The yellow halo eventually changes to dark brown or black and the water-soaked margin surrounding the lesion may diminish (Figure 3.24). The middle of the lesion (on the underside of the leaf) will be corky in texture with a volcano or pimple-like point. With the exception of very young lesions, lesions always penetrate through both sides of the leaf. In the presence of damage,
the lesion may follow the contours of the damage and therefore may not be circular. In older lesions, a saprophytic white fungus may grow over the center of the lesion. The center of a lesion may fall out producing a shot-hole appearance.\cite{5}

3.8.2.2 Fruit

Typical citrus canker lesions on fruit will range from 1 to 10 mm in size. Larger lesions usually penetrate a few mms into the rind. Fruit lesions may vary in size and may coalesce. Fruit lesions consist of concentric circles. On some varieties these circles are raised with a rough texture; on other varieties the concentric circles are relatively flat like the surface of a record. The middle of the lesion will be corky in texture with a volcano or pimple-like point. The center of a lesion may crack and has a crusty material inside that resembles brown sugar (Figure 3.25). Frequently on green fruit, a yellow halo will be visible; however, it will not be visible on ripened fruit. Lesions may have a water-soaked margin and the water-soaked margin is especially evident on smaller lesions. In the presence of damage, the lesion may follow the contours of the damage therefore not being circular. In older lesions a saprophytic white fungus may grow over the center of the lesion. Figures 3.26 and 3.27 refer to citrus canker on acid lime and grapefruit.\cite{5}
3.8.2.3 Twigs

On twigs and fruit, citrus canker symptoms are similar: raised corky lesions surrounded by an oily or water-soaked margin. No chlorosis surrounds twig lesions but may be present on fruit lesions (Figure 3.28).

Twig lesions on angular young shoots perpetuate Xac inoculum in areas where citrus canker is endemic. Twig dieback, fruit blemishes, and early fruit drop are major economic impacts of the disease in advanced stages. If twigs are not killed back by girdling infections, the lesions can persist for many years, causing raised corky patches in the otherwise smooth bark.

3.8.3 Cause and Disease Development

Since Xanthomonads have a mucilaginous coat, they easily suspend in water and are dispersed in droplets. Spread of canker bacteria by wind and rain is mostly over short distances, i.e., within trees or neighboring trees. Cankers develop more severely on the side of the tree exposed to wind-driven rain. Long-distance spread more often occurs with the movement of diseased propagating material, such as bud wood, rootstock seedlings, or budded trees.

3.8.4 Favorable Conditions of Disease Development

Optimum temperature for infection falls between 20°C and 30°C. Citrus canker is severe in regions where temperature and rainfall ascend and descend together during the year. Therefore, the disease

FIGURE 3.25 Fruit lesion with center cracking.

FIGURE 3.26 Canker on acid lime.
Citrus occurs in its most severe form in seasons and/or areas characterized by warm and humid weather conditions.

### 3.8.5 Disease Cycle

The bacterium propagates in lesions on leaves, stems, and fruit. When there is free moisture on the lesions, bacteria ooze out and can be dispersed (Figure 3.29) to new growth on the plant already infected. Rainwater collected from foliage with lesions contains between 10^5 and 10^8 cfu/mL. Wind-driven rain is the main natural dispersal agent, and wind speeds 18 mph (8 m/s) aid in the penetration of bacteria through the stomatal pores or wounds made by thorns, insects such as the Asian leaf-miner, and blowing sand. The serpentine mines under the leaf cuticle caused by the larvae of the Asian citrus leaf-miner, a pest first detected in 1993 in Florida, provide ample wounding on new growth to greatly amplify the citrus canker infection. Water congestion of leaf tissues can be seen following rainstorms with wind. Citrus foliage can hold 7 µL/cm² of leaf area. Studies of inoculum associated with water congestion have demonstrated how as few as one or two bacterial cells forced through stomatal openings can lead to infection and lesion formation. Windblown inoculum was detected up to 32 ms from infected trees in Argentina. However, in Florida, evidence for much longer dispersals (up to seven miles) associated with meteorological events such as severe rainstorms and tropical storms has been presented. Pruning causes severe wounding and can be a site for infection.
3.8.6 Management

The following table mentions the citrus cultivars which are highly resistant to highly susceptible to the disease (Table 3.7).

3.8.6.1 Cultural Practices

Cultural practices including windbreaks, and pruning or defoliation of diseased summer and autumn shoots, are recognized throughout the world as important measures for the management of citrus canker. Windbreaks are the most effective measure for the control of the disease on susceptible citrus cultivars. Windbreaks alone or in combination with copper sprays may reduce disease incidence on leaves and fruits to non-detectable levels on field resistant cultivars. Pruning and defoliation of diseased shoots in combination with copper sprays as a complete control have also been effective in light outbreaks. Pruning of the citrus trees is performed during the dry season when the environmental conditions are less favorable for the spread of the bacterium from pruned to adjacent non-infected trees. However, pruning is very labor intensive and therefore expensive.

3.8.6.2 Chemical Control

Worldwide, citrus canker is managed with preventive sprays of copper-based bactericides. Such bactericides are used to reduce inoculum build up on new leaf flushes and to protect expanding fruit surfaces from infection. Effective suppression of the disease by copper sprays depends on several factors, such as the susceptibility of the citrus cultivar, environmental conditions, and adoption of other control measures. As a stand-alone measure, control of citrus canker with copper sprays on resistant or moderately resistant citrus cultivars may be achieved, whereas adequate control on susceptible or highly susceptible cultivars requires the implementation of several control measures.

The timing and number of copper sprays for effective control of citrus canker are not only highly dependent on the susceptibility of the citrus cultivar, but on the age of the citrus trees, environmental conditions, and the overall disease pressure.
conditions, and the adoption of other control measures. In general, three to five copper sprays are necessary for effective control of citrus canker on citrus cultivars with intermediate levels of resistance, whereas, in years with weather that is highly conducive for epidemic development of citrus canker, up to six sprays may be recommended.

3.8.6.3 Integrated Management Programs

In regions where citrus canker is endemic, integrated control measures rely most heavily on the planting of resistant varieties of citrus. In Southeast Asia, where climatic conditions are most favorable for epidemics, the dominant cultivars grown are based on mandarins. Citrus canker has not been a serious problem until more susceptible sweet oranges were introduced into disease prone areas of Japan and China. In Brazil, eradication/control programs have been on-going since the 1950s to control the spread of *Xac* into the largest sweet orange production area in the world: São Paulo State. The strategies of the integrated program for citrus canker control are based on research carried out in the 1960s and early 1970s in Japan, and later in the 1970s in Argentina and 1980s in Brazil.

The most important feature of this program is the shift in planting from susceptible to field resistant citrus cultivars. Regulations in these regions not only address the requirement for more resistant cultivars but also mandate production of *Xac*-free nursery trees and other means for exclusion of canker from orchards. Guidelines also specify management practices for citrus canker and marketing of fresh fruit and nursery stock. Under these regulations, nurseries can only be located in areas free of citrus canker. In orchard production areas designated as citrus canker-free, regulations are designed to prevent or reduce the risk of citrus canker epidemics through the establishment of windbreaks, construction of fences to restrict the access to the orchard, and the use of preventive copper sprays. Fresh fruit for internal and export markets is subject to inspection protocols for freedom of citrus canker symptoms on fruit in orchards and sanitation treatments in the packinghouse.

### 3.9 CITRUS GREENING

Citrus greening, also known as Huanglongbing (HLB) or yellow dragon disease, is one of the most serious citrus diseases in the world. It is a bacterial disease that greatly reduces production, destroys...
the economic value of fruit, and can kill trees. It has significantly reduced citrus production in Asia, Africa, the Arabian Peninsula, and Brazil. Once infected, there is no cure for a tree with the citrus greening disease. In areas of the world where citrus greening is endemic, citrus trees decline and die within a few years. The disease specifically attacks citrus plants and presents no threat to humans or animals.

Sweet orange and mandarin orange are highly susceptible to the disease; grapefruit and lemons are moderately susceptible.

### 3.9.1 Causal Organism

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candidatus Liberibacter asiaticus (Asian Strain)</td>
<td>Stunting, Sparse Yellow Foliage, Severe Fruit Drop</td>
<td>Most Severe</td>
</tr>
<tr>
<td>Ca. L. africanus (African Strain)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.9.2 Symptoms

Symptoms are many and variable: yellow shoots, twig dieback, leaf drop, leaves with blotchy yellow/green coloration similar to the symptoms of zinc nutritional deficiency, enlarged veins that appear corky (Figure 3.30), excessive fruit drop, small and misshapen fruit, fruit that remains green at one end (the stylar end) after maturity, fruit with mottled yellow/green coloration (Figure 3.31), small dark aborted seed inside fruit, discolored vascular bundles in the pithy center of the fruit, bitter-tasting fruit, and silver spots left on fruits that are firmly pressed.

The time from infection to the appearance of symptoms is variable, depending on the time of year, environmental conditions, tree age, host species/cultivar and horticultural health ranging from less than one year to several years. The three disease agents (C. Liberibacter spp.) are not distinguishable from each other based on symptoms produced.

### 3.9.3 Transmission of the Disease

The disease can be transmitted by bud grafting but not at high rates due to necrosis in sieve tubes and uneven distribution of the bacteria. Dodder (Cuscuta spp.) also causes the spread of the disease. Citrus psyllid is, however, the primary vector. Also, the disease occurs with high psyllid populations when the host is flushing which is when the psyllid migrations are highest. Two species of citrus psyllid are vectors.

![Citrus greening resulting in a blotchy leaf.](image3.30)
• The African Citrus Psyllid, *Trioza erytreae*, occurs in Africa, Réunion, and Yemen and vectors the African strain of greening. It survives well in cool upland areas.

• The Asian Citrus Psyllid, *Diaphorina citri*, is in Asia, India, Saudi Arabia, Réunion, and North, South and Central America. It is more resistant to high temperatures and survives in hot lower altitudes.

### 3.9.4 Disease Cycle

*Candidatus Liberibacters* are gram-negative bacteria with a double-membrane cell envelope. *Ca. L. asiaticus*, *africanus*, and *americanus* are found only in the phloem cells of plants. The bacteria are transmitted by psyllids, a type of insect, as they feed. *Ca. L. asiaticus* and *Ca. L. americanus* are transmitted by the adults of the citrus psyllid *D. citri Kuwayana*. *Ca. L. africanus* is transmitted by the adult psyllid *Trioza erytreae Del Guercio*. The bacteria can be acquired by the insects in the nymphal stages and the bacteria may be transmitted throughout the life span of the psyllid.

Eggs are laid on newly emerging leaves and hatch in two to four days. Five nymphal instars complete development in 11–15 days. The entire life cycle takes 15–47 days, depending upon temperature, and adults may live several months with females laying up to 800 eggs in a lifetime.

In an orchard, diseased trees are clustered together, with secondary infections produced 25–50 m away. *Ca. L. africanus* is found at elevations greater than 700 m and is less heat tolerant than *Ca. L. asiaticus*. *Ca. L. americanus* resembles *Ca. L. africanus* in being less heat tolerant. Infections of *Ca. L. asiaticus* and *Ca. L. americanus* are more severe than *Ca. L. africanus* and can lead to tree death.

### 3.10 Citrus Variegated Chlorosis

Citrus variegated chlorosis (CVC) was described as a new disease of citrus in 1987 in Brazil. CVC is also a highly injurious disease of citrus. Caused by a strain of the bacterium *Xylella fastidiosa*, CVC causes severe chlorosis between veins on the leaves of affected plants. Leaves on affected plants frequently have discoloration of the upper leaf coupled with brown lesions underneath. CVC may reduce plant growth and lead to abnormal flowering and fruit production. CVC is currently not known to occur in the United States.

Sweet oranges are the most susceptible. Grapefruit, mandarins, mandarin hybrids, lemons, and limes are moderately susceptible, showing less severe symptoms.

#### 3.10.1 Causal Organism

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>X. fastidiosa</em></td>
<td>Chlorosis of Leaves and Abnormal Fruits</td>
<td>Severe</td>
</tr>
</tbody>
</table>
3.10.2 Symptoms

3.10.2.1 Leaf

Foliar symptoms of CVC are very similar to nutrient deficiency and other diseases; therefore, it is difficult to rely on foliar symptoms alone for identification. Early leaf symptoms resemble zinc deficiency with interveinal chlorotic areas on the upper surface (Figure 3.32). Early symptoms may be limited to a single branch. As the leaf matures, gummy lesions become visible on the lower leaf surface (Figure 3.33) corresponding to chlorotic areas on the upper surface of the leaf. The chlorotic areas gradually enlarge toward the leaf margin, and the lesions on the underside of the leaf may become dark brown or necrotic. Leaves may be smaller than normal. Leaf symptoms are most pronounced on mature leaves (behind the new flush).

3.10.2.2 Fruit

Blossom and fruit occur at the normal time, but fruit thinning does not occur. This results in clusters of four to ten early maturing fruit. Fruit size is significantly reduced (Figure 3.34), with increased sugar content and hard rind. Fruits of infected trees may exhibit sunburn damage because of defoliation at branch terminals. In addition, fruit may change color early, have hard rinds, lack juice, and have an acidic flavor. Fruit symptoms of CVC are more easily recognized from a distance (Figure 3.35).

3.10.2.3 Whole Tree

Affected trees may exhibit reduced vigor and growth and show abnormal flowering and fruit set. Newly affected trees may only exhibit symptoms on one limb or branch, and then symptoms may spread to the entire canopy. Older trees may only show symptoms on the extremities of the branches.

FIGURE 3.32 CVC symptoms on upper side of the leaf.

FIGURE 3.33 CVC symptoms on lower side of the leaf.
Severely diseased trees frequently possess upper crown branches with defoliation at terminal twigs and small leaves and fruit (Figure 3.36).

3.10.3 Favorable Conditions for Disease Development and Disease Transmission

The fastidious bacteria grow well at 20°C–25°C and pH 6.7–7.0. The bacterium has been found to be transmitted in Brazil by sharpshooter leafhoppers (Cicadellidae). Sharpshooters are present in most citrus growing areas of the United States. The sharpshooter leafhopper, *Oncometopia nigricans* Walker, frequently is found feeding on citrus in Florida.6

3.10.4 Disease Cycle

CVC is a systemic disease that only survives in plant xylem or within its vector. *X. fastidiosa* has been shown to move from seed to seedling in sweet orange. CVC has a latency period of nine to twelve months before symptoms occur. Natural spread of *X. fastidiosa* occurs by several species of sharpshooter leafhoppers in the order Hemiptera. At least eleven species of sharpshooter have been shown to vector CVC. Some of these species currently occur in the United States. Sharpshooters are xylem feeders and acquire *X. fastidiosa* within two hours of feeding. Sharpshooters have a high rate of feeding and retain infectivity indefinitely. Sharpshooters do not pass *X. fastidiosa* onto the next generation. Sharpshooters have an extensive host range and may undergo one to several generations per year.

3.10.5 Management

Disease management is costly. It involves insecticide applications, pruning of symptomatic branches and elimination of affected trees. Pruning success is erratic, especially in areas of high CVC

FIGURE 3.34 Reducing fruit size. (Picture by: MAM and Francisco Laranjeira.)

FIGURE 3.35 Fruit of sweet orange affected by CVC. (Picture by: MAM and Francisco Laranjeira.)
incidence, and has been recommended only for affected trees over three years of age expressing initial leaf symptoms. Although all commercial sweet orange cultivars are susceptible, the commonly used commercial rootstocks have shown considerable levels of CVC resistance. The strategy consists of removing the entire canopy of the condemned tree by pruning the trunk at soil level, below the graft line. Two to three months later, one healthy bud is grafted on each of the two or three new selected shoots. Around six weeks later, the shoot portion above graft is removed and the new scion is allowed to grow to form a new canopy. The method was tested in four experiments in three distinct locations (north, center, and south São Paulo State) involving 320 four- to five-year-old Pêra Rio/Rangpur lime trees expressing severe and extensive CVC symptoms. The healthy buds used were from the same sweet orange cultivar. In total, CVC symptoms have appeared in 13 (4.1%) canopies that developed on the trunks, 32–48 months after pruning. Probably due to a high xylem sap influx coming from the already established root system, in general, the new canopies grew and started producing fruits faster than the new young trees planted in one same orchard. This study confirms high levels of resistance of Rangpur lime to *X. fastidiosa* and demonstrates the possibility of reusing the rootstock of a tree severely affected by CVC to generate a healthy and productive sweet orange scion.

### 3.11 GREEN MOLD ON CITRUS

Green mold occurs in all citrus-producing regions of the world. Green mold is the most common and serious postharvest disease of citrus. All types of citrus fruit are susceptible to green and blue mold.

#### 3.11.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Penicillium digitatum</em></td>
<td>Rotting of the Fruit</td>
<td>Severe</td>
</tr>
</tbody>
</table>

#### 3.11.2 SYMPTOMS

The first symptom is a tiny soft, watery spot 5–10 mm in diameter. In one day, the spot enlarges until it measures 2–4 cm across. White mycelium appears on the rind surface (Figure 3.37). After it reaches a size of 2.5 cm, the fungus begins to produce green spores (Figure 3.38). These disperse easily if the fruit is handled, or exposed to the wind. The decayed fruit becomes soft and shrinks in size. If the atmosphere is humid, the infected fruit also becomes attacked by other molds and bacteria, and soon collapses into a rotting mass.

#### 3.11.3 CAUSE AND DISEASE DEVELOPMENT

The fungus survives in the orchard from season to season mainly in the form of conidia. Infection is from airborne spores, which enter the peel of the fruit in places where there are small injuries or
blemishes. It can also invade fruit which have been damaged on the tree by chilling injury. Infected fruit in storage do not infect the fruit packed around them. However, infected fruit may give off abundant green fungus spores which soil the skin of adjacent fruit. Since it attacks only injured fruit, the best way to prevent green mold is to handle the fruit carefully during and after harvest.

3.11.4 FAVORABLE CONDITIONS OF DISEASE DEVELOPMENT

Infections develop from damaged areas. The growth of mold increases with storage temperatures (up to an optimum of 24°C). Late season fruit is more susceptible. Damaged rind is more susceptible. Green mold develops most rapidly at temperatures near 24°C and much more slowly above 30°C and below 10°C. The rot is almost completely inhibited at 1°C.

3.11.5 DISEASE CYCLE

P. digitatum (green mold) survives in the orchard from season to season primarily as conidia. Infection is initiated by airborne spores, which enter the rind through injuries. Even injuries to the oil glands alone can promote some infection. It can also invade fruit through certain physiologically induced injuries, such as chilling injury, oleocellosis, and stem-end rind breakdown. The fungus does not usually spread from decayed fruit to adjacent, intact healthy fruit in packed containers. The infection and sporulation cycle can be repeated many times during the season in a packinghouse, and inoculum pressure increases as the picking season advances if precautions are not taken.

Green mold develops most rapidly at temperatures near 24°C and much more slowly above 30°C and below 10°C. The rot is almost completely inhibited at 1°C.
3.11.6 MANAGEMENT

Careful picking and handling of fruit minimize injuries to the rind and the risk of molds. Sanitary practices should be applied to prevent sporulation on diseased fruit and the accumulation of spores on equipment surfaces and in the atmosphere of packing and storage facilities. Immediate cooling after packing, significantly delays development of molds, particularly if combined with an effective fungicide.

The following table includes the commonly used fungicides (Table 3.8).

Penicillium spp. can develop resistance to some fungicides. The use of two or more fungicides minimizes resistance problems in addition to the use of stringent sanitary practices.

3.12 CITRUS MELANOSE

Melanose disease can affect young leaves and fruits of certain citrus species or varieties when the tissues grow and expand during extended periods of rainy or humid weather conditions. The symptoms of this widely distributed fungal disease vary from small spots or scab-like lesions to patterns of damage referred to as tear-drop, mudcake, and star melanose.

Grapefruit and lemons tend to be more susceptible than other kinds of citrus.

3.12.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Diaporthe citri</em> (anamorph: <em>Phomopsis citri</em>)</td>
<td>Scab-like Lesions on Leaf and Rind</td>
<td>Severe</td>
</tr>
</tbody>
</table>

3.12.2 SYMPTOMS

3.12.2.1 Leaf

About 1 week after infection foliar symptoms appear as small brown discrete spots (Figure 3.39). These spots become impregnated with a reddish-brown gum and are raised above the leaf surface. Early pustules on leaves are surrounded by a yellow halo. However, this halo quickly disappears leaving only small corky pustules. The numerous small pustules give the leaf a rough sandpaper texture. Distortion and dieback of young shoots are associated with severe infections.

3.12.2.2 Fruit

Fruit symptoms can vary depending on the age of the fruit at the time of infection. Early infections will result in premature petal fall and plants will have relatively large pustules, which in large
numbers may coalesce to form extensive areas that often crack to produce a pattern described as “mudcake melanose” (Figure 3.40). Infections during later stages of fruit development produce small discrete pustules distributed by spore-laden rain or dew which flows over the fruit surface creating the “tear-stain melanose” pattern. These injuries to the fruit rind are superficial and are not important if the crop is processed. If copper fungicides are applied for control, stippling, copper fungicide damage may occur, which can resemble the disease and is often called star melanose.

3.12.3 CAUSE AND DISEASE DEVELOPMENT

The fungus reproduces in dead twigs, particularly those which have died recently. For this reason, pruning away deadwood is an essential part of controlling melanose.

The fungus produces two kinds of spores. One kind are numerous but do not travel far. They are mainly carried in splashes of water such as raindrops. Infected dead twigs in the upper part of the tree may cause heavy infestations in lower branches.

The other kind of spore is fairly scarce. These spores are airborne and can be carried on the wind. They are likely to cause outbreaks if heaps of dead citrus wood are left lying on the ground in or around the citrus orchard.

3.12.4 FAVORABLE CONDITIONS OF DISEASE DEVELOPMENT

The causal pathogen is the fungus *D. citri*. Trees are susceptible only for a few months after petal fall. The severity of the disease is determined mainly by the amount of dead wood in the canopy, and by the length of time the fruit remains wet after rainfall or sprinkler irrigation.
Temperature also plays a role. After a spore lands on wet leaves or fruit tissue, it must remain moist for some hours to transmit the disease. At 15°C, 18–24 hours of wetness are needed for infection, but at 25°C, only 10–12 hours are needed. Young trees suffer less from melanose than older ones because they have less dead wood.

### 3.12.5 Disease Cycle

#### 3.12.5.1 Dispersal

Rain or overhead irrigation water spreads the anamorph spores over short distances to susceptible tissues in the citrus canopy. The ascospores are dispersed by wind over longer distances. The more dead wood that exists in a canopy, the more ascospores will be produced. Most fruit infections probably start other infections caused by conidia.

#### 3.12.5.2 Infection

Fruits are susceptible to infection from about three to five months after petal drop, depending on the area. Approximately 8–24 hours of continuous moisture on leaf or fruit surfaces is required for infection to occur, depending on air temperature (shorter periods at higher air temperature). Therefore, periods of extended rainfall at warm locations are most likely to initiate rapid and severe melanose disease development.

### 3.12.6 Management

The disease may not severely impact fruit yield, and if fruits are grown for juicing or other processing, melanose disease management may not be warranted.

- **Pruning**—Periodically prune away dead branches. This will reduce pathogen survival, increase air circulation to dry out the canopy, and allow for more effective fungicide penetration and coverage of the foliage.
- **Fungicides**—Sprays of fungicides to young fruits and leaves may be necessary for disease management. Where the disease tends to be severe, frequent fungicide applications may be required (refer to Table 3.9). Worldwide, copper fungicides are the most commonly applied. After application of copper sprays to citrus fruits, star melanose symptoms may appear which differ from the symptoms described above on unsprayed fruits. Postharvest treatments and storage conditions of fruits are not effective in reducing melanose disease damage to citrus rinds.
- **Citrus variety**—Avoid planting very susceptible citrus varieties or species (sweet orange, grapefruit) in high-rainfall areas.
- **Choice of planting location**—Plant citrus in sunny, low-rainfall regions.
- **Cropping system**—Interplant citrus with non-susceptible hosts (avoid monocrops).
- **Sanitation**—Pick up and destroy plant materials that have fallen from the citrus canopy.

Rates for pesticides are given as the maximum amount required to treat mature citrus trees unless otherwise noted. To treat smaller trees with commercial application equipment including handguns, mix the per acre rate for mature trees in 125 gallons of water. Calibrate and arrange nozzles to deliver thorough distribution and treat as many acres as this volume of spray allows (Table 3.9).

### 3.13 Postbloom Fruit Drop

Postbloom fruit drop (PFD) caused by *Colletotrichum acutatum*, affects citrus flowers and produces abscission of young fruitlets. PFD is a serious problem in most humid citrus production areas of the
TABLE 3.9
Recommended Chemical Controls for Melanose

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOAa</th>
<th>Mature Trees Rate/Acreb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper fungicide</td>
<td>M1</td>
<td>Use label rate.</td>
</tr>
<tr>
<td>Abound 2.08Fc</td>
<td>11</td>
<td>12.0-15.5 fl oz. Do not apply more than 92.3 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem 25WGc</td>
<td>11</td>
<td>4.0–8.0 oz. Do not apply more than 32 oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem 500 SCc</td>
<td>11</td>
<td>1.9–3.8 fl oz. Do not apply more than 15.2 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Headlinec</td>
<td>11</td>
<td>12–15 fl oz. Do not apply more than 54 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Pristinec</td>
<td>11/7</td>
<td>16–18.5 oz. Do not apply more than 74 oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Quadris Topp</td>
<td>11/3</td>
<td>15.4 fl oz. Do not apply more than 61.5 fl oz/acre/season for all uses. Do not apply more than 0.5 lb ai/acre/season difenconazole. Do not apply more than 1.5 lb ai/acre/season azoxystrobin</td>
</tr>
</tbody>
</table>

Note: This table is from PP-145, one of a series of the Plant Pathology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 1999. Revised February 2012.


b Lower rates can be used on smaller trees. Do not use less than the minimum label rate.

c Do not use more than 4 applications of strobilurin-containing fungicides/season. Do not make more than 2 sequential applications of strobilurin fungicides.

world. PFD must be controlled on processing and fresh market fruit. PFD affects all species and cultivars of citrus, but severity on a given cultivar varies according to the time of bloom in relation to rainfall.

3.13.1 Causal Organism

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. acutatum</td>
<td>Infection on Citrus Flowers</td>
<td>Severe</td>
</tr>
</tbody>
</table>

3.13.2 Symptoms

The pathogen infects flower petals causing peach to orange-colored lesions on open flowers (Figure 3.41) and flower buds (Figure 3.42). Subsequently, the fruitlet abscises leaving the calyx and floral disk

FIGURE 3.41 Peach to orange-colored PFD lesions on flower.
attached to the twig. These persistent structures remain attached for the life of the twig, and the leaves around inflorescences are usually twisted and distorted. Necrotic spots on petals often coalesce, producing a blight of the entire inflorescence. Senescent petals on healthy flowers usually are light tan in color or dry from the tip downward, but diseased petals are dark brown to orange and dry first in the areas affected (Figure 3.43). Affected petals become hard and dry, persisting for several days after the healthy flowers have fallen. After petal fall, the young fruit show a slight yellowish discoloration and usually abscise, leaving the calyx and floral disc intact. These structures are commonly called buttons (Figure 3.44) and stay green for a year or more and callous tissue begins to form around the abscission zone. Occasionally, young fruit remain attached to the button but never develop.

3.13.3 Cause and Disease Development

PFD severity on a given cultivar may vary according to the time of bloom in relation to rainfall. Most spores of this fungus are produced directly on the surface of infected petals. Spores are splash-dispersed by rains to healthy flowers where they infect within 24 hours. Long-distance spread may
Citrus

171

171

FIGURE 3.44  PFD leaves a persistent calyx or button after the petals fall.

occur by windblown rain, by bees or other insects that visit flowers, or by plant debris carried on equipment or in picking sacks or boxes.7

3.13.4  Favorable Conditions of Disease Development

3.13.4.1  Rainfall

Rain is needed for epidemic development to supply moisture for infection and, as importantly, to disperse conidia by the force of droplets impacting on spore-laden petals. The amount of rain is considered in the system, but the force of the rain is as important. Fortunately, these two factors are highly related, and the amount of rainfall is a good indicator of conidial dispersion.

3.13.4.2  Leaf Wetness

At least eight hours of moisture is needed for infection and the amount of infection increases as the duration of wetness increases. Only the number of hours of wetness that occurred during and after a rain in the last five days is considered. Without the force of rainfall, conidia are not dispersed. Dews and fogs are not considered since only localized infection results from even extended wetting periods. Few aids in the growth of inoculum by spreading from infected leaves and flowers to uninfected leaves and flowers. This is considered under inoculum level.

3.13.5  Disease Cycle

Asexual spores of *C. acutatum* are produced in abundance on infected petals. These spores are dispersed by rain splashing onto adjacent healthy flowers; they germinate in the presence of moisture in 12–24 hours, infect petals in 24–48 hours and produce symptoms and new spores in four to five days. The fungus survives between blooms on the surface of leaves, twigs, and buttons as appressoria (single-celled, thick-walled structures). The following spring, these structures germinate in the presence of moisture and substances present in flower petals to produce new asexual spores. These spores may then be dispersed to the fresh flowers by splashing rain (Figure 3.45).

3.13.6  Management

The increase in the incidence of PFD is very high under optimum conditions making the disease difficult to control. Overhead irrigation should be avoided during bloom, if possible, or trees should be irrigated at night and allowed to dry during the day. Trees declining because of blight, tristeza, or other factors often flower out of season, thus maintaining high levels of inoculum. Such trees should be removed prior to bloom in PFD-affected blocks.

Refer to the following table for fungicides registered for citrus which control PFD (Table 3.10).
3.14 SOOTY BLOTCH OF CITRUS

Sooty blotch is a fungal disease in which dark, round smudges, that may expand to form irregular shaped blotches that cover most of the fruit, occur. The smudges are initially circular but may form irregular shapes as they overlap.

3.14.1 CAUSAL ORGANISM

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloeodes pomigena</td>
<td>Rind Blemish</td>
<td>Minor</td>
</tr>
</tbody>
</table>

3.14.2 SYMPTOMS

Sooty blotch is a rind blemish caused by the development of the fungus *G. pomigena* over the fruit surface. The gray to black fungal strands give the appearance of a light dusting of soot (hence the name), which can be rubbed vigorously and removed (Figure 3.46). This is convenient for smooth-skinned varieties. Rubbing off the soot of rough-skinned varieties is particularly difficult because of the rough texture of the rind. The growth of the fungus is generally superficial, and it can only rupture the cuticle, not the epidermis. Fruits can be eaten, but it looks unsightly. It usually makes the fruit unmarketable for the fresh trade and its storage life is reduced.
3.14.3 Favorable Conditions of Disease Development

The disease is a frequent problem under wet and shaded conditions and is commonly observed during autumn and winter in coastal regions of the world. Mature fruit on the inside of the tree canopy are most affected.

3.14.4 Management

Application of copper fungicides can help control Sooty Blotch to some extent. Since wet conditions are favorable for disease development, an additional application of copper fungicides during autumn will help reduce the disease.

3.15 Sweet Orange Scab

Sweet orange scab (SOS) is a fungal disease that causes unsightly corky lesions on fruit. This disease is so named because it results in scab-like lesions that develop primarily on the fruit rind (thick outer skin) and infrequently, on leaves and twigs. These lesions do not generally affect yield as there

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**TABLE 3.10**

Recommended Chemical Controls for Post-Bloom Fruit Drop

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>FRAC MOA</th>
<th>Mature Trees Rate/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abound 2.08 F</td>
<td>11</td>
<td>12.0–15.5 fl oz. Do not apply more than 92.3 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Abound 2.08 F + Ferbam</td>
<td>11, M3</td>
<td>12.0 fl oz + 5 lb</td>
</tr>
<tr>
<td>Gem 500 SC</td>
<td>11</td>
<td>1.9–3.8 fl oz. Do not apply more than 15.2 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Gem + Ferbam</td>
<td>11, M3</td>
<td>1.9 fl oz. + 5 lb</td>
</tr>
<tr>
<td>Headline</td>
<td>11</td>
<td>12 fl oz. Do not apply more than 54 fl oz/acre/season for all uses.</td>
</tr>
<tr>
<td>Headline + Ferbam</td>
<td>11, M3</td>
<td>12-15 fl oz + 5 lb</td>
</tr>
</tbody>
</table>

*Note:* This table is from PP-45, one of a series of the Plant Pathology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 1995. Revised January 2012.

- Lower rates can be used on smaller trees. Do not use less than the minimum label rate.

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**FIGURE 3.46** Soot dust on the rind giving a gray to black appearance.
is little effect on the internal fruit quality but can reduce the marketability of the fruit. However, the disease can cause stunting of the young nursery trees and new field planting and premature fruit drop. This disease is known to occur principally in South America.

### 3.15.1 Causal Organism

<table>
<thead>
<tr>
<th>Species</th>
<th>Associated Disease Phase</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elsinoe australis</em></td>
<td>Lesions on Fruit</td>
<td>Low</td>
</tr>
</tbody>
</table>

### 3.15.2 Symptoms

The initial scab is observed during the early stages of fruit development. The lesion is slightly raised and pink to light brown in color. These are the early lesions (Figure 3.47). As the lesion expands, it takes on a cracked or warty appearance and may change color to a yellowish-brown and eventually to a dark gray, forming advanced lesions (Figure 3.48). The scabs typically form a pattern on the fruit similar to water splashes.

On young stems, the lesions resemble an area of dieback that has been scabbed over. Lesions begin on the underside of leaves as water-soaked spots. They typically form along the edge of the leaf or the mid-vein.
3.15.3 Cause and Disease Development

The SOS disease is spread by spores which are dispersed by splashing water and wind-driven rain. The spores are produced when scab lesions are wet for at least one or two hours, the humidity is very high, and the temperatures are from 20°C–28°C. Spores can spread the disease to susceptible plants if there is a sufficient level of moisture in the environment.

3.15.4 Favorable Conditions of Disease Development

Diseases develop over a range of temperatures as long as there is sufficient moisture, and disease can develop quite rapidly (in less than four hours) under favorable temperature range of 20°C–28°C. The fungus can live through the winter in the tree canopy on limbs and on fruit that were infected during the previous season.

3.15.5 Disease Cycle

SOS forms spores on the surface of the scab pustules. This species of scab attacks mainly fruits. The conidia (asexual spores) are similar to those of *E. fawcettii*, require moisture for spore production and are primarily spread by splashing rain. Fruits are susceptible for six to eight weeks after petal fall. The role of ascospores (sexual spores) is uncertain.

3.15.6 Management

- It is important that the trees are sprayed with a copper fungicide from petal fall until the fruit is two months old. This, preferably, should be done in three sprays—the first spray should be applied prior to bloom to protect the foliage, the second spray three to four weeks later, and the third spray three to four weeks after the second spray. The copper-based fungicides should not be applied during bloom.
- The removal of infected fruit, leaves, and plant parts is also recommended to help control the disease. With proper spraying of a copper fungicide and with proper removal of plant parts the SOS disease can be controlled and possibly eliminated.
- Maintaining cleanliness, good sanitation, and hygiene practices also help in keeping the disease away.
- The symptoms of the disease should be well known so as to detect it at an early stage.

REFERENCES
