

## PEST MANAGEMENT

### 7.1 FUNGAL DISEASES

#### 7.1.1 Brown Rot

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**M***onilinia fructicola* (Wint.) Honey is one of several species of *Monilinia* that cause brown rot of peach. Other species of this genus have not been reported in the southeastern United States. Brown rot was first described in 1796 in Europe. Fungi that cause brown rot are distributed worldwide. The species that causes the disease in the Southeast is also found throughout the Americas, New Zealand, Australia, Africa, Japan, and Argentina. Brown rot was recognized in the United States as early as 1807, but it was not determined to be caused by a fungus until 1855.

#### SYMPTOMS

The brown rot fungus can infect fruit, shoots, and flowers of peaches and other stone fruits. Spores infect flower and fruit tissues. Stems are usually infected by invasion of the fungus from infected blossoms and fruit. Direct infection of leaves and stems by spores is rare in the Southeast; such infections are more likely to occur in plum and certain ornamental *Prunus* species.

#### Blossoms

Blossom blight, the bloom-infecting stage of brown rot fungus, can invade through any part of the flower (Figure 7.1.1.1); following infection, diseased tissues turn dark brown. Almost immediately, tan- to buff-

colored tufts of spores appear on infected tissues.

When a full flower crop is present, blossom blight seldom causes significant crop loss in peach. Under conditions of a reduced flower crop, as with spring frost or bloom thinning, blossom blight can result in unacceptable crop loss. Bloom sprays are critical when flower numbers are significantly reduced. When a full flower crop is present, the primary benefit of blossom blight control is reduction of inoculum levels, which will often reduce pre-harvest brown rot levels. Blossom blight infections are generally more prevalent in blocks where severe brown rot occurred in fruit the year before.

Ordinarily, less than 1% of blossoms will be affected by brown rot. However, the confluence of high inoculum levels and environmental conditions conducive to blossom blight can lead to heavy losses. For example, spring crop losses that prompt abandonment of disease control can lead to heavy overwintered brown rot inoculum. In Georgia, blossom blight has infected up to 40% of blooms when a wet bloom period followed this type of inoculum buildup. Even this unusually high level of blossom blight does not directly result in crop loss. However, destructive levels of brown rot inoculum often build up in these blocks, and heavy crop losses can occur before and during harvest.



### Stem Cankers

When flower or fruit pedicels are infected, the brown rot fungus frequently spreads into twigs and small branches and forms a brown, collapsed lesion known as a canker. These depressed, elliptical areas may enlarge until the entire stem is girdled. After girdling, the shoot tip withers and dies, while the leaves remain attached. A drop of gum is present when brown rot cankers are formed. During moist weather, tufts of spores may be visible on the cankers. Lesions of *Phomopsis amygdali* (constriction canker or *Phomopsis* twig blight) are often confused with brown rot lesions. However, there are distinctive differences. Lesions of constriction canker are generally found at buds or nodes, whereas brown rot lesions are found at a blossom site. Very limited gum exudate is found with constriction canker lesions, but profuse gumming is observed with brown rot. Constriction canker lesions also form zonate patterns as they develop.

### Fruit

Brown rot results in four types of fruit infections in the Southeast: infections of aborted, non-abscised fruit (buttons) (Figure 7.1.1.2); infection of late-thinned fruit on the orchard floor; infected green fruit (Figure 7.1.1.3); and infection of mature fruit during harvest and handling operations (Figure 7.1.1.4). After harvest, the development of fruit mummies provides a significant overwintering mechanism. Fruit that is thinned at or after pit-hardening provides a good growth medium for the fungus. Inoculum from thinned fruit after pit-hardening can dramatically increase infection of mature fruit. Fruit that is thinned prior to pit-hardening will quickly disintegrate.

Latent infections of immature fruit can serve as a source of inoculum for subsequent fruit rot. High levels of latent infection are more common following blossom blight infections. In addition, insect- or cold-damaged green fruit are more susceptible to brown rot. Research on plums suggests that fruit-to-fruit contact may also predispose fruit to infection by *M. fructicola*. Unfortunately, detection of the pathogen on any fruit is based on the presence of masses of gray to brown fungal spores. Unless sporulation occurs, infection of these fruit is not easily detected.



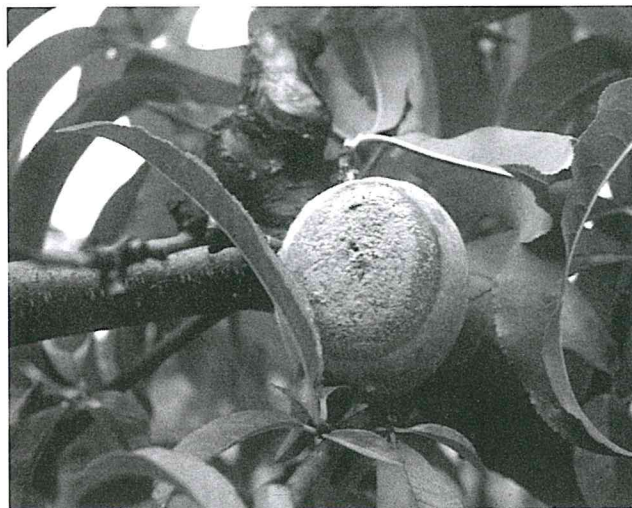
**FIGURE 7.1.1.1. Brown rot blossom blight. Note production of grayish-tan spore masses on the twig at the base of the blighted blossom. (color plate, page 181, Figure 7.1.1.1)**



**FIGURE 7.1.1.2. Brown rot on an aborted fruit ("button"). (color plate, page 181, Figure 7.1.1.2)**

Infection of maturing fruit just prior to harvest is the most destructive phase of the brown rot fungus. The first indication of pre-harvest infection is the development of small, superficial, circular brown spots, sometimes called pen-rot. Under optimal conditions, spots can enlarge at a rate of 0.02 to 0.04 inches per hour. As lesions enlarge, the skin of the fruit is ruptured with tufts of gray to light tan spores, frequently formed in concentric rings (Figure 7.1.1.4).





**FIGURE 7.1.1.3.** Brown rot on insect-damaged green fruit. Note small insect feeding puncture in the center of the rotted area. (color plate, page 181, Figure 7.1.1.3)

Before sporulation occurs, the fruit rot lesions of brown rot, Rhizopus rot, and anthracnose are more difficult to separate from one another. When infected by *Rhizopus nigricans* (Figure 7.1.1.5), the skin of rotted fruit slips off very easily, and the flesh is softer and more watery than that of brown rot-infected fruit. Brown rot fruit infections are smooth. Anthracnose infections (*Glomerella cingulata*) (Figure 7.1.1.6) form a depressed, circular spot on the fruit surface. Anthracnose lesions are marked by the occasional presence of cream to salmon-pink concentric rings of spores; also, a cone of rotted flesh can easily be separated from the healthy flesh.

### Mummies

Brown rot completely permeates a peach fruit. As the disease cycle progresses, the fruit tissue is darkened by thick-walled fungal cells. Fruit shrivel to produce a wrinkled, very dark brown to black “mummy,” which may remain attached (Figure 7.1.1.7) or drop to the ground (Figure 7.1.1.8).

Brown rot mummies that are partially buried within a couple of inches of the surface in moist soil may produce spore-bearing apothecia during the next bloom period. Apothecia (Figure 7.1.1.9) are smooth, fleshy, brown to reddish brown, cup-like structures that vary in size from 1/4 to 3/4 inch in diameter. The cup-like structures arise on a stalk that may be up to 2 inches in length. A slight jarring of the apothecia will result in a small



**FIGURE 7.1.1.4.** Brown rot on a ripe fruit. Note the production of spore masses in more or less concentric rings. (color plate, page 181, Figure 7.1.1.4)

cloud of visible spores. Apothecia are seldom seen in Georgia, but they increase in importance as one moves north through the Carolinas.

### DISEASE CYCLE

The brown rot fungus overwinters predominantly as mummies or in cankers. Each year, the disease cycle is initiated by primary spores produced either in apothecia or infected tissues, including mummies on the tree. The air-borne spores infect blossoms of peach and other susceptible plants such as wild plum.

Infection can take place at temperatures as low as 41°F, but the optimum temperature for infection is 77°F. Moisture, in the form of exudate on stigmata, wounds, or free water as dew or rain, is important for infection. Infection can take place at relative humidities (RH) as low as 94%, but higher humidity levels are conducive to higher infection levels. Under optimal conditions of moisture and temperature, infection takes one to six hours.

Almost immediately after symptoms appear on the blossoms, and subsequently the stems, brown rot will begin producing spores. This spore production is important for secondary infections. If sources of secondary inoculum can be eliminated or avoided, disease control opportunities improve. Spore production on infected flowers can continue





**FIGURE 7.1.1.5. Rhizopus rot on a ripe fruit. (color plate, page 182, Figure 7.1.1.5)**



**FIGURE 7.1.1.6. Anthracnose rot on ripe fruit. (color plate, page 182, Figure 7.1.1.6)**



**FIGURE 7.1.1.7. Mummy of a brown-rotted peach fruit hanging in the tree. (color plate, page 182, Figure 7.1.1.7)**



**FIGURE 7.1.1.8. Mummy of a brown-rotted peach fruit that has fallen to the ground. (color plate, page 182, Figure 7.1.1.8)**

through early June during dry seasons. Sporulation of infected blooms may occur over an even longer period during a wet season.

Even without continued spore production on infected blossoms, the disease cycle can continue if infected buttons or damaged, infected fruit are present. Fruit that has been removed during thinning, at or after pit-hardening, can also provide a continuous source of spore production. Infected fruit can provide a bridge, assuring abundant inoculum from blossom to mature fruit infection.

Mature fruit are very susceptible. Assuming that a continuum of spores is present, infection of

maturing fruit is probable. Given the short period of time required for infection, the high likelihood of optimal conditions for infection (moisture and temperature), and the overwhelming spore numbers that result from a continuum of infection, pre-harvest brown rot infections readily reach epidemic level.

Rain splashing is an important means of spore dissemination. Spores can also be released in copious quantities through bumping and brushing of leaves and stems by wind. Insects such as driedfruit beetles (nitidulid beetles) can also be important in the spread of brown rot.





**FIGURE 7.1.19.** Cup-like brown rot apothecia that form on partially buried peach mummies on the ground. These fungal structures produce the spores that result in some of the primary infections in the spring. (color plate, page 182, Figure 7.1.19)

## CONTROL

Pre-harvest brown rot is a very serious disease. A season-long management strategy is normally best. The most critical times for control of brown rot are during bloom and prior to harvest. A minimum-risk, protective fungicide program requires two to three applications during bloom and two to three applications prior to harvest.

Sanitation is a key to management of brown rot. The proximity of readily available inoculum sources (i.e., wild plums, off-type trees where the disease was not controlled the previous season, otherwise abandoned *Prunus* species, and mummies from the previous season) all but assures high inoculum carryover. Crops abandoned after a destructive frost often experience a tremendous build-up of brown rot inoculum on the few remaining fruit. These blocks will require special attention the following spring.

Wild plum thickets are an important source of spores for both primary and secondary infections. Wild plums bloom before and during peach bloom, and the fruit mature continuously from early to late in the season, providing a continuing

source of inoculum. Removal of wild plums adjacent to a peach orchard is an important sanitation procedure.

Research on plums suggests that thinning fruit to reduce fruit clustering and application of fungicides effective against brown rot before fruit contact occurs might reduce fruit losses from brown rot. Additional hand-thinning to remove buttons would be ideal, but is probably not practical. When buttons are abundant, orchards should be watched more closely for brown rot. An intensive pre-harvest spray program should be used if brown rot becomes evident.

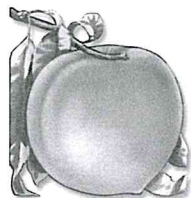
Brown rot losses can continue after harvest during storage and transit. See the discussion of post-harvest diseases for additional information on this phase of brown rot.



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## 7.1.2 Green Fruit Rots

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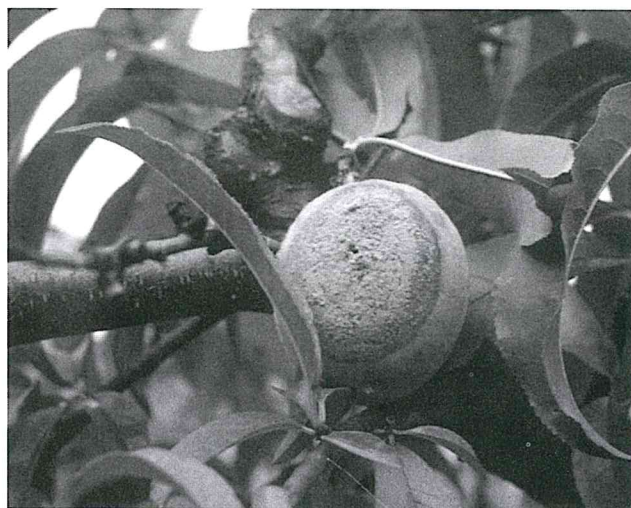
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**G**reen fruit rots, *Botrytis cinerea* Pers. ex. Fr. (gray mold) and *Monilinia fructicola* (Wint.) Honey (brown rot), develop from latent infection of the gray mold and brown rot fungi. Most green fruit rot is initiated in damaged ovules or fruit damaged by insect-punctures or hail (Figure 7.1.2.1). Latent brown rot lesions commonly develop on fruit when wounding results in elevated levels of sugar in the fruit. Very close inspection can reveal latent infection lesions, tiny necrotic spots barely visible to the naked eye. These lesions are easily missed or confused with other minor injuries. Latent brown rot infections are thought to develop into green fruit rot when wetness periods exceed 30 hours. The lesion expands rapidly and can involve entire young fruit. Eventually the infected fruit may be covered with grayish brown spore masses. If conditions are right, all stages of fruit development are susceptible. Green fruit rot can be a very significant source of inoculum for pre-harvest brown rot. Scouting for blossom blight (as a source of inoculum) and adoption of fungicide programs effective against both scab and brown

rot until the inoculum source dries up should preclude green fruit rot outbreaks. Because many fungicides do not control both green fruit rot organisms, it is important to know whether brown rot or gray mold is involved. *Botrytis* is less common.

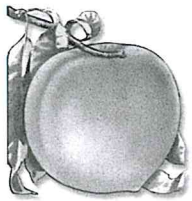
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**FIGURE 7.1.2.1. Brown rot development on an insect-damaged green fruit. (color plate, page 182, Figure 7.1.2.1).**





## 7.1.3 Peach Scab

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**S**cab is a very common problem on stone fruits in the southeastern United States. The disease is caused by *Cladosporium carpophilum* Thuem., an asexual fungus that produces conidia (splash and airborne spores that infect shoots, leaves, and fruit during the season) and chlamydospores (thick-walled survival spores formed on infected twigs during the winter). Regionally, scab pressure is generally greatest in the Carolinas and decreases as one moves into south Georgia. The disease is readily controlled with fungicides, but control failures still occur and may result in considerable yield losses.

### SYMPTOMS

The fungus causes twig, leaf, and shoot infections. Among these, leaf infections are generally least noticeable and least important. Twig infections, although not associated with direct yield losses, are epidemiologically very significant because they provide the fungus with an overwintering site. Fruit infections can result in considerable yield losses, mainly from grade reductions or culling of affected fruit that is less desirable in the marketplace.

**Twig Symptoms.** Twig infections take place as soon as new shoot growth is available in early spring, and they can continue to occur throughout the summer. Early symptoms, which develop during spring and summer, are minute, reddish-gray, diffuse spots of 1 to 2 mm in diameter. During fall

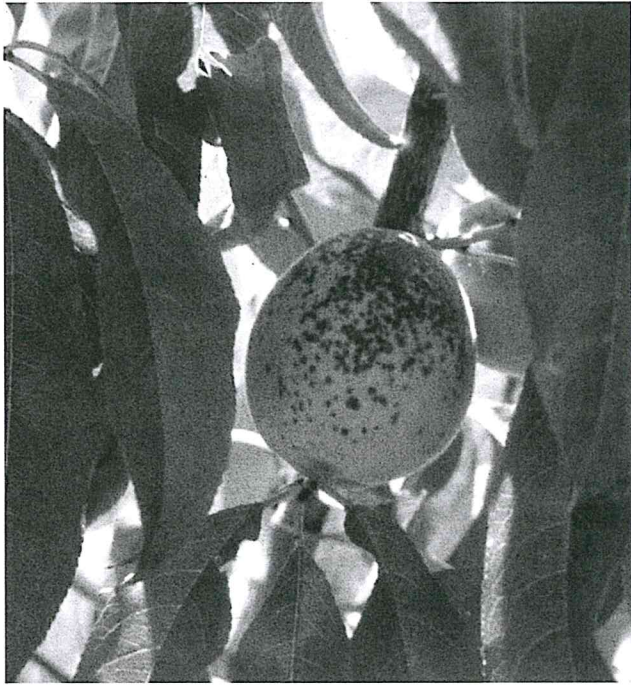
and winter, these spots enlarge to form reddish-brown, irregularly circular to oval lesions that measure approximately 3 x 6 mm. Lesions tend to elongate along the stem and, as they mature during the winter, they develop a slightly raised, dark to brown-purple border (Figure 7.1.3.1). Sporulation does not generally occur on current year's lesions, but it occurs on mature lesions during the spring and summer of the year following infection. Examination of such lesions in late spring reveals a black, rough surface, which is evidence of sporulation. Spores are produced in large numbers as olivaceous tufts of conidia.

**Fruit Symptoms.** Fruit symptoms first appear when the fruit is in mid-development. Greenish-gray to olive circular spots that are 1 to 2 mm in diameter are formed, with more pronounced infections on the stem end of the fruit (Figure 7.1.3.2). Spots expand to 2 to 3 mm in size, and a yellow halo



**FIGURE 7.1.3.1.** Scab twig lesions. Note the oval to irregular lesion shape with a raised margin. Image by P. F. Bertrand. (color plate, page 183, Figure 7.1.3.1)





**FIGURE 7.1.3.2. Scab lesions on green fruit. Note that lesions are more concentrated near the stem end. Image by P. F. Bertrand. (color plate, page 183, Figure 7.1.3.2)**

may form around them (Figure 7.1.3.3). The fungus sporulates on these fruit lesions, producing conidia that can lead to additional (secondary) infections of fruit and twigs. Fruit scab lesions generally have a raised, corky appearance, whereas in the case of bacterial spot infection, which causes similar fruit spotting, lesions are sunken. Severe infection may lead to cracking of the fruit skin surrounding scab lesions, generating entry points for fruit-rotting organisms such as the brown rot fungus.

### DISEASE CYCLE

Scab lesions on 1-year-old twigs play a key role in the disease cycle; they provide the sole overwintering site for pathogen survival. Overwintering takes place as mycelium in lesions and as chlamydospores on the surface of lesions. Production of conidia, which serve as infectious propagules, begins in late winter and continues throughout the spring and early summer. Maximum conidial production requires average daily temperatures exceeding 16°C in concert with high relative humidity for at least 24 hours. In the southeastern United States, peak conidial production occurs



**FIGURE 7.1.3.3. Scab lesions on mature fruit. Note the yellow halo surrounding the lesions. (color plate, page 183, Figure 7.1.3.3)**

between petal fall and shuck-off, with numbers remaining high through mid- to late May. Thereafter, conidial numbers tend to taper off, signaling a period of reduced scab risk.

Conidia are carried to new infection sites (fruit and current season's shoot growth) by wind and rain-splash, with splashing being the more important mode of dispersal. Infection of current-season shoots can occur any time during the growing season. Fruit infections on peach are important from shuck-off to about 4 to 6 weeks before harvest; on nectarine, the susceptible period begins earlier (at shuck split) due to the lack of protective hairy fruit covering. Late infections (within 4 to 6 weeks of harvest) are generally unimportant due to the long time (40 to 70 days) between infection and symptom appearance. This lengthy "incubation period" is also the reason why secondary infections (those originating from conidia produced on early fruit lesions) are of limited importance other than in conditions of poor scab control on late-season varieties. On such varieties, both large lesions (from primary infection) and small spots (from secondary infection) may be present on fruit at harvest.

Infection is favored by the presence of free water (rain or dew) during periods when air temperatures exceed 10°C; the optimum temperature range for infection is 22° to 30°C. Seasonally, rainy weather during the first 6 weeks following shuck split (when conidial numbers are highest and fruit are susceptible) is strongly associated with increased



scab risk. However, considerable infection occurs, even in the absence of rain, during periods of prolonged fruit wetness caused by dew or fog.

## CONTROL

There are no cultural controls for scab and no resistant peach varieties are available. Thus, scab control relies exclusively on well-timed fungicide applications. Based on the disease cycle described above, the following control periods may be distinguished:

- *Petal fall.* At this time, no fruit tissue is exposed, and there is thus no need to protect fruit from infection. However, as stated above, the peak of conidial production on twig lesions may occur as early as petal fall. An application of a fungicide with antispore activity at petal fall may therefore be useful in suppressing conidial production on overwintered twig lesions and in reducing inoculum potential for subsequent periods. This may be particularly important for orchards that were not sprayed the previous season (e.g., orchards coming into production for the first time or those where the crop was lost the previous year due to spring freezes). It should be noted, however, that the benefits derived from a petal fall application often are inconsistent.
- *Shuck split.* At this time, scab conidial numbers tend to be very high and exposed fruit tissue may or may not be susceptible to infection, depending on the pubescence (hairiness) of the fruit. Research trials consistently document considerable benefits of an early shuck split application. This application should be made with a highly effective contact or systemic fungicide, rather than with the less expensive but less efficacious sulfur products.
- *Shuck-off and early cover sprays.* This period marks the greatest scab risk, given the presence of large conidial numbers and the increased susceptibility of the developing fruit. Closely spaced applications with effective fungicides are recommended, particularly for the shuck-off application and during rainy weather.
- *Mid-season cover sprays.* During this period, conidial production on twig lesions tapers off,

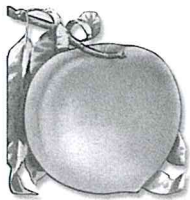
leading into a period of reduced scab risk starting about 6 to 8 weeks past petal fall. Control intensity may also be reduced at this time. In middle Georgia, this can be implemented by using alternate-row middle (ARM) applications and/or by switching to sulfur as the primary fungicide. Note, however, that extensive use of sulfur may contribute to reduced fruit coloring and finish. If this period is very rainy, closer application intervals, use of more effective fungicides, and/or a switch back to standard applications (instead of ARM) would be advisable.

- *Pre-harvest interval.* No fungicide applications against scab are needed during the final 4 to 6 weeks before harvest. This period can therefore focus on control of pre-harvest brown rot.

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## 7.1.4 Post-Harvest Decay

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**P**ost-harvest decay can cause severe losses in peaches. Monetary losses are especially high because all production, harvest, and packing costs have already been invested in the fruit. Aside from direct losses due to product loss, there are important indirect losses a packer can suffer. Key among them are price discounting and/or loss of repeat sales due to suspect fruit quality in a given year, or a general loss of reputation, which can last several years.

If decay occurs, it is not enough to know the fruit rotted or was moldy. Accurate diagnosis of which disease or diseases were involved is imperative so specific corrective measures can be taken. The post-harvest diseases southeastern peach packers may encounter are brown rot, Rhizopus and Gilbertella rots, sour rot, gray mold rot, and bitter rot. Brown rot and Rhizopus rot are the region's most common post-harvest peach rots, they occur to some extent every year. Controlling these diseases requires a coordinated program of rapid cooling, low temperature storage and transit, gentle handling, sanitation, and fungicides.



**FIGURE 7.1.4.1.** Brown rot on a mature peach. Pre-harvest infections continue to spread during and after harvest. (color plate, page 183, Figure 7.1.4.1)

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#### BROWN ROT

Brown rot is the most important post-harvest decay disease of peaches. The brown rot fungus, *Monilinia fructicola* (Wint.) Honey, attacks the blossoms, aborted fruit or "buttons," insect-injured or otherwise damaged green fruit, and, most importantly, mature ripening fruit (Figure 7.1.4.1). Research shows that the majority of the spores attacking fruit of mid- and late-season peaches come from infected wild plums, overripe fruit of off-type varieties, late thinned fruit, buttons, and damaged green fruit. This continuum of infection sources means control programs must protect fruit through each period of vulnerability to provide adequate brown rot control and assure post-harvest quality. Latent (invisible) infections of immature fruit can serve as a source of inoculum for subsequent fruit rot. Latent infections are more likely when infection pressure due to blossom blight and infected aborted fruit is high. Latent infections are usually few in number but, where they occur, they are important. Insect damaged or otherwise injured green fruit can be lost to brown rot.



**FIGURE 7.1.4.2.** Brown rot mummy. (color plate, page 183, Figure 7.1.4.2)



Research on plums suggests that fruit-to-fruit contact predisposes fruit to infection by *M. fructicola*, probably due to prolonged wetness following dew events. The brown rot control strategy currently considered economically and environmentally sound is to apply pre- and post-harvest fungicides to prevent new infections and suppress latent infections instead of 6 to 10 or more applications during the green fruit phase.

The flesh of brown-rotted peaches becomes watersoaked and brown but remains more or less firm. Tan to gray spore masses form, often in concentric rings, on the surface of infected areas. Brown rot can be distinguished from *Rhizopus* and *Gilbertella*, with experience, by how readily the skin of rotted flesh slips. The skin of *Rhizopus* and *Gilbertella* infected fruit slips easily, whereas the skin of fruit with brown rot does not. After the fruit is completely decayed, brown rot shrivels into a mummy (Figure 7.1.4.2). Mummies carry the brown rot fungus through the winter.

Post-harvest, the brown rot fungus is spread in hydrocoolers used to remove field heat and in water dumps used to reduce bruising. It is important to continuously sanitize hydrocoolers and dump tanks. In bins or cartons, brown rot can spread by simply growing from fruit to fruit at points where peaches contact one another. A single rotted peach can destroy a carton of peaches without any help from wind or insect-borne spores or infested cooling or dump systems. The brown rot fungus can germinate and cause disease between 32° and 90°F. Cold temperatures, however, greatly reduce the rate of acute and latent infections, which slows both hydrolysis or breakdown of post-harvest fungicides and disease spread from fruit to fruit.

See the brown rot chapter for a complete discussion of brown rot disease cycle and epidemiology.

## RHIZOPUS ROT

*Rhizopus* rot is primarily caused by *Rhizopus stolonifer* (Ehr. ex. Fr.) Vuill. It is the second leading cause of post-harvest decay in peaches. It is frequently found closely associated with *Gilbertella persicaria* (E. D. Eddy) Hesseltine, *Mucor* species,

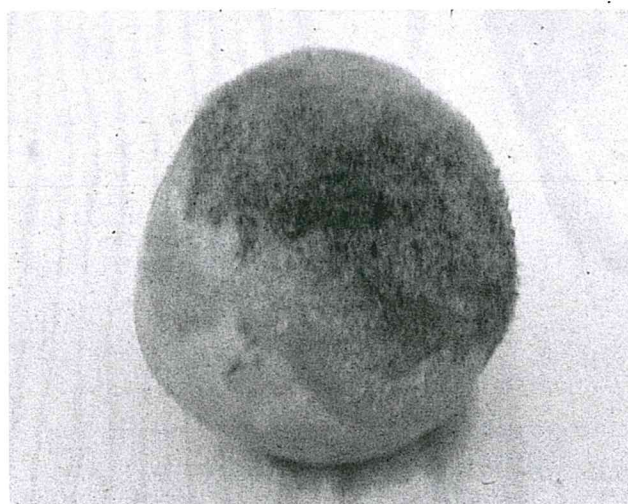
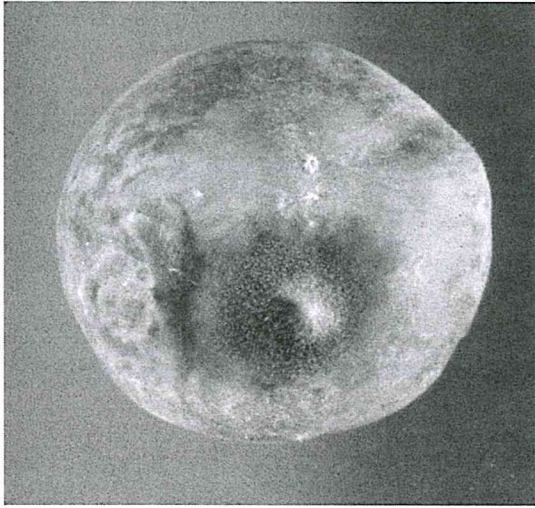


FIGURE 7.1.4.3. *Rhizopus* rot on peach. (color plate, page 183, Figure 7.1.4.3)

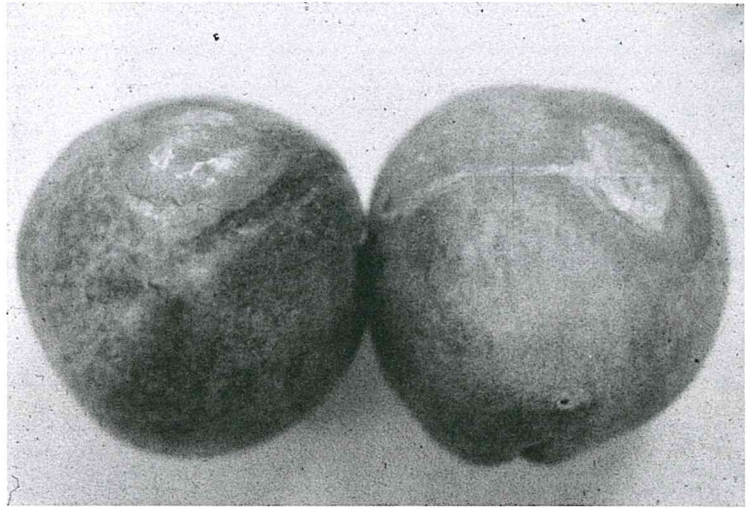
and other *Rhizopus* species. *Rhizopus* rot is generally a problem of fully mature and ripe fruit at point of sale or after purchase. It is important that cooling and handling systems be continuously sanitized to prevent contamination of fruit surfaces. The pathogen enters the peach only through an injury. Careful fruit handling to avoid cuts and bruises is an important factor in *Rhizopus* rot control. Fruit diseased with *Rhizopus* quickly decompose. The skin of infected fruit readily slips. The flesh becomes brown, very soft, and soon collapses. The surface becomes covered with coarse black fungal growth (Figure 7.1.4.3). At temperatures above 50°F, the disease can quickly spread through an entire bin or carton of peaches. Spore germination and disease development will not occur below 45°F. Rapidly cooling peaches below 45°F, preferably to 32° to 33°F, is a key to *Rhizopus* rot control. Cool temperatures do not kill ungerminated spores, but a post-harvest fungicide treatment will ensure *Rhizopus* rot control should the fruit warm above 45°F.

Chinese scientists have used the yeast antagonist *Pichia membranefaciens*, isolated from wounds of peach fruit, to completely control the pathogen when applied as washed cell suspension into nectarine wounds artificially inoculated with *Rhizopus* spores. The practical importance of this biological control agent remains to be determined.





**FIGURE 7.1.4.4. Gray mold on peach.** (color plate, page 184, Figure 7.1.4.4)



**FIGURE 7.1.4.5. Sour rot on peach.** Image by C. M. Wells. (color plate, page 184, Figure 7.1.4.5)

### GRAY MOLD ROT

Gray mold rot, caused by *Botrytis cinerea* Pers. ex. Fr., occasionally causes losses in peaches. Gray mold causes a brown, somewhat firm decay of the flesh. The skin over the diseased flesh slips away with a slight touch. The decay surface finally becomes covered with gray-brown fungal growth (Figure 7.1.4.4). Gray mold occurs more commonly during wet and somewhat cooler-than-normal harvest seasons (70° to 80°F daily maxima). Gray mold is rare in the southeastern United States due to high temperatures. The disease will develop, though slowly, at 32°F. Careful handling to minimize injuries, sanitizing cooling and dump systems, and the use of an effective fungicide provide excellent gray mold control.

### SOUR ROT

Sour rot, caused by *Geotrichum candidum* Lk. ex Fr., causes periodic problems in the Southeast. It is often associated with injured or split pit peaches. Spores may reach the injured fruit on vinegar flies feeding in the injuries, or by passing the peaches through contaminated dump or hydrocooler water. Peaches affected by sour rot have a characteristic sour odor and are often covered with pasty, yeast-like fungal growth (Figure 7.1.4.5). Fluid dripping from infected fruit ruins other fruit below. Spore germination and disease development do not occur below 36°F. At 60°F, the disease can spread

very rapidly in packed peaches. Careful handling to avoid injuries and sorting to remove injured or split pit peaches are important in sour rot control. Use of chlorinated hydrocooler and dump water also aid sour rot control.

### ANTHRACNOSE

Anthracnose is caused by two species of the fungus *Colletotrichum*, *C. acutatum* J. H. Simmonds and *C. gloeosporioides* (Penz. & Sacc. in Penz.). World-wide in distribution, the disease was an important problem in the Southeast from 1945 to 1955, but it occurs only occasionally today. Varieties vary in susceptibility. The fungus forms latent infections in many hosts, including peach. Disease development starts at final fruit maturation, beginning as a small more or less circular brown spot on the fruit. Spots slowly enlarge, but rarely exceed 1 inch in diameter. The tissue beneath the lesion dries and collapses, leaving a cavity 1/8 to 1/4 inch into the flesh (Figure 7.1.4.6). When pressed firmly, the rotted flesh will separate from healthy tissue. It is sometimes referred to as pocket rot. In later stages, pink or creamy white spore masses may be present in concentric rings. Spore germination and disease development do not occur below 40°F. Symptoms are generally present at harvest, but infections easily go undetected in less mature fruit, hence its discussion here as a post-harvest decay organism. The fungus has a wide host range, including legumes, herbaceous annuals,





**FIGURE 71.4.6. Anthracose on peach. Image by N. E. McGlohon. (color plate, page 184, Figure 71.4.6)**

and perennials. Blue lupine has been associated with increased incidence of the disease.

The control strategy is to determine blocks or varieties that have an anthracose problem. In these blocks, select an effective fungicide and use it, at a minimum, in the last six sprays before harvest.

### POST-HARVEST DECAY CONTROL

- (1) Use a good pre-harvest fungicide program to prevent disease buildup in the orchard. This program is critical for control of brown rot and suppresses some of the minor diseases as well.
- (2) A good insect control program will prevent insect damage and infestations by driedfruit beetles, which may carry brown rot spores to injured fruit. Brown rot epidemics spread by driedfruit beetles are nearly impossible to control with fungicides.
- (3) Supervise harvest, transport, and packing to minimize fruit injuries due to careless handling.
- (4) Remove cull fruit from the packing house and dispose of it as far as possible from the packing house or orchard.
- (5) Spores of the post-harvest decay fungi may be

carried from the orchard as surface contamination on the fruit. Continuously sanitize and monitor hydrocooler and dump water to avoid buildup of these spores. Water changes should be made daily, even where a conscientious sanitation procedure is used. Alternatively, use of forced-air cooling is recommended.

- (6) Quickly cool the fruit to 32° to 33°F. Maintain this temperature during handling and storage and take all steps to ensure this temperature is maintained in transit to the terminal market. Peach fruit between 38° and 55°F experience chilling injury, and such fruit will have a greater propensity to experience post-harvest rot problems. The activity of all decay organisms is greatly reduced or stops below 38°F.

### SANITATION, DUMPING, AND FIELD HEAT REMOVAL

Prompt removal of field heat is an essential step in peach packing. To reduce injury when fruit are dumped, a water dump is often used. Traditionally in the Southeast, hydrocoolers have been used to remove field heat. A hydrocooler consists of a tunnel, approximately 100 feet long, in which the fruit is treated with 32°F water as 20-bushel field bins slowly advance through the tunnel. Both the water dump and the hydrocooler must be continuously sanitized to avoid spreading inoculum from infected fruit to healthy fruit. Traditionally, chlorine has been used as the sanitizing agent, either from chlorine gas or sodium hypochlorite. Recently, systems using ozone or direct generation of free oxygen radicals and copper ions have been marketed, but the compatibility, safety, and effectiveness of these systems for peach and other stone fruits has not been demonstrated. Dry dumps and forced-air cooling to remove field heat are less prone to spread of post-harvest decay. The disadvantage in forced-air cooling is the greater length of time, from 30 minutes (hydrocooling) to 24 hours (forced air), required to remove field heat, and the increased cold storage space required with forced-air systems.

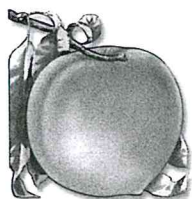


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## 7.1.5 Fungicide Resistance Management

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Resistance to systemic fungicides has been recognized as a major challenge for crop protection since the early 1970s. It became an issue of concern to southeastern peach producers when resistance to benomyl arose in *Monilinia fructicola*, the causal organism of blossom blight and brown rot. Since then, several other groups of systemic and semi-systemic fungicides belonging to the dicarboximide, demethylation inhibitor (DMI), anilinopyrimidine (AP), and strobilurin type action and resistance (STAR) fungicide families have been introduced and made available in stone fruits in the southeastern United States and elsewhere.

- (1) *Benzimidazole (MBC) fungicides*: Members of this family are benomyl (Benlate) and thiophanate methyl (Topsin-M). Control failure due to resistance development was found in brown rot (*M. fructicola*) and scab (*Cladosporium carpophilum*) within a few years of their introductions in the mid-1960s. Benomyl and thiophanate methyl, although different chemicals, both break down upon wetting into methyl benzimidazole carbamate (MBC). It is actually MBC that provides most of the fungicidal activity of these two products. Research also demonstrated that these resistant pathogen strains were resistant to MBC rather than either specific product.
- (2) *Demethylation Inhibitor (DMI) fungicides*: Members of this family are tebuconazole (Elite), propiconazole (Orbit), myclobutanil (Nova), and fenbuconazole (Indar). The DMIs were introduced in the early 1980s and represent an important class of agricultural fungicides. They make a major contribution to world agriculture via their broad spectrum of disease control. Although DMIs are structurally diverse and may have active groups containing a pyrimidine, pyridine, inidazole, or a triazole, they all share a common mode of action that targets a discrete aspect of sterol biosynthesis. This highly specific mode of action suggests a considerable risk of resistance development. Field experience and research results, however, have indicated that DMI resistance evolved more slowly than for the benzimidazoles. Studies on *M. fructicola* isolates from South Carolina indicated a shift of pathogen populations from commercial orchards toward reduced sensitivity, but it was suggested that the shift is not yet strong enough to cause control failure.
- (3) *Dicarboximide fungicides*: Compounds in this class of chemistry include vinclozolin (Ronilan) and iprodione (Rovral). Dicarboximide fungicides were introduced in the mid-1970s, and within a decade resistant isolates of *Botrytis cinerea* (gray mold) were common in several crops. *B. cinerea* remains the only resistant pathogen of real concern. In a 1996 survey, resistance to dicarboximides in other fungal species, for example *M. fructicola* and *Alternaria* spp., was sporadic and did not cause practical problems.
- (4) *Anilinopyrimidine (APs) fungicides*: Of this family only one member, cyprodinil (Vangard), is currently registered. The APs are a novel group of fungicides and are active against a broad range of fungi. The mode of action includes inhibition of methionine biosynthesis and secretion of hydrolytic enzymes. Although field monitoring has shown no sensitivity shifts in either gray mold or apple scab (*Venturia inaequalis*) under practical conditions, evidence from field and lab trials indicates a substantial



resistance risk. APs are volatile in high temperatures, thus restricted in use for the cooler springtime.

- (5) *Strobilurin Type Action and Resistance (STAR) fungicides*: Only one member, azoxystrobin (Abound), is currently registered in peach; other products are expected. The STAR fungicides were introduced in the late 1990s and also represent a novel group of fungicides highly active against a broad range of fungi. They inhibit electron transport in the mitochondrial membranes of fungi. Although it has been known for some time that a single point mutation within the cytochrome *b* gene could confer high levels of resistance, it was generally believed to be unlikely that this point mutation would occur in a majority of the mitochondria within a fungal cell. Thus, it was expected that resistance would develop slowly. However, control failures due to resistance development caused by exactly this point mutation have been reported worldwide in six powdery mildew species on cereals, cucurbits, and bananas. Most recently, resistance development in apple scab was reported.

For updates on resistance to fungicides, consult the web page of the Fungicide Resistance Action Committee (FRAC), <http://www.frac.info/>. All fungicides that have run into trouble with pathogen resistance have one thing in common: they are single-site inhibitors, which means they interfere in a very specific way with a single process of fungus development. Often the systemic fungicides are the ones that will run into resistance trouble. There are several reasons for this:

- (1) A systemic fungicide is taken into a plant, resulting in more uniform distribution through the plant, providing, at least in theory, the maximum uniform coverage. Coverage is certainly much more uniform than randomly placed dried droplets of a fungicide on the outer plant surface. The greater the portion of the target pathogen population exposed to a fungicide, the greater the risk of selection for resistance. As coverage becomes more uniform, more of the pathogen population comes

in contact with the fungicide. Because a systemic fungicide provides the maximum in uniform application, then it also provides the maximum contact with a pathogen population. In any case, the effect of the improved coverage factor for systemics is almost certainly trivial compared with the effects of repeated fungicide applications during a season on selection for pathogen resistance.

- (2) Fungi are related to plants. As a consequence, systemic fungicides with modes of action that are toxic to multiple vital life processes have been of no use, because of toxicity to both fungi and higher plants. In fact, most usable systemic fungicides developed to date have a rather specific mode of action. It is this specific mode of action, rather than the systemic property, that leads to resistance selection.

### WHERE DOES RESISTANCE COME FROM?

It is believed that pathogen populations contain naturally occurring resistant types in very low numbers. There is normally no adaptive advantage to this trait in the absence of the particular fungicide, so this portion of the population remains very minor. However, when a fungus population is exposed to a particular fungicide, the resistant strains have a great advantage and are left with no competition, thus they build up. Eventually they may become dominant in at least a significant part of the population and control failures are observed. The more times per season an at-risk fungicide is used, the more rapid the shift to resistance will be.

### WHY DON'T ALL FUNGICIDES EVENTUALLY RUN INTO RESISTANCE PROBLEMS?

Many fungicides have a variety of antifungal actions that interfere with several unrelated fungus life processes. These materials are very unlikely to run into widespread resistance problems. Those fungicides most likely to have problems with fungal resistance have a very specific site of activity.



## HOW CAN FUNGICIDE RESISTANCE PROBLEMS BE AVOIDED?

Basically, there are two different approaches to avoid rapid resistance development:

- (1) Use at-risk fungicides in tank-mix combination with other fungicides with different modes of action.
- (2) Alternate applications of at-risk fungicides with other fungicides with different modes of action.

These two ideas are very reasonable, and in one form or another are used as the major means of fungicide resistance management. Several mathematical models have been developed to test which of these two approaches would be better. The best approach, combinations or alternating, depends on the specific situation. The results of testing these models can be briefly summarized:

- (1) The more often an at-risk fungicide is used in any way, the more quickly it selects out the resistant strains.
- (2) Neither fungicide combinations nor alternating prevent the selection of resistance. The best either approach can do is slow the process.
- (3) Combinations usually can be expected to slow the process more than alternating. However, combinations are more expensive and may mask the selection of resistance. This can be a major concern to peach producers in the Southeast.

In most cases, cross-resistance exists between members of a fungicide family. Thus, when any one product fails because of resistance, the other product in that same family would no longer work either. As a consequence, when switching to a new fungicide for resistance management purposes, one needs to switch to a compound from a different fungicide family (i.e., different mode of action).

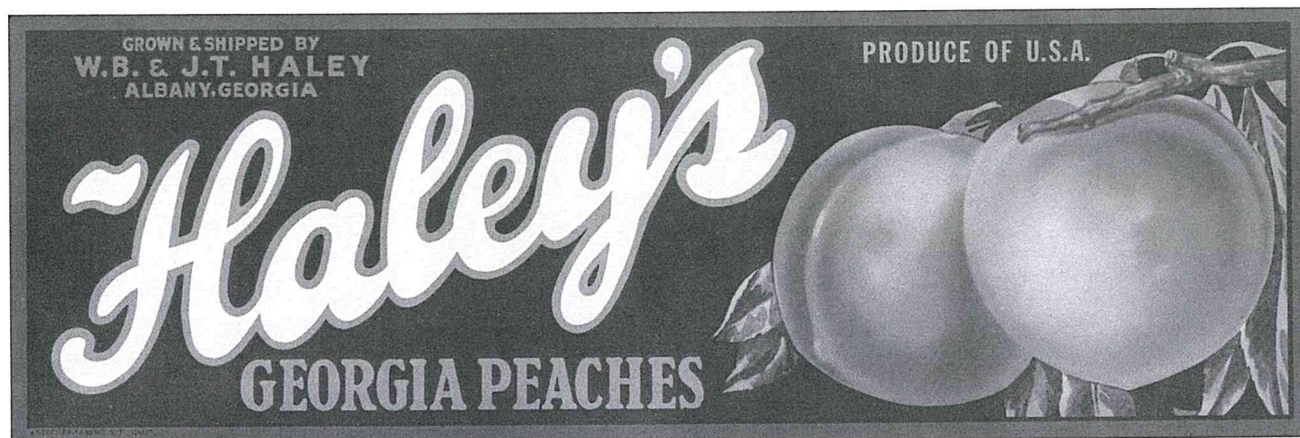
## WHAT APPROACH TO FUNGICIDE RESISTANCE MANAGEMENT SHOULD BE FOLLOWED?

The best approach to fungicide resistance management is to use a program consisting of both combinations and alternating of fungicides with different modes of action. An at-risk fungicide should be used only at key times in the season when absolutely necessary. Other products should be used at other times. When used, an at-risk fungicide should be used in combination with another product of a differing mode of action. The combination helps slow the rate of resistance selection and provides some control of resistant strains already present. Use of a combination is critical if some documented resistance has already occurred. In the total absence of locally documented resistance, combinations are less critical, as long as an alternating program to limit use of the at-risk fungicide is followed. The fungicide recommendations of the Southeastern Peach, Nectarine and Plum Pest Management and Culture Guide are written to emphasize this sort of program. Any and all fungicide programs should be supplemented, wherever possible, by cultural and sanitation practices that reduce disease carryover or otherwise assist disease control.

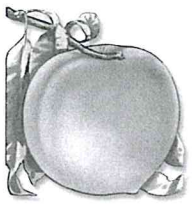


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## 7.1.6 Phomopsis Twig Blight and Fruit Rot

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**P**homopsis twig blight of peach is most often observed in early spring following bud break. Symptoms include wilt and death of leaves on new shoots. Wilt and death of blossoms and young fruit on fruiting wood also occur (Figure 7.1.6.1). A diffuse canker, often with a concentric appearance and exuding gum, can be found on the fruiting wood at the base of the blighted shoots. The canker is usually centered on a dead bud, which is believed to be the infection court for the pathogen. Most bud infection is believed to occur during the previous fall or winter, but new infections can also occur in the spring, leading to shoot blight during early summer. Superficially, Phomopsis twig blight can be confused with other causes of twig death (e.g., *Cytospora* canker), but can be

distinguished by close examination of the canker and by laboratory culture. *Cytospora* spp. and *Botryospheria* spp. often invade cankers and shoots killed by Phomopsis infection.

### CAUSAL AGENT

There is considerable confusion in the literature concerning the etiology of Phomopsis twig blight and its relationship to several other canker and blight diseases of peach, including constriction canker and fusicoccum canker. However, consensus suggests the three diseases are identical. Likewise, there is no general agreement on the species epithet of the *Phomopsis* sp. that causes twig blight or

fruit rot, although *P. amygdali* has been implicated. More research is needed to clarify these relationships. The pathogen has a perfect stage (*Diaporthe* sp.), which has been rarely reported from field material, although many peach Phomopsis isolates from Arkansas produce the perfect stage in culture.

Phomopsis fruit rot, which has been rarely reported as an orchard problem, can be recognized only on ripening fruit. Phomopsis will invade and rot green fruit if introduced through wounds. Rot lesions are very moist, generally round to oval, and develop rapidly on the cheek or pistil end of the fruit (Figure 7.1.6.2). The rotted tissue is easily and cleanly



**FIGURE 7.1.6.1.** Typical symptoms of Phomopsis twig blight of peach include wilt and death of emerging shoots and leaves in the spring.



**FIGURE 7.1.6.2.** Phomopsis lesions on ripening fruit of Babygold 5 peach. Lesions are round to oval, develop rapidly, and have a very moist texture. (color plate, page 184, Figure 7.1.6.2)





**FIGURE 7.1.6.3. Fruit with Phomopsis lesions readily fall from the tree. The rot lesions are easily dislodged, exposing the pit.**

dislodged to the depth of the pit by pushing on the lesion edge or vigorously shaking the fruit. This characteristic and the wet nature of the rotted tissue help distinguish Phomopsis fruit rot from brown rot (*Monilinia*) or anthracnose (*Colletotrichum*) with which it may be confused. An additional difference is that fruit with large developing Phomopsis lesions readily fall from the tree (Figure 7.1.6.3). Phomopsis lesions will sporulate on either the ripening fruit on the tree or on abscised fruit on the ground.

Morphological and cultural characteristics, inoculation experiments, and molecular characterization indicate that twig blight and fruit rot isolates of *Phomopsis* are the same pathogen.

### DISTRIBUTION AND IMPORTANCE

Currently, Phomopsis twig blight is found in peach-growing areas from New Jersey south to Georgia and west to Arkansas and Oklahoma. In most areas, in most years, Phomopsis twig blight is not severe nor does it limit production. However, extensive damage has been reported in Georgia, Alabama, and South Carolina where losses of fruiting wood may be sporadically severe, and overall tree health and productivity have been jeopardized. The wide variation in incidence of Phomopsis twig blight may be related to environmental conditions, orchard management (pruning and sanitation), and to differences in varietal susceptibility to

Phomopsis infection.

Phomopsis fruit rot has been sporadic and may have been suppressed or controlled by the broad-spectrum fungicides used historically to control scab and brown rot. Phomopsis fruit rot is rare in the southeastern states, where twig blight is more often important. Fruit rot has been important in some Arkansas production areas where fruit losses of up to 50% have occurred, but Phomopsis twig blight has been a minor problem in orchards prone to fruit rot. In Arkansas orchards, the incidence of twig blight appears to be unrelated to the incidence of fruit rot. Regional differences in these diseases may arise because of varying environments, orchard management, virulence of *Phomopsis* isolates, and susceptibility of peach varieties to twig blight or fruit rot. Some clingstone cultivars such as the Babygold series and some nectarines appear to be particularly susceptible to Phomopsis fruit rot. In processing peaches, Phomopsis lesions, if not removed during processing, can affect several quality parameters of peach puree and limit its acceptability for some food uses.

### CONTROL

Phomopsis twig blight is generally not the direct target of disease control measures, but in orchards where blight is severe, pruning of diseased wood and chemical sprays may be required. Fungicide sprays have limited efficacy in controlling twig blight, and some of the older, more effective chemicals are no longer available. Resistant varieties would offer the best means of managing twig blight.

Management of Phomopsis fruit rot is problematic because the pathogen forms latent (symptomless) infections in developing peach fruit. A grower cannot anticipate the incidence of Phomopsis fruit rot until rot lesions develop on ripening fruit. Fruit can be infected any time from shuck split until fully ripe. Post-harvest rot can develop rapidly if fruit are not stored cold or processed promptly. Several fungicides with systemic activity can delay infection and slow the rot in ripening fruit. In an orchard trial, benomyl sprays significantly lowered the incidence of latent Phomopsis





## 7.1.8 Rust

### Guido Schnabel

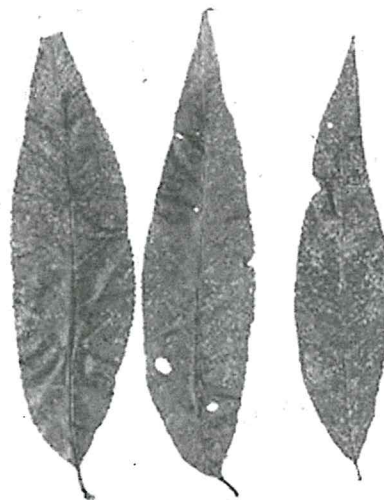
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**P**each leaf rust, caused by fungi in the genus *Tranzschelia*, is fairly common in southeastern fall-line and coastal plain production areas; it is less common in cooler production areas. Usually rust symptoms do not appear until early fall. Peach leaf rust is first noticed as pale yellowish spots on both surfaces of the leaf that later become bright yellow. On the bottom of the leaf, the spots gradually enlarge and turn orange. Finally, they swell and crack open to release masses of rusty brown fungus spores (uredospores) (Figure 7.1.8.1). Defoliation may occur when the leaves are severely infected.

In the Southeast, peach leaf rust is a minor disease. It is seldom serious enough to require special control measures. Where peach leaf rust is severe, use of demethylation-inhibiting fungicides as part of a normal spray program may reduce severity.



**FIGURE 7.1.8.1. Peach leaf rust. (color plate, page 184, Figure 7.1.8.1)**

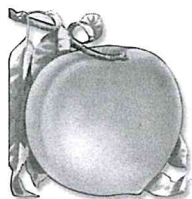
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## 7.1.9 Peach Leaf Curl

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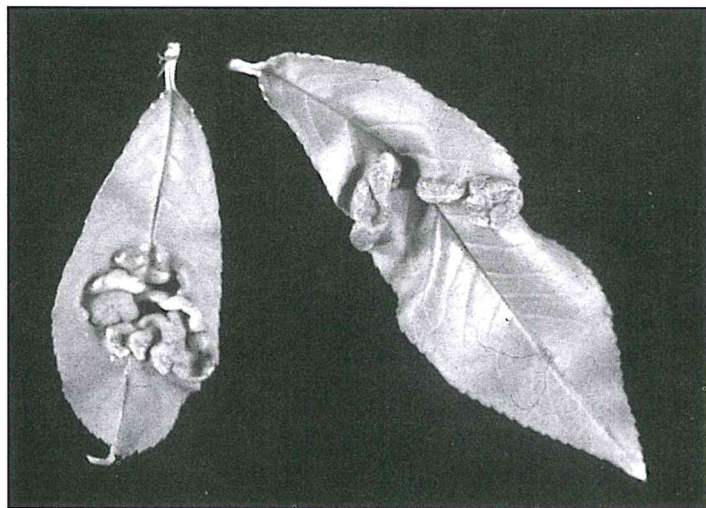
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**P**each leaf curl, caused by the fungus *Tapbrina deformans* (Berk) Tulasne, occurs in springtime, especially when the weather is cool and wet. In the Southeast, leaf curl is seldom more than a curiosity in the coastal plain, but it is occasionally severe in the piedmont or mountain production areas. The leaf curl fungus survives epiphytically on twigs and as spores in infested/infected buds. Under cool, wet conditions, infested buds become infected. Varieties vary significantly in susceptibility. Leaf curl is more severe in cooler production areas.

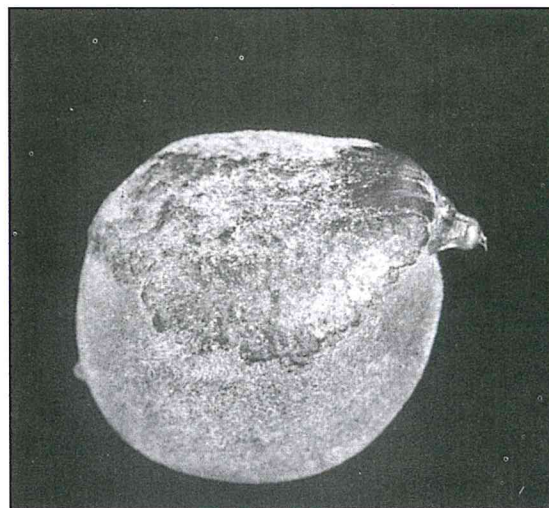
Affected leaves become thick, curled, and distorted; infected leaves are often flushed with yellow, red, or purple (Figure 7.1.9.1). During periods of cool, moist weather the fungus continues to multiply and infect emerging leaves and young fruit. Fruit infections appear as raised, wrinkled areas

with reddish discoloration (Figure 7.1.9.2). Frequently only a few bumps are present. When the disease is severe, it can result in heavy defoliation, weakened trees, and reduced fruit set, yield, and quality. Leaf curl occasionally infects newly transplanted trees, even in the coastal plain, likely from infections initiated in field nurseries.

Except in the coolest southeastern production areas, established orchards are not sprayed for leaf curl. Perhaps one year in ten, leaf curl will be severe in susceptible varieties that were not sprayed the previous season. Leaf curl infections develop in cool, wet, protracted springs. Where leaf curl is common, excellent control can be obtained with a single application of a proper fungicide in early spring before the leaf buds begin to open.



**FIGURE 7.1.9.1.** Peach leaf curl symptoms on leaves. (color plate, page 185, Figure 7.1.9.1)



**FIGURE 7.1.9.2.** Peach leaf curl symptoms on fruit. (color plate, page 185, Figure 7.1.9.2)



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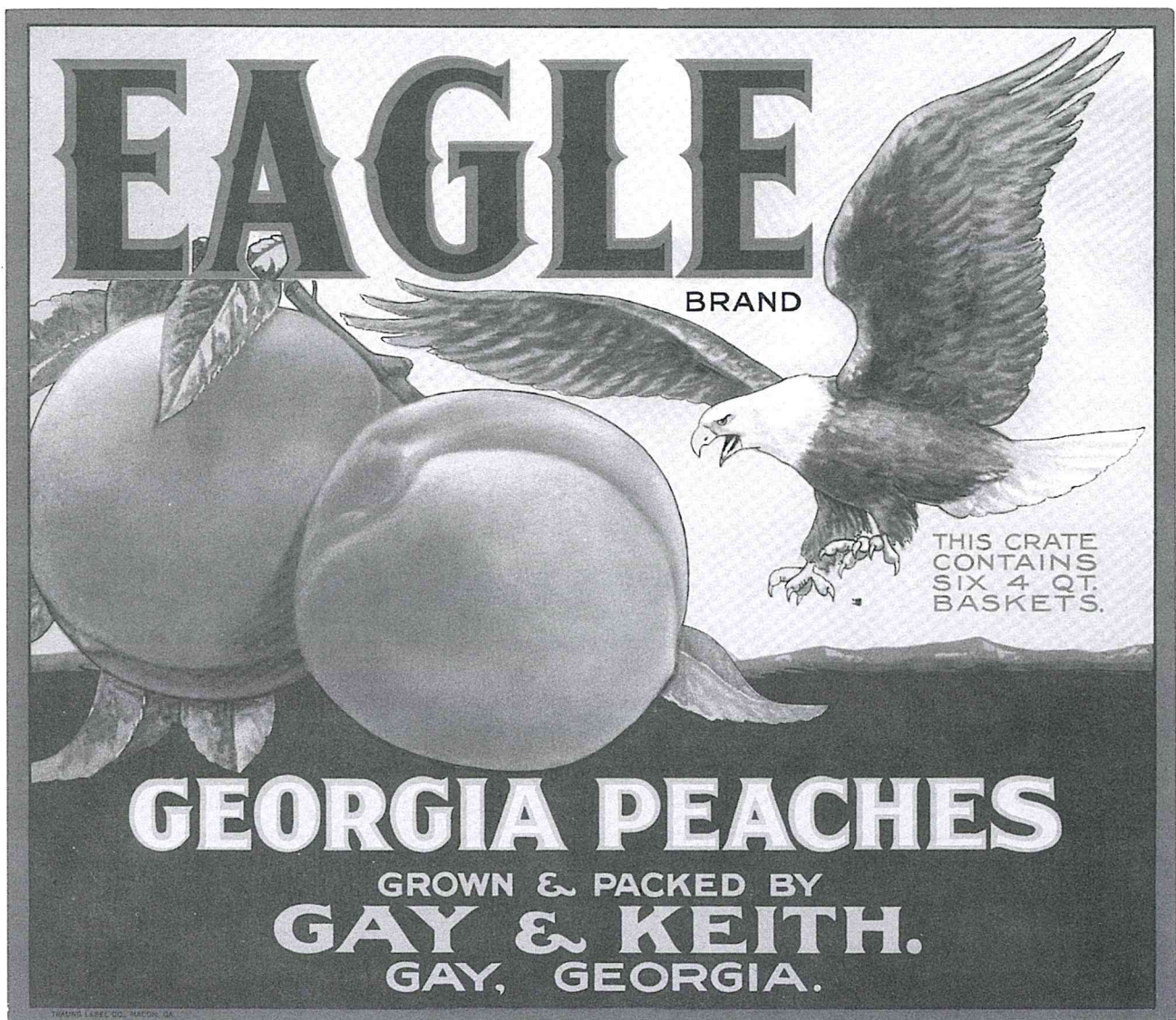
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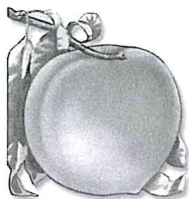
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## 7.1.10 Fungal Gummosis

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Peach tree fungal gummosis was initially observed in the United States near Fort Valley, Georgia, during the 1960s. It subsequently spread to other production areas of the Southeast. The disease was independently discovered at about the same time in Japan, where it is described as peach blister canker or *ibokawa byo*, and was later reported in China and Australia. This disease, characterized by symptoms associated with bark lenticels, contributes to a general decline of trees.

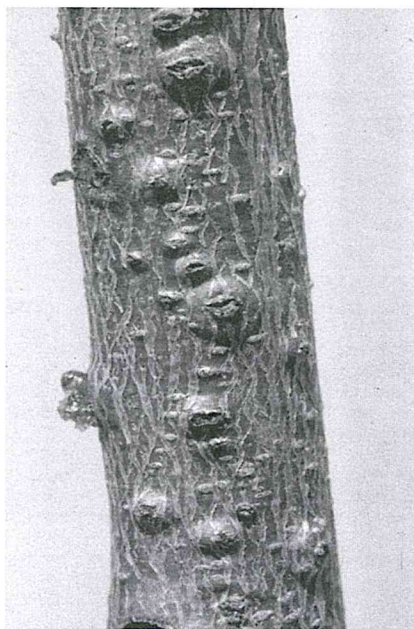
been reported to cause peach gummosis in the United States; however, these species are primarily wound invaders that are not known to cause infections at lenticels. *B. rhodina* (Cooke) Arx is relatively rare on peach. *B. obtusa* (Schwein.) Shoemaker is very common in the southeastern United States, but its importance as a peach pathogen is unclear. *B. obtusa* is localized in dead tissue and outer bark (rhytidome) and is absent or infrequent in the newly infected cortex and phloem.

### CAUSAL ORGANISM

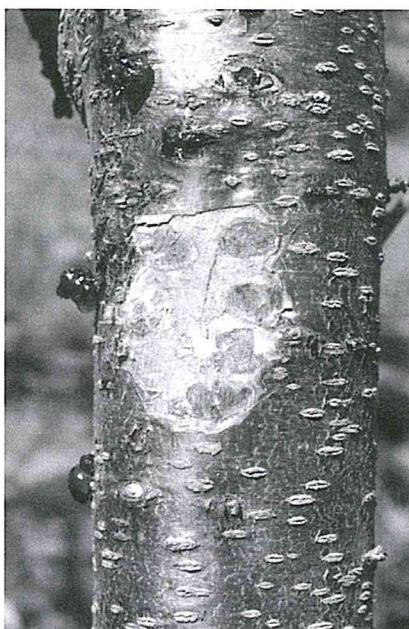
Symptoms of fungal gummosis are caused by a physiological race of *Botryosphaeria dothidea* (Moug.:Fr.) Ces. & De Not. (syn. *B. berengeriana* De Not., anamorph *Fusicoccum aesculi* Corda) specific to peach. Other *Botryosphaeria* species have

### SYMPTOMS

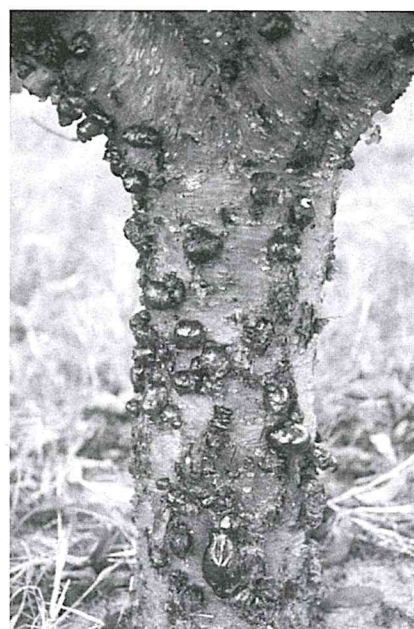
The earliest fungal gummosis symptoms appear on young bark of vigorous trees as blisters 1 to 6 mm in diameter, generally each with a lenticel at its center (Figure 7.1.10.1). These raised areas are due to an abnormal multiplication of plant cells



**FIGURE 7.1.10.1.** Peach branch with blisters caused by the fungus *Botryosphaeria dothidea*. (color plate, page 185, Figure 7.1.10.1)



**FIGURE 7.1.10.2.** Three-year-old peach trunk with bark section removed to show multiple necrotic lesions. (color plate, page 185, Figure 7.1.10.2)



**FIGURE 7.1.10.3.** Trunk of peach tree with multiple infection sites exuding resin. (color plate, page 185, Figure 7.1.10.3)





**FIGURE 7.1.10.4.** Peach branch with canker formed by coalescence of multiple infections. (color plate, page 185, Figure 7.1.10.4)

(hyperplasia) in response to the causal organism at the lenticel. Removal of outer bark with a knife reveals diseased tissue at the lenticel margin surrounded by the hyperplastic tissue. Blisters may be observed late in the season when infection occurs or the following spring. By the end of the second season, the area of necrosis surrounding lenticels has enlarged, and the hyperplasia is often less visible or absent. Some second season necrotic lesions exude resins. Lesions that appear in the second season after infection may or may not be preceded by the formation of blisters. Beginning when trees are 2 or 3 years old, sunken necrotic lesions encircling lenticels can be seen on the trunk and major branches (Figure 7.1.10.2).



**FIGURE 7.1.10.5.** Cracking and peeling of peach bark due to cork formation associated with old lesions. (color plate, page 185, Figure 7.1.10.5)

Typically, copious resin exudate is associated with lesions at multiple sites (Figure 7.1.10.3). Lesions 2 cm or more in diameter on the oldest bark may coalesce to form large cankers (Figure 7.1.10.4). Phloem and cortex are primarily affected; however, necrosis may extend to the xylem.

Peach orchards that are poorly managed or water stressed are more likely to have severely infected trees. In its most severe form, the gummosis kills branches or entire trees. When growing conditions are optimal and inoculum levels are low, trees produce a cork layer (periderm) below the infected area, and the diseased tissue peels away from the tree (Figure 7.1.10.5). After repeated infections, the bark becomes rough and scaly.

## DISEASE CYCLE

The fungus overwinters in diseased bark and in dead and dying wood, where it produces an abundance of spores (Figure 7.1.10.6). It spreads within the orchard mainly by dispersal of conidia in rainwater. In the southeastern United States, asexual spores of the fungus are present from March through October. Infections at lenticels develop from March through August, but May through July is the key infection period. The fungus also invades through wounds, causing cankers. Cankers may



**FIGURE 7.1.10.6.** Asexual fruiting bodies of *Botryosphaeria dothidea* exuding spores (white) at edge of bark lenticel. (color plate, page 186, Figure 7.1.10.6)





**FIGURE 7.1.10.7. Fungal invasion of pruning wound and secondary lesions encircling lenticels.**

remain active for more than one year and lead to secondary infections at lenticels (Figure 7.1.10.7). Blossoms, leaves, and fruit are not infected.

### CONTROL

Dead wood should be removed during winter pruning, and pruned wood should be taken from the orchard or destroyed mechanically (e.g., with a flail mower) to reduce inoculum from these sources. Summer pruning encourages fungal gummosis, because available inoculum can germinate and colonize wounds rapidly during this time. Abstaining from summer pruning and alleviating water and nutrient stress can reduce disease incidence and severity. Fungicides such as captan, applied to bark thoroughly and repeatedly (e.g., biweekly) during the key infection period (May through July), can be effective, but this may not be economically feasible. Use of this intensive fungal gummosis program for the first three years after planting trees generally prevents the non-wound invasion of the trunk and major scaffold branches.

Peach varieties vary in their resistance or susceptibility to fungal gummosis. For instance, Summergold is highly susceptible, whereas Harbrite has a relatively low susceptibility. In the long term, the best solution to this disease is the development of host resistance. Peach trees are evaluated for resistance to fungal gummosis within the breeding program at the USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, Byron, Georgia.

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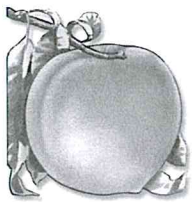
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## 7.1.11 Cytospora Canker

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**C**ytospora canker, also known as perennial canker, peach canker, Valsa canker, and Leucostoma canker, is caused by *Leucocytospora cincta* (Sacc.) Hohn. (syn. *Cytospora cincta* Sacc.) and *Leucocytospora leucostoma*, Sacc. (syn. *Cytospora leucostoma* Sacc.). These fungi are also known by their less common sexual reproductive stages as *Leucostoma cincta* (Fr.:Fr.) Hohn. (syn. *Valsa cincta* Fr.:Fr.) and *Leucostoma persoonii* Hohn. (syn. *Valsa leucostoma* (Pers.:Fr.).

### SYMPTOMS AND DISEASE DEVELOPMENT

Cytospora fungi are very opportunistic on peach; infections often develop in association with wounding from sunscald, pruning, cold injury, lesser peachtree borer, or bacterial canker.

Cytospora fungi infect multiple sites, resulting in several different symptoms. Cankers can develop on individual branches and scaffold limbs. "Perennial" cankers may persist for several years before killing the branch. These cankers extend along the branch, producing a sunken elliptical lesion (Figure 7.1.11.1). Perennial cankers are commonly observed surrounding pruning wounds. Cutting into the bark at the edge of the sunken area reveals a zonate or banded canker area and discolored sapwood (Figure 7.1.11.2). Cytospora fungi also readily infect the crotch and trunk, spreading rapidly through the bark and sapwood; often this follows injury from freezing temperatures that occur when trees experience severe temperature changes before they are adequately dormant (Figure 7.1.11.3).

Cytospora fungi rapidly colonize cold-damaged tissue in late winter and early spring; infected trees usually die by the following summer. From late winter to early spring, Cytospora fungi produce an abundance of pimple-like spore-producing structures termed "pycnidia" (Figure 7.1.11.4). Removal of the outer part of the bark may reveal developing pycnidia (Figure 7.1.11.5). As the pycnidia develop, they push through the bark, giving the branch the appearance of being pebbled with small, raised dots. During rainy weather, spores ooze from the pycnidia and are dispersed to new infection sites by splashing and wind-blown rain. If the rain period is short in duration and followed by humid, but not wet conditions, amber-colored cirrhi, or



**FIGURE 7.1.11.1.** Cytospora canker with an elliptical, sunken appearance.



**FIGURE 7.1.11.2.** Zones of discolored bark and sapwood in a Cytospora canker. (color plate, page 186, Figure 7.1.11.2)

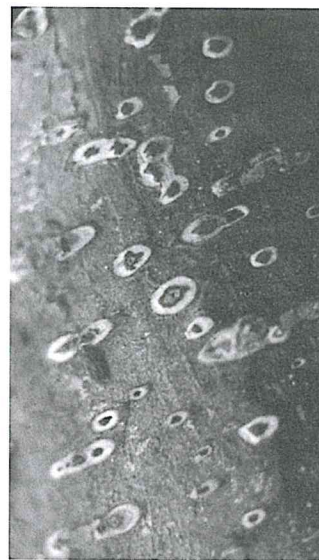




**FIGURE 7.1.11.3.** Splitting of bark from freezing temperature.



**FIGURE 7.1.11.4.** Scaffold branch with fungal fruiting bodies (pycnidia) just beneath the bark surface. (color plate, page 186, Figure 7.1.11.4)



**FIGURE 7.1.11.5.** Outer bark removed to expose the pycnidia. (color plate, page 186, Figure 7.1.11.5)

spore tendrils, ooze from the pycnidia and dry, leaving a fine thread. These tendrils consist of spore masses embedded in a very soluble matrix. When numerous spore tendrils form, branches may appear to be covered with hair (Figure 7.1.11.6). Upon rewetting, the tendrils quickly dissolve and the spores are carried away.

Cytospora fungi also infect fruit and leaf buds (Figure 7.1.11.7). These nodal infections are observed three to four weeks after budbreak. Symptoms are first seen with the failure of the infected buds to open, followed by formation of elongated cankers that extend from the node, often with an amber-colored gum developing.

The basic symptoms seen with each type of Cytospora canker are the same. The site and severity of infection encountered is regulated by tree health and environmental factors. Cytospora canker is not responsible for all sudden tree collapse, but it can be a factor in the peach tree short life complex when tissue damaged from bacterial canker (caused by *Pseudomonas syringae* pv. *syringae*) or freezing temperatures is invaded and colonized.

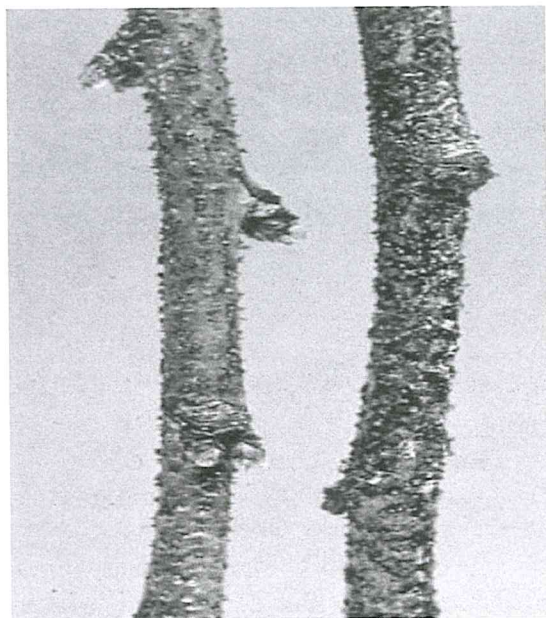
### Tree Susceptibility

Cytospora canker is generally a disease of injured, stressed, or unhealthy trees. Cytospora cankers seldom do significant damage to healthy, vigorous trees, even though infections occur. A healthy tree is usually able to heal around the cankered area when growth begins in the spring after infection. If an orchard is heavily damaged by Cytospora canker, it is a sign that trees are weakened. Factors known to predispose fruit trees to damage from Cytospora canker are drought, freeze injury, and poor soils. Nematode infestations may also play a role in some orchards. Although there are differences among peach varieties in susceptibility to Cytospora canker, no truly meaningful resistance has been identified.

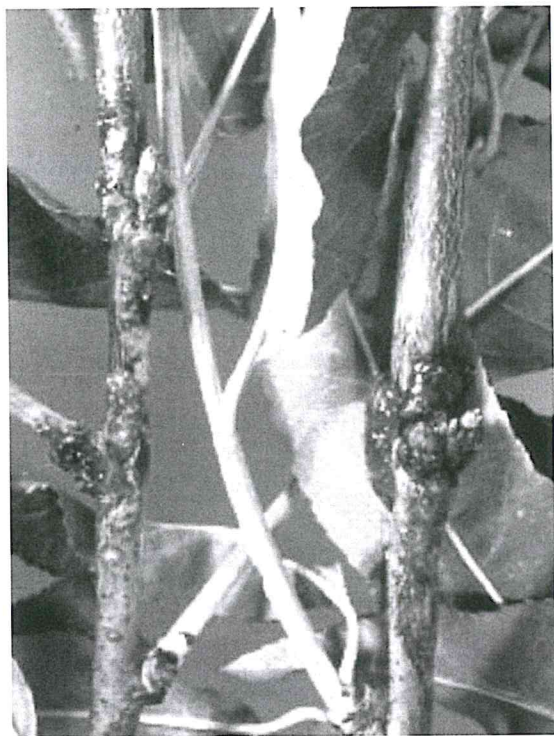
### Seasonal Activity

The rate of Cytospora canker expansion depends upon temperature and the peach tree's vigor. Even in weak trees susceptible to extensive damage from Cytospora canker, host growth probably has some effect on reducing canker extension. The two species of *Cytospora* show peak activity, as measured by canker expansion, at different times of the year. *C. cincta* is most active in the spring and fall when optimal canker expansion occurs between 60° and 75°F. *C. leucostoma* shows its peak activity during summer, with an optimal tempera-





**FIGURE 7.1.11.6.** Hairy appearance of *Cytospora* spore tendrils. (color plate, page 186, Figure 7.1.11.6)



**FIGURE 7.1.11.7.** Nodal infection with developing canker and amber gum. (color plate, page 186, Figure 7.1.11.7)

ture range of 86° to 91°F. In the southeastern United States, both species are active to some extent in nearly all months of the year.

### Infection Sites

Both *C. leucostoma* and *C. cincta* require a wound or natural opening to infect a peach tree. Sites that have been reported as openings for *Cytospora* invasion include sunburns, cold injuries, pruning cuts, leaf scars, insect injuries (especially lesser peachtree borer), bacterial cankers, and broken limbs. Sunburn can occur when heavy pruning opens up the trees excessively, when premature defoliation occurs due to drought or mites, or when a heavy crop bends down the branches. Cold injuries can injure and weaken trees, providing an entry point for infection. Cold injury is often associated with excessively low winter temperatures, or from periods of warm weather followed by a sudden drop to 20°F or less in late winter or early spring. Pruning cuts are important points of infection in southeastern peach orchards. Trees pruned in fall or early winter are especially susceptible to *Cytospora* infection. Cuts made during this time heal slowly.

### CONTROL

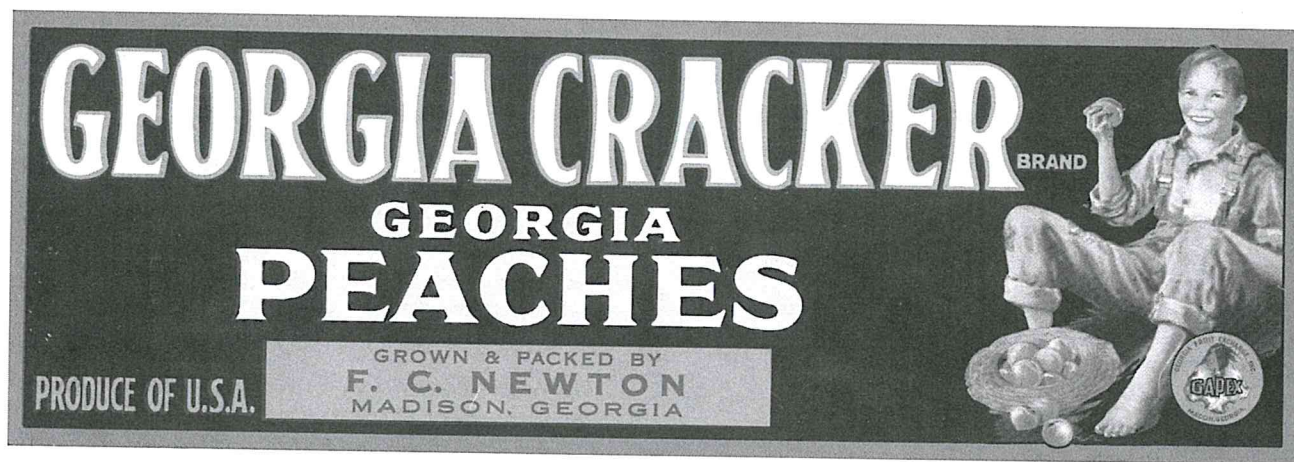
*Cytospora* canker is very difficult to control in weakened or injured trees. *Cytospora* fungi release spores throughout the year when rain occurs. Fungal growth takes place over a wide range of temperatures during most of the year. Fungicide programs have never been successful in mitigating infection.

Removal of infected branches several inches below any infected tissue can help, but is practical if only a few cankers are present. However, if the disease is common throughout an orchard, it is a sign that the orchard is stressed and in poor condition. The only effective control of *Cytospora* canker is to keep the trees in a state of good vigor. Good cultural practices, described more fully elsewhere in this text, are: (1) never prune trees in the fall or early winter; (2) avoid establishing new orchards in poor soils; (3) take cultural steps to minimize freeze injury; and (4) remove dying trees and weak, non-productive branches. Ideally, this should be done before the fungus begins to sporulate on this material.

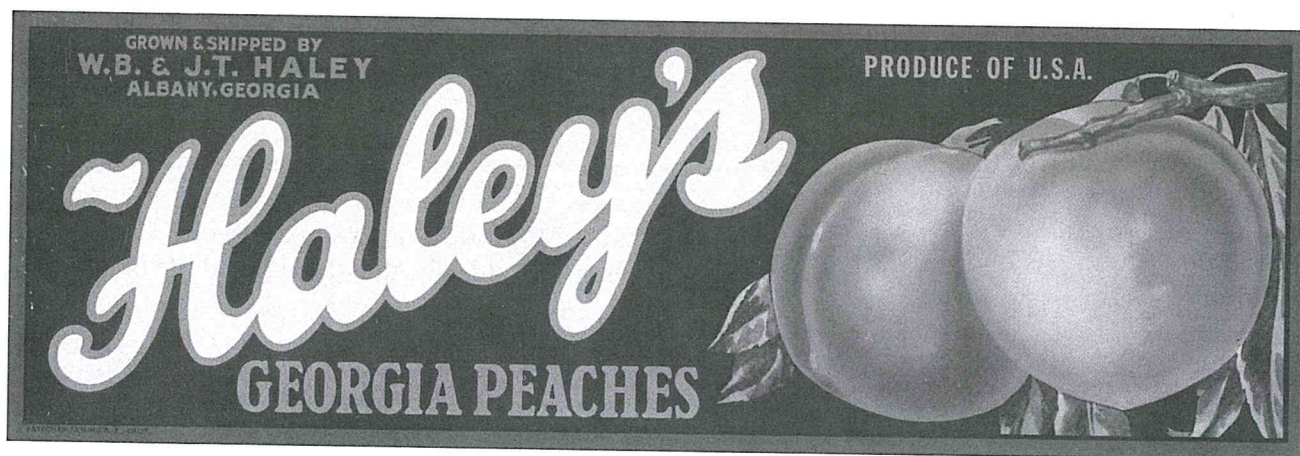


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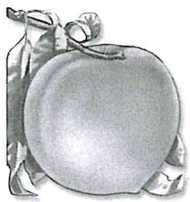
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7







## 7.1.13 Armillaria Root and Crown Rot

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**A**rmillaria root and crown rot (also known as oak root rot) is a major cause of premature tree death in southeastern stone fruit orchards. In addition, the persistence of the causal agent on root pieces in the soil frequently prevents the establishment of new orchards in previously infested sites. Two species in the fungal genus *Armillaria*, *A. tabescens* (Scop.) Dennis et al. (= *Clitocybe tabescens* (Scop.) Bres.) and *A. mellea* (Vahl.:Fr.) P. Kumm., can cause the disease in the Southeast. Although the two species are generally very similar, there are a few features that distinguish them. The mushrooms (basidiocarps) of *A. tabescens* (Figure 7.1.13.1A) lack an annulus or ring just below the cap and can be a darker shade of brown than those of *A. mellea* (Figure 7.1.13.1B). In contrast, an annulus is present in the basidiocarps of *A. mellea* and, in some cases, rhizomorphs (shoe-string-like networks of condensed, black hyphae)

may be produced from host tissues infected by this species (Figure 7.1.13.2). Although there is evidence that *A. mellea* is more aggressive than *A. tabescens*, little is known about the relative importance of the two species and their roles in Armillaria root disease in southeastern peach production systems. However, basidiocarps of *A. tabescens* are more commonly found in orchards than those of *A. mellea*.

### SYMPTOMS AND SIGNS

*Armillaria* infects root and crown tissues, which results in the development of below- and above-ground symptoms. Above-ground symptoms include chlorotic and stunted leaves with little terminal growth (Figure 7.1.13.3A). A distinctive symptom in stone fruits is the curling of leaves along the mid-rib (sometimes accompanied by a



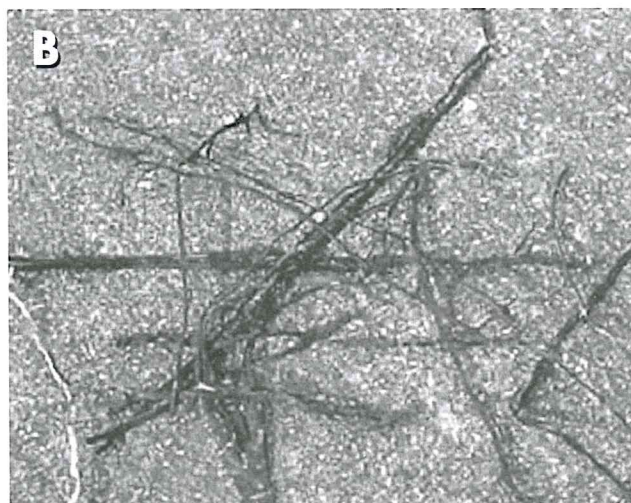
**FIGURE 7.1.13.1.** Basidiocarps (mushrooms) produced by *Armillaria* from severely infected peach root systems. (A) Darker mushrooms of *Armillaria tabescens* (B) and pale yellow mushrooms of *Armillaria mellea*. (color plate, page 187, Figure 7.1.13.1)



bronzing of the foliage and stems), followed by wilting (Figure 7.1.13.3B). As the disease progresses, a rapid yellowing and defoliation occurs, followed by the death of individual limbs above diseased roots (Figure 7.1.13.4A). Eventually, the entire tree is killed (Figure 7.1.13.4B). Gum produced from the cambium may exude in copious amounts from cracks in the bark after the infection has reached the root collar. These above-ground symptoms may not appear until severe damage to the root system has already occurred. Young trees may die within the same season these symptoms manifest.

Below-ground infection results in the decay of

woody tissue that appears water-soaked, becoming white to yellow in color, spongy, and gelatinous. Removing the bark at the crown and roots often reveals the presence of white to pale yellow fan-like sheets of mycelium, indicative of *Armillaria* (Figure 7.1.13.5A). These mycelial sheets are usually 1 to 3 mm thick and often marked with varying degrees of perforation (Figure 7.1.13.5B). Although rarely seen in the southern states, dark, shoe-string-like rhizomorphs, produced by *A. mellea*, may originate from infected tissues (Figure 7.1.13.2). Under proper temperature and moisture conditions, clusters of the yellow to brown mushrooms (basidiocarps) can be found at the base of infected trees (Figure 7.1.13.1).



**FIGURE 7.1.13.2.** Rhizomorphs produced by *Armillaria mellea*, one of the fungal species causing Armillaria root disease. (A) Rhizomorphs emerging from an infected peach root; (B) a closer view of rhizomorphs removed from the root.



**FIGURE 7.1.13.3.** Curling of peach leaves following root and crown infection by *Armillaria*. (A) Overall appearance of tree; (B) a closer view of an individual shoot with leaf curl and bronzing. (color plate, page 187, Figure 7.1.13.3)



## DISEASE DEVELOPMENT

*Armillaria* occurs primarily in orchards planted on cleared forest land (especially oaks and other hardwoods) or on old orchard sites. The disease can survive for many years after the removal of the previous stand on infected root pieces in the soil. Contact between peach roots and such infected root pieces in the soil is thought to initiate the disease in the orchard, whereas spores from mushrooms in nearby forests likely contribute little to the establishment of the disease. Once peach roots contact infected root pieces, the fungus grows throughout the peach roots to the crown, which rots their cambial tissues. The disease is

thought to spread through the orchard by root-to-root contact and results in clusters of infected trees radiating from initially infected trees as neighboring trees subsequently become diseased. New sites of infection can also become established in uninfested parts of the orchard by movement of infected root pieces through cultivation, erosion gullies, and careless tree removal practices.

## CONTROL

Control of *Armillaria* is extremely difficult once the pathogen is established in an orchard. Nevertheless, there are several management



**FIGURE 7.1.13.4. Peach trees showing severe above-ground symptoms of root and crown infection by *Armillaria*. Symptoms range from wilted foliage and dead limbs (A) to death of entire tree (B).**



**FIGURE 7.1.13.5. Outer bark removed from tissues of an infected peach tree to reveal the presence of mycelial sheets of *Armillaria*. (A) A large root showing mycelial sheets; and (B) a piece of crown bark showing mycelial sheet with perforations typical of *A. tabescens*. (color plate, page 187, Figure 7.1.13.5)**



options that can help prevent the establishment of the disease and/or slow its spread in the orchard.

**Pre-plant Inoculum Reduction.** Before planting on cleared forest land or replanting an old orchard site, it is beneficial to employ inoculum reduction measures to reduce the risk of disease development from contact with infected root pieces remaining in the soil. The following pre-plant land clearing procedures should be carried out to obtain maximum reduction of residual inoculum.

- (1) Surface slash should be pushed from the block with a rock rake or similar implement.
- (2) All stumps should be pushed out with a bulldozer or tractor-mounted blade. If stumps are too large, they should be partially excavated before pushing them out.
- (3) The block should be ripped repeatedly to drag deep roots to the surface.
- (4) Between rippings, soil from the root zone should be turned with a blade and raked with a rock rake to remove exposed roots.
- (5) Visible roots should be removed by hand between machine passes.

Hand removal of roots between machine passes is time consuming and complete elimination of inoculum is impossible, but this pre-plant sanitation procedure reduces subsequent mortality and contributes to improved tree growth. With the exception of hand removal, research has demonstrated that all of the previous steps must be carried out to achieve any control benefit at all.

**Resistant Rootstocks.** Recent work has shown that small differences in susceptibility exist among currently available commercial peach seedling rootstocks; nevertheless, all rootstocks should be considered susceptible to *Armillaria* root disease. Plum species, as a group, appear to offer better tolerance to *Armillaria* than peach, and most breeding efforts for *Armillaria* resistance are utilizing such materials. Recently several complex plum and plum x peach hybrid stocks, developed in part for use on *Armillaria*-infested sites, were tested in the Southeast against *A. tabescens*. Surprisingly, all three hybrid stocks (Marianna 2624, Ishtara, and Myran) proved to be only comparable to, if not significantly more susceptible

than, Lovell, a peach seedling stock widely utilized in the Southeast that is considered susceptible to *Armillaria*. These results are in apparent conflict with published reports that indicate the three hybrid stocks have some level of field resistance to *A. mellea* in California and Europe. The discrepancy in the findings may reflect a variation in aggressiveness within or among *Armillaria* species. These rootstocks may not be resistant to *A. tabescens*, or their resistance may be diminished by other abiotic or biotic factors in the Southeast. The conflict of results is moot, however, because all of the hybrid stocks tested are susceptible to peach tree short life, an even more common cause of premature tree mortality than *Armillaria* root disease. A wide range of new rootstocks is currently under development and evaluation in the Southeast and other parts of the world.

**Sanitation by Tree Removal.** In established orchards, spread of *Armillaria* root disease can be slowed by tree removal. Complete removal of the tree and its root system is necessary to prevent root-to-root initiated infection of neighboring trees. It is important that the presence of *Armillaria* is verified by examination of the roots and crown for signs of the fungus.

- (1) All trees showing symptoms must be removed. Great care must be taken not to scatter the infected roots about the orchard.
- (2) The first symptomless trees on each side of infected trees must also be removed.
- (3) Examine the roots of the symptomless trees; if any of them show signs of root infection, also remove the trees adjacent to these individuals.

The above procedures should stop or greatly reduce the spread of the disease, but the cleared area must still be considered infested. Because of the extensive tree loss that results from this measure, it is doubtful that tree removal is economically feasible on leased land. It is more economical to undertake extensive pre-plant inoculum reduction before planting or re-planting as described above.

**Chemical Control.** Chemical control of *Armillaria* has met with limited success. Much of the research on fumigation, soil drenches, and tree injection with chemicals has been inconclusive

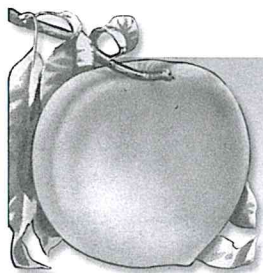


or carried out with insufficient field testing. Methyl bromide, however, is a notable exception. When 1 or 2 lbs of methyl bromide is applied per 100 sq ft as a pre-plant treatment to sandy, dry soil in the fall, it has been documented to prevent Armillaria root disease from recurring for at least 3 to 5 years in the Southeast. However, fumigants are expensive and, owing to regulatory concerns, their long-term availability is uncertain.

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## 7.2 BACTERIAL DISEASES

### 7.2.1 Bacterial Spot

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**B**acterial spot is caused by *Xanthomonas arboricola* pv. *pruni* (Smith 1903) Vauterin, Hoste, Kersters & Swings 1995 = *Xanthomonas campestris* pv. *pruni* (Smith 1903) Dye 1978. This disease is also referred to as bacteriosis, bacterial leaf spot, or bacterial shot hole. Bacterial spot was first described in 1902-1903 on plums in Michigan. Bacterial spot occurs on leaves, twigs, and fruit of peaches and nectarines, and almost all other stone fruits (*Prunus* spp.).

#### SYMPTOMS

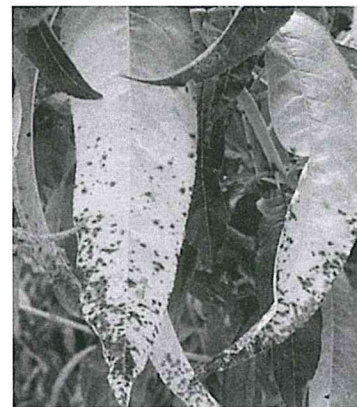
##### Leaf Symptoms

The most obvious leaf symptoms are yellow, chlorotic leaves (Figure 7.2.1.1) with angular lesions at the leaf tip, mid-rib, and/or along the leaf margin. Infected leaves frequently experience premature drop. Developing foliar lesions are water-soaked, sometimes grayish colored, and angular in shape, being delimited by the veinlets of the leaf. Initially, individual lesions (Figure 7.2.1.2) are only 1 to 2 mm (pencil point) in size, usually expanding to 2 to 3 mm, but seldom exceeding 5 mm. As lesions age, centers may become dark or purple in color and necrotic (Figure 7.2.1.3); when lesion center abscission occurs, a shot-hole appearance results. The very earliest leaves to emerge in spring, on some varieties before bloom, can become infected

and serve as secondary sources of inoculum for later emerging leaves and fruit. Leaves are most susceptible before becoming fully expanded. Leaf symptoms usually are first visible 5 to 14 days after infection. Rapid symptom expression is dependent on warm temperatures. Care should be taken to differentiate bacterial spot lesions, which are angular in shape, from foliar lesions caused by pesticide sprays or other injuries that are usually circular in shape and do not have a water-soaked appearance.

##### Twig Symptoms

On peaches and nectarines, twig symptoms usually consist of cankers on the previous year's growth associated with and initially extending 1 to 2 cm (~ 1 inch) either side of leaf and flower buds; these affected buds usually fail to open. These overwintering cankers, often



**FIGURE 7.2.1.1. Chlorotic leaves with multiple bacterial spot lesions that commonly develop in areas where moisture aggregates and evaporates slowly (e.g., at the leaf tip). Once leaves develop these symptoms, they readily drop. (color plate, page 188, Figure 7.2.1.1)**

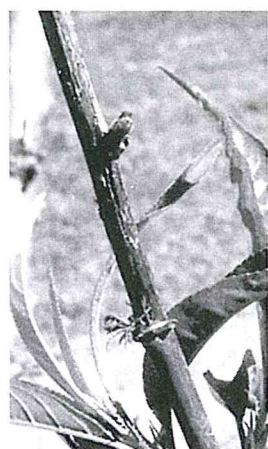




**FIGURE 7.2.1.2.** Newly formed bacterial spot lesions. Light yellowish-green halo surrounds the water-soaked, angular-shaped, brownish-yellow center of the lesion. (color plate, page 188, Figure 7.2.1.2)



**FIGURE 7.2.1.3.** Lesions develop a dark brown center. If the center of the lesions abscises, a shot-hole symptom develops, giving the leaf a tattered appearance. (color plate, page 188, Figure 7.2.1.3)



**FIGURE 7.2.1.4.** An overwintering canker or spring canker on the previous year's growth. Spring cankers are first visible during bloom and develop a black, water-soaked appearance. They extend along the length of the twig from a leaf/flower bud that has failed to open. (color plate, page 188, Figure 7.2.1.4)

termed spring cankers (Figure 7.2.1.4), are first visible during bloom. When a canker extends downward from the terminal bud, which fails to open, it is termed a black tip (Figure 7.2.1.5). When conditions are moist, the canker surface has a black, water-soaked appearance. As the season progresses, the canker can lengthen and the bark surface cracks (Figure 7.2.1.6). Summer cankers are formed on current-season growth and are visible early to mid-summer (June through early August).

### Fruit Symptoms

The earliest fruit lesions are normally observed about three weeks after petal fall. Fruit infection is favored by moist and warm conditions from petal fall to early shuck split. Developing fruit lesions have a water-soaked appearance with a small necrotic area in the center (Figure 7.2.1.7). As the lesions mature, they become brown to black in color and enlarge (Figure 7.2.1.8). Infections that occur for approximately four weeks from petal fall develop into large, open lesions that extend deep into the fruit flesh, sometimes almost to the pit by harvest (Figure 7.2.1.9). In contrast, infections that occur after initiation of pit-hardening usually remain near the fruit surface. These shallow lesions may coalesce, resulting in cracking of the skin (Figure 7.2.1.10).

### DISEASE DEVELOPMENT

The bacterial spot pathogen overwinters in association with buds, in protected areas on the woody surface of the tree (e.g., cracks in the bark), and in leaf scars that become infected during leaf drop the previous season. Leaf scar infections usually result in spring cankers. In late winter as temperatures warm, leaf and flower buds swell, new tissue emerges, and the bacteria begin to multiply. The bacteria are spread from cankers by dripping dew and in splashing and/or wind-blown rain to the newly emerging leaves. Bacterial spot can also infect through natural openings or wounds. High moisture conditions are very favorable for both leaf and fruit infections. Leaf infections can occur for at least as long as terminal growth and leaf emergence continue. Several highly susceptible varieties (e.g., O'Henry and Ryan Sun), experience early leaf emergence, usually before bloom buds, and can be infected very early in the growing season. This results in a high concentration of bacterial inoculum, which is available

**FIGURE 7.2.1.5.** An overwintering canker that developed from the terminal bud downward; such cankers have been termed **black tip**. (color plate, page 188, Figure 7.2.1.5)







**FIGURE 7.2.1.6.** An overwintering canker soon after the shuck-off stage of fruit growth that did not completely girdle the twig. The canker color changes from black to brownish red and the outer bark begins to crack as the tissue beneath the canker grows. (color plate, page 188, Figure 7.2.1.6)

to infect other emerging leaves and young fruits as they emerge from the shuck. Severe fruit infections are more common when frequent periods of rainfall or even extended heavy dews and very high humidity occur from late bloom to near pit-hardening. Bacterial spot is more severe in areas where peaches are grown in light, sandy soils than in heavier soils. Wind and wind-blown sand can increase the severity of bacterial spot by creating wounds for the bacteria to infect.

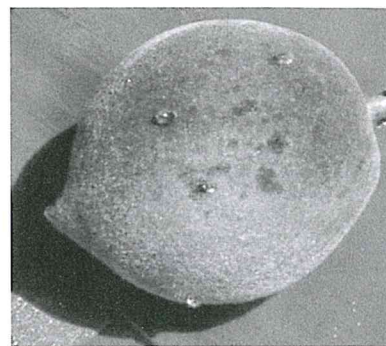
## CONTROL

Bacterial spot is very difficult to control on highly susceptible varieties. Under optimal environmental conditions for infection and disease, control can be similarly difficult on moderately susceptible varieties. Control and management measures must be applied preventatively to successfully reduce losses from this disease. Once bacterial spot symptoms are observed, it is almost impossible to bring the disease under control if environmental conditions remain favorable.

There is a wide range of susceptibility within peach varieties, from highly resistant varieties such as Sentinel and Clayton to highly susceptible varieties like O'Henry and Ryan Sun. Most, if not all, varieties developed west of the Rocky Mountains are highly susceptible because bacterial spot is so uncommon there that breeding programs cannot screen new selections for susceptibility. Unfortunately, several varieties with excellent bacterial spot resistance lack desirable fruit quality characteristics. When establishing an orchard in areas prone to bacterial spot, varieties having at least moderate resistance should be strongly considered. In years when disease pressure is low, such varieties will sustain little to no fruit loss; in years when disease pressure is high, chemical sprays are much more effective on less susceptible varieties.

Because trees under nutrient stress are more severely affected by bacterial spot than trees not experiencing stress, it is advisable to maintain optimum soil fertility. High populations of ring nematode have also been associated with increased bacterial spot, which may be related to stress caused by this nematode.

Minimize blowing sand within and surrounding the orchard by



**FIGURE 7.2.1.7.** Newly formed, water-soaked lesions on fruit first visible near the time of pit-hardening. Gum also may exude from lesions. (color plate, page 189, Figure 7.2.1.7)



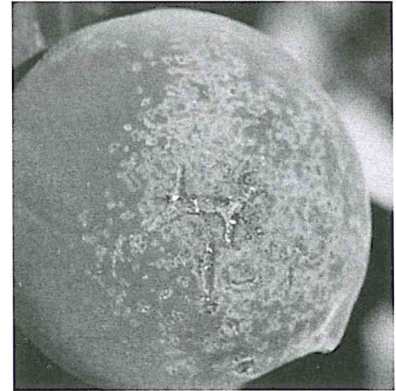
**FIGURE 7.2.1.8.** Lesions resulting from infections occurring near the time of shuck split become black and start to extend into the fruit flesh. Gum commonly exudes from these lesions. Fruit growth stage is about three weeks after pit-hardening. (color plate, page 189, Figure 7.2.1.8)



**FIGURE 7.2.1.9.** Fruit that was infected soon after bloom; lesions continued to develop throughout the season and now extend deep into the flesh. Fruit is about two weeks from harvest. (color plate, page 189, Figure 7.2.1.9)



**FIGURE 7.2.1.10.** Fruit having lesions that remain near the fruit surface and do not extend deep into the flesh. Such "surface lesions" are associated with infections that occurred near or after pit-hardening rather than near or just following shuck-split. (color plate, page 189, Figure 7.2.1.10)



employing appropriate ground covers and abstaining from disking. Windbreaks appropriately placed to blunt the damaging effects of strong winds, while still allowing for air movement through the orchard, may reduce bacterial spot severity.

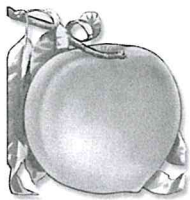
Available antibacterial materials, copper-containing compounds and oxytetracycline, have limited efficacy. To optimize the performance of these modestly effective materials, they must be used preventatively. The foliage of peaches is very sensitive to copper and can be easily damaged, which results in leaf discoloration, shot holes, and premature leaf drop if sprays are not correctly applied. Use of copper sprays is focused early in the growing season, from dormant through early shuck split, when only a limited amount of new growth is present. The goal of the early-season copper sprays is to cover the tree surface and serve as a barrier through which bacteria must pass (being killed in the process) as they move from their overwintering sites. Dormant sprays contain relatively high rates of copper, which are **significantly reduced** as the new growth emerges. By shuck split, initiate use of oxytetracycline, which is relatively safe to peach foliage and fruit. In orchards where bacterial spot has been a problem in previous years, an early-season copper spray program should be used. Subsequently, the number and frequency of applications can be adjusted based on the occurrence of precipitation. If at least one period of precipitation occurs weekly, a 7- to 10-day spray program should be followed using oxytetracycline starting at shuck split. Local, annually updated spray guides should be consulted for specific application times and rates of chemicals.

Most chemicals for bacterial spot control are not labeled for use within three weeks of harvest.

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## 7.2.2 Bacterial Canker

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**B**acterial canker, caused by *Pseudomonas syringae* pv. *syringae* van Hall, has been known to occur in stone fruits since the late 1800s. It can be a major component of the peach tree short life complex in southeastern United States peach orchards. This disease has sometimes been referred to as sour sap, blast, die-back, or gummosis. However, in the southeastern United States, gummosis is typically a reference to peach fungal gummosis caused by *Botryosphaeria* spp.

### SYMPTOMS AND DISEASE DEVELOPMENT

Bacterial canker is most severe in trees younger than seven years. Twig and branch die-back are often the first symptoms observed (Figure 7.2.2.1). However, twig die-back is preceded by the failure of flower and leaf buds to open (Figures 7.2.2.2 and 4) in spring and subsequent development of elongated cankers at the base of one or more dead buds (Figures 7.2.2.2 and 3) usually on the previous season's terminal growth. Cutting into

cankers reveals a brown margin, sometimes with streaks or flecks of necrotic areas extending beyond the surface canker margin (Figure 7.2.2.4). Trees diseased from bacterial canker may leaf out normally, but the foliage suddenly withers, turns brown, and dies (Figure 7.2.2.1). Closer examination usually reveals the presence of buds that failed to open with discolored bark and wood (Figure 7.2.2.4). Collapse and rapid tree death can occur within two months after bud break. However, in some instances trees will put out new shoot growth (Figure 7.2.2.5) and recover if not affected by *Cytospora* spp. or other canker-causing fungi. Successful diagnosis of bacterial canker is best accomplished when symptoms are examined during the early stages of development. This is usually 2-3 weeks before and after full bloom. After this period, it becomes very difficult to isolate the bacterial pathogen and to differentiate its symptoms from those caused by freeze injury, bacterial spot pathogen (*Xanthomonas arboricola* pv. *pruni*) canker, and secondary microbes. Bacterial canker is believed to be the major cause of sudden spring collapse of

7



**FIGURE 7.2.2.1.** Die-back of branches associated with bacterial canker in spring on a second leaf tree.



**FIGURE 7.2.2.2.** Leaf and flower buds failed to open (dead-bud) and branch die-back occurred. Also, note the strappy-like leaf growth on the other branches. (color plate, page 189, Figure 7.2.2.2)



**FIGURE 7.2.2.3.** Developing canker at the base of a dead bud that has failed to open.



**FIGURE 7.2.2.4. Branch of previous year's growth that has died from bacterial canker with areas of necrotic tissue developing in the wood of older, secondary scaffold limb into which the disease has spread. (color plate, page 189, Figure 7.2.2.4)**



**FIGURE 7.2.2.5. Apparently healthy shoots emerging below the areas killed from bacterial canker. (color plate, page 190, Figure 7.2.2.5)**

peach trees in California. In the Southeast, bacterial canker is regarded as a component in the peach tree short life complex; it is thought to typically be secondary to cold injury.

The bacterial canker pathogen can enter the twigs through leaf scars as leaf drop occurs in autumn. The bacterium is a weak, opportunistic pathogen, being ubiquitous and capable of surviving on the surfaces of host and non-host plants without causing disease. Numerous factors can predispose a peach tree to infection and development of bacterial canker. These factors include low soil pH, rootstock, nematodes (especially the ring nematode), soil type (more common in light, sandy soils), tree age, inappropriate cultural practices such as early pruning, deep disking that damages roots, and environmental factors such as excess autumn and winter rainfall and temperature extremes that injure the tree. Winter months in which rainfall is frequent, with temperatures seldom dropping below freezing, are most commonly associated with the occurrence of "dead bud" and bacterial canker the following spring on peach trees in the Southeast.

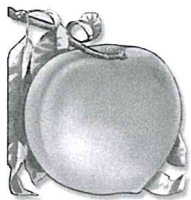
## CONTROL

In the Southeast, the occurrence of bacterial canker on peaches is sporadic. Controls, such as fall application of coppers timed with the occurrence of leaf drop, are generally not practical. In southeastern peach culture, management of bacterial canker is considered an important component of managing the peach tree short life complex. Management tactics for bacterial canker are described in the peach tree short life chapter.

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## 7.2.3 Crown Gall

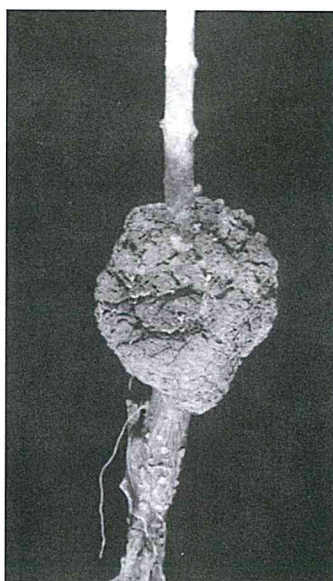
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**C**rown gall is caused by *Agrobacterium tumefaciens* Smith & Townsend (Conn), a widespread soil bacterium in temperate regions of the world. This bacterium has one of the widest known host ranges among plant pathogens, having been reported on more than 140 genera of broadleaf plants. The disease can be very severe in stone fruit nurseries, but it is generally not a problem in established orchards unless infected nursery stock is planted.

### SYMPTOMS

Crown gall is characterized by the development of tumorous overgrowths (galls) on roots, crowns, and occasionally trunks and scaffolds (Figure 7.2.3.1). These galls are initially soft and smooth, but they turn dark, hard, rough, and woody as they enlarge and age. Mature galls, which may reach more than 10 cm in diameter, often appear gnarled and fissured (Figure 7.2.3.2). Cracking allows secondary decay organisms to enter, leading to the breakdown of gall tissues. Such cracks also have been reported as entry sites for the fungi causing Armillaria root and crown rot.



On roots, young galls of *A. tumefaciens* may be confused with galling due to root-knot nematode infection. However,

**FIGURE 7.2.3.1. A mature crown gall that has girdled and killed a first-leaf peach tree. Image by P. F. Bertrand. (color plate, page 190, Figure 7.2.3.1)**

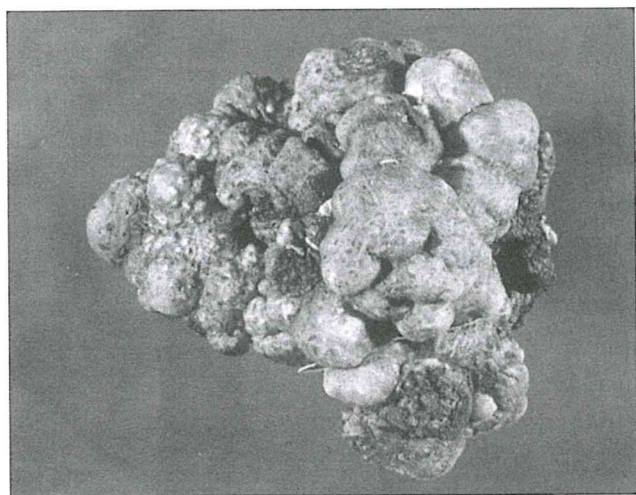
*A. tumefaciens* galls generally occur only on one side of the root, while those caused by root-knot nematodes encompass swelling of the root across its entire diameter.

If galling is limited to the root system, there may be no clear above-ground symptoms in mature trees. Symptoms are variable in *Prunus*. Infected peaches may appear stunted, while infected cherry trees will often reveal no consistent effects on growth.

### DISEASE DEVELOPMENT

Pathogenic crown gall bacteria occur commonly in nursery soils and less frequently in orchard soils. The pathogen is able to survive in the soil for extended periods of time, even in the absence of a suitable host plant. Infection of the host invariably occurs at sites of natural or mechanical wounding. In stone fruit nurseries, such wounds are created during seed germination, during mechanical cultivation of nursery beds, and at harvest. In the orchard, natural growth cracks on roots and wounds generated during mechanical cultivation (such as disking or harrowing; practices now less commonly used by peach producers) can serve as entry points for the pathogen. Above-ground plant parts, such as crown or trunk tissues, become infected when crown gall bacteria are rain-splashed from the soil to wounds such as those caused by careless operation of farm equipment. Cells of *A. tumefaciens* attach to and release part of their genetic material into the wounded host cells. Incorporation of this genetic material prompts the affected host cells to proliferate in an uncontrolled fashion (not unlike a human tumor), leading to gall formation. The galls provide nutrients and physical protection for the pathogen. Individual galls may expand and persist for several





**FIGURE 7.2.3.2. An enlarged view of an active crown gall. Image by P. F. Bertrand. (color plate, page 190, Figure 7.2.3.2)**

years, after which the ingress of secondary decay organisms leads to their breakdown and the release of *A. tumefaciens* back into the soil.

## CONTROL

**Established Orchards.** In stone fruit, prevention is generally the only viable management option against the disease. Prevention involves the use of crown gall-free nursery stock from a reputable nursery. Carefully inspect nursery stock before planting and return the entire lot if symptomatic trees are found. Crown gall symptoms are generally well developed on finished nursery stock, making inspection a useful prevention strategy.

Paint application to galls of xylene- and cresol-based products has been proposed as a therapeutic treatment for affected orchard trees. However, this procedure would only be feasible for above-ground galls, due to the cost associated with excavating and treating roots of established trees.

**Nursery.** As stated above, crown gall can be very problematic in stone fruit nurseries because affected nursery stock cannot be sold.

Unfortunately, management options are limited. Crop rotation will be effective only if the land can be planted to non-hosts (such as grasses) for an extended period of time. Fumigation does not control crown gall because it does not completely

eradicate *A. tumefaciens* from the soil, and bacteria in gall tissue are protected from the fumigant. Biological control of the disease by seed-application of non-pathogenic *A. radiobacter* strains K84 or K1026, a practice developed in Australia, has been used successfully in stone fruit nurseries worldwide, but this is not widely utilized in southern nurseries. This bacterium acts by producing an antibiotic that kills most pathogenic strains of *A. tumefaciens*. Heat treatment of root systems of dormant nursery trees at 18° to 25°C for one to three weeks has been shown to reduce crown gall incidence on affected roots. With this practice, the root-heating boxes are maintained in a cold room at 2° to 4°C to prevent bud break of the dormant trees.

Resistance breeding is a long-term strategy for managing the disease. Development of crown gall resistance in *Prunus* rootstocks currently is only a secondary objective behind more pressing root disease problems such as peach tree short life, Armillaria root and crown rot, and nematodes. Furthermore, with the exception of *P. mahaleb* (Mahaleb cherry), the incidence of useful crown gall resistance in *Prunus* accessions is very low.

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7







## 7.2.4 Phony Peach Disease

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**P**hony peach disease (PPD) is caused by a fastidious, xylem-limited bacterium, *Xylella fastidiosa*. Isolates of this same bacterium cause plum leaf scald and other diseases of woody plants, such as Pierce's disease of grapes, citrus variegated chlorosis, and leaf scorch of almond, coffee, elm, oak, oleander, and sycamore. PPD occurs from North Carolina to Texas, wherever the average annual minimum temperature is warmer than 13°F. PPD is spread by leafhoppers, small wedge-shaped insects that may be quite abundant in peaches. The pest status of leafhoppers in peach is solely attributable to vectoring or spreading PPD. PPD is commercially important in Georgia south of a line from LaGrange to Augusta. In south Georgia, PPD is very often the major factor that limits peach orchard life. Major epidemics of PPD occurred in Georgia in 1929, 1951, and 1976. Another epidemic can be expected whenever orchard conditions are favorable for the spread of the disease.

### SYMPTOMS

Trees with symptoms of PPD were first noticed in Georgia around 1890. Starting in early July, phony trees appear more compact, leafier, and darker green than normal trees because of shortened internodes (Figure 7.2.4.1). Fruit size, quality, and number are drastically reduced. Fruit may be more highly colored and ripen a few days earlier than normal. PPD-infected peach trees bloom several days earlier than normal trees and hold their leaves later in the fall. Peach leaves, in contrast to plum leaves, are not scorched or scalded. Trees that develop PPD symptoms before bearing age never become productive.

### DISEASE DEVELOPMENT

*X. fastidiosa*, the PPD organism, multiplies and spreads slowly up and down the xylem of the tree from the site of infection. Symptoms develop 18 months or more after infection. Symptoms may develop in one scaffold limb or over the entire tree at the same time. An extremely dry summer seems to delay the development of symptoms for at least a year. PPD does not kill the tree, but may make it susceptible to other diseases.

*X. fastidiosa* is readily transmitted by root grafts. The bacteria are plentiful in roots of infected peach trees and in roots and stems of infected plum trees. Grafting experiments and microscopic examination of the xylem indicate that few *X. fastidiosa* are present in peach stems during much of the year. Colonization by high populations of *X. fastidiosa* in vascular tissue restricts water movement in the xylem, but the true biochemical and biophysical mechanisms involved in PPD symptom manifestation remain unknown.



**FIGURE 7.2.4.1.** Symptoms of phony peach disease include greener foliage and shortened internodes on stems.



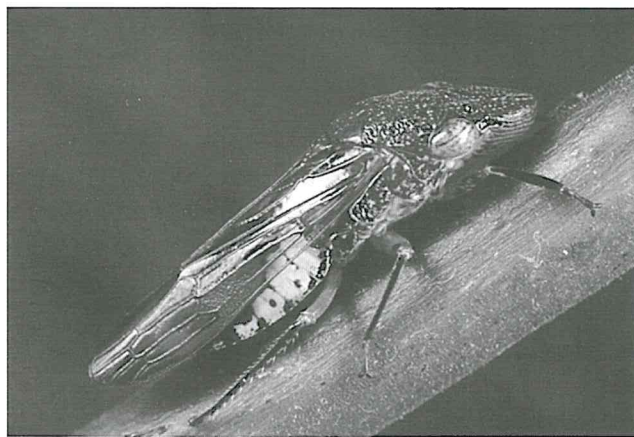
## INSECT VECTORS

PPD is spread (vectored) by leafhoppers, insects that are commonly called sharpshooters. The major insect vector in the coastal plain of the southeastern United States is probably *Homalodisca coagulata*, the glassy-winged sharpshooter (Figure 7.2.4.2), but any xylem-feeding insect must be considered a potential vector of PPD and related diseases. *H. insolita*, *Oncometopia* spp., *Graphocephala* spp., and *Draeculacephala* spp. leafhoppers are also commonly found in association with the host plants and pathogen. Leafhoppers can become infectious after feeding on a diseased tree for a short period of time (Figure 7.2.4.3). Once infected, adult leafhoppers apparently remain infectious until death. *H. coagulata* is eight times more abundant in south Georgia (Brooks County area) than in middle Georgia (Ft. Valley area). *H. coagulata* reaches its peak abundance in peaches later on the fall line than in the lower coastal plain. *H. coagulata* numbers peak in the fall in middle Georgia, and in June to July in south Georgia and north Florida (Figure 7.2.4.4). Orchards with poor weed control and greater plant diversity will have higher numbers of leafhoppers. Healthy peach is usually not a favorite host plant of most leafhopper vectors, and trees displaying PPD symptoms will not support *H. coagulata*. Other plant species such as crapemyrtle, *Lagerstroemia indica*, native and domesticated plum, grape, sumac, *Rhus* sp., *Baccharis halimifolia*, and many other woody and herbaceous weeds are used frequently as hosts by

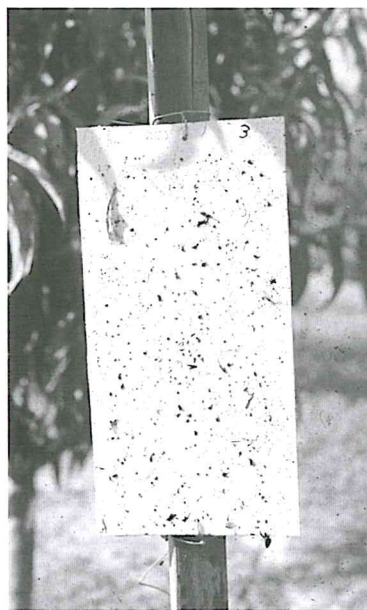
the vectors. Leafhoppers feed and oviposit on an extremely wide range of plant species, but the adults (Figure 7.2.4.5) and nymphs (Figure 7.2.4.6) have different nutritional requirements. The number of host plant species capable of supporting nymph development of *H. coagulata* is much lower than the number of acceptable adult feeding hosts. Overwintering adults of *H. coagulata* do not hibernate, but their winter behavior is not well understood. In winter, they feed mostly on oak and perhaps other hosts and fly during warm spells. Leafhoppers infected with *X. fastidiosa* have been collected in almost every month of the year in south Georgia.



**FIGURE 7.2.4.3.** Leafhoppers have enlarged heads that house the musculature necessary to penetrate and feed against the negative pressure gradient of the xylem tissue. (color plate, page 190, Figure 7.2.4.3)



**FIGURE 7.2.4.2.** One of the major vectors of phony peach disease in the Southeast, the glassy-winged sharpshooter (*Homalodisca coagulata*), also transmits Pierce's disease of grapes. Image by Jeff Brushwein. (color plate, page 190, Figure 7.2.4.2)



**FIGURE 7.2.4.4.** Leafhopper vector populations may be monitored using yellow sticky traps.





**FIGURE 7.2.4.5.** Leafhopper vectors feed on many host plant species from trees to grasses and are well camouflaged with the plant for protection.



**FIGURE 7.2.4.6.** Leafhopper vector nymphs feed on the leaves of host plants.



**FIGURE 7.2.4.7.** Symptoms of plum leaf scald caused by *Xylella fastidiosa*. (color plate, page 190, Figure 7.2.4.7)

## HOST PLANTS

The full range of host plants for the *X. fastidiosa* isolate that causes PPD is not known. *X. fastidiosa* has a diverse host range encompassing over 30 families of monocotyledonous and dicotyledonous plants. Only recently have laboratory tools been developed to detect and identify different isolates of *X. fastidiosa*. Wild and domestic plums are known carriers, but many plums show few, if any, disease symptoms (Figure 7.2.4.7). Wild cherry, *Prunus serotina*, may be a minor host of PPD. Goldenrod is a host of *X. fastidiosa*, and future research will probably identify additional hosts. Johnsongrass, which is a host of Pierce's disease in California, has been reported to contain *X. fastidiosa* in Georgia. However, the strain of the bacterium found in Johnsongrass was not shown to cause PPD. *X. fastidiosa* can be extracted from a large number of hosts that display no symptoms of infection. Whether these are only transient colonizations or chronic infections is unknown, but remains an important, unanswered aspect of understanding the epidemiology of PPD.

## CONTROL

There is no cure for PPD or any other disease caused by *X. fastidiosa*. Control efforts are limited and focused on preventing disease spread. Satisfactory control is difficult in areas of heavy infection. In Georgia, information on orchard inspection for PPD is available from the State Department of Agriculture. Removal of diseased trees in 2- to 5-year-old peach orchards extends productive orchard life, although the underlying mechanism explaining this phenomenon remains unknown. Infected trees are readily identified by their reduced shoot growth in July and August unless trees are summer-pruned. Diseased trees should thus be identified and removed before an orchard is pruned. Avoid heavy summer-pruning, because the vigorous regrowth that often follows is especially attractive to leafhoppers. Plant new orchards as far as possible (at least 300 yards) from all existing peaches and wild cherries. Do not plant peaches near plums, and remove or kill all plums, whether wild or domestic, near any peach site before planting. Never plant a new



orchard near an orchard showing PPD symptoms. This has been tried with disastrous results. Maintain weed-free tree rows with a herbicide program and closely mowed sod middles in orchards to reduce feeding and breeding plants for leafhoppers. This usually reduces leafhopper populations in the orchards, although leafhoppers are strong fliers and can easily travel long distances in search of hosts and mates. Elimination of adjacent hardwood stands, particularly oaks, and broadleaf weeds near the orchard may minimize

overwintering and alternate feeding sites for the leafhoppers. Routine spraying of orchards after harvest to control leafhoppers will not eliminate disease spread and is not cost-effective. In a 3-year program from 1948 through 1950, DDT was sprayed on a 1,000 acre (100,000 trees) orchard in middle Georgia. This program was judged a failure. Similarly, plots sprayed with parathion every other week during June and July in south Georgia failed to show a consistent decrease in leafhoppers.

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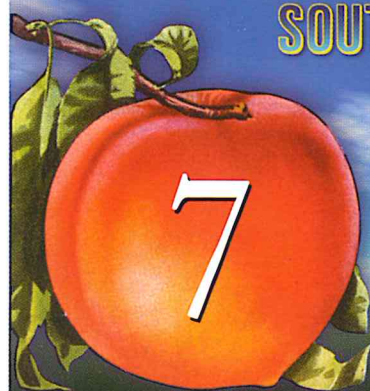
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# SOUTHEASTERN PEACH GROWERS' HANDBOOK



## • FUNGAL AND BACTERIAL DISEASES

### Color Plates



**FIGURE 7.1.1.1.** Brown rot blossom blight. Note production of grayish-tan spore masses on the twig at the base of the blighted blossom.



**FIGURE 7.1.1.2.** Brown rot on an aborted fruit ("button").



**FIGURE 7.1.1.3.** Brown rot on insect-damaged green fruit. Note small insect feeding puncture in the center of the rotted area.



**FIGURE 7.1.1.4.** Brown rot on a ripe fruit. Note the production of spore masses in more or less concentric rings.





**FIGURE 7.1.1.5.** Rhizopus rot on a ripe fruit.



**FIGURE 7.1.1.6.** Anthracnose rot on ripe fruit.



**FIGURE 7.1.1.7.** Mummy of a brown-rotted peach fruit hanging in the tree.



**FIGURE 7.1.1.8.** Mummy of a brown-rotted peach fruit that has fallen to the ground.



**FIGURE 7.1.1.9.** Cup-like brown rot apothecia that form on partially buried peach mummies on the ground. These fungal structures produce the spores that result in some of the primary infections in the spring.



**FIGURE 7.1.2.1.** Brown rot development on an insect-damaged green fruit.





**FIGURE 7.1.3.1.** Scab twig lesions. Note the oval to irregular lesion shape with a raised margin. Image by P. F. Bertrand.



**FIGURE 7.1.3.2.** Scab lesions on green fruit. Note that lesions are more concentrated near the stem end. Image by P. F. Bertrand.



**FIGURE 7.1.3.3.** Scab lesions on mature fruit. Note the yellow halo surrounding the lesions.



**FIGURE 7.1.4.1.** Brown rot on a mature peach. Pre-harvest infections continue to spread during and after harvest.



**FIGURE 7.1.4.2.** Brown rot mummy.

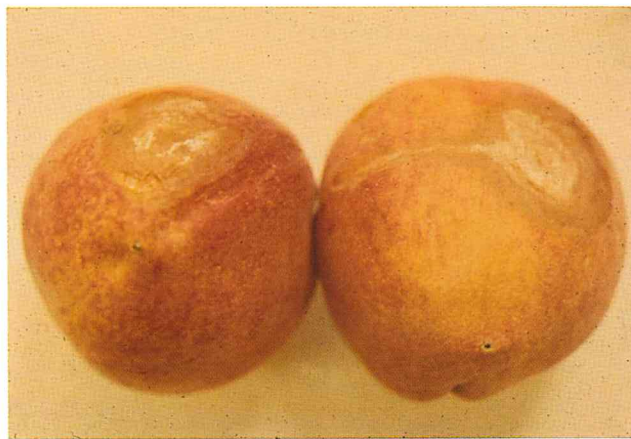


**FIGURE 7.1.4.3.** Rhizopus rot on peach.





**FIGURE 7.1.4.4. Gray mold on peach.**



**FIGURE 7.1.4.5. Sour rot on peach. Image by C. M. Wells.**



**FIGURE 7.1.4.6. Anthracnose on peach. Image by N. E. McGlohon.**



**FIGURE 7.1.6.2. Phomopsis lesions on ripening fruit of Babygold 5 peach. Lesions are round to oval, develop rapidly, and have a very moist texture.**



**FIGURE 7.1.7.1. Powdery mildew on green peach fruit.**



**FIGURE 7.1.8.1. Peach leaf rust.**





**FIGURE 7.1.9.1.** Peach leaf curl symptoms on leaves.



**FIGURE 7.1.9.2.** Peach leaf curl symptoms on fruit.



**FIGURE 7.1.10.1.** Peach branch with blisters caused by the fungus *Botryosphaeria dothidea*.



**FIGURE 7.1.10.2.** Three-year-old peach trunk with bark section removed to show multiple necrotic lesions.



**Figure 7.1.10.3.** Trunk of peach tree with multiple infection sites exuding resin.



**Figure 7.1.10.4.** Peach branch with canker formed by coalescence of multiple infections.



**Figure 7.1.10.5.** Cracking and peeling of peach bark due to cork formation associated with old lesions.



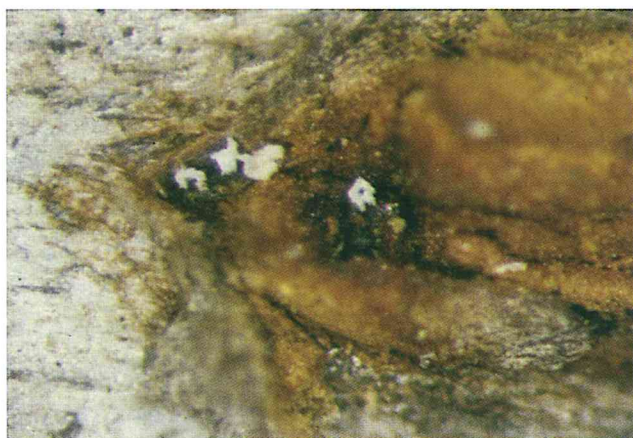


Figure 7.1.10.6. Asexual fruiting bodies of *Botryosphaeria dothidea* exuding spores (white) at edge of bark lenticel.



Figure 7.1.11.2. Zones of discolored bark and sapwood in a *Cytospora* canker.



Figure 7.1.11.4. Scaffold branch with fungal fruiting bodies (pycnidia) just beneath the bark surface.



Figure 7.1.11.5. Outer bark removed to expose the pycnidia.



Figure 7.1.11.6. Hairy appearance of *Cytospora* spore tendrils.



◀ Figure 7.1.11.7. Nodal infection with developing canker and amber gum.

► Figure 7.1.12.2. Cutting away the bark of a *Phytophthora*-affected tree reveals that although the upper trunk and scaffolds are still green, the lower trunk has been girdled and killed. This is typical of *Phytophthora* crown rot.







Figure 7.1.13.1. Basidocarps (mushrooms) produced by *Armillaria* from severely infected peach root systems. (A) Darker mushrooms of *Armillaria tabescens* (B) and pale yellow mushrooms of *Armillaria mellea*.



Figure 7.1.13.3. Curling of peach leaves following root and crown infection by *Armillaria*. (A) Overall appearance of tree; (B) a closer view of an individual shoot with leaf curl and bronzing.

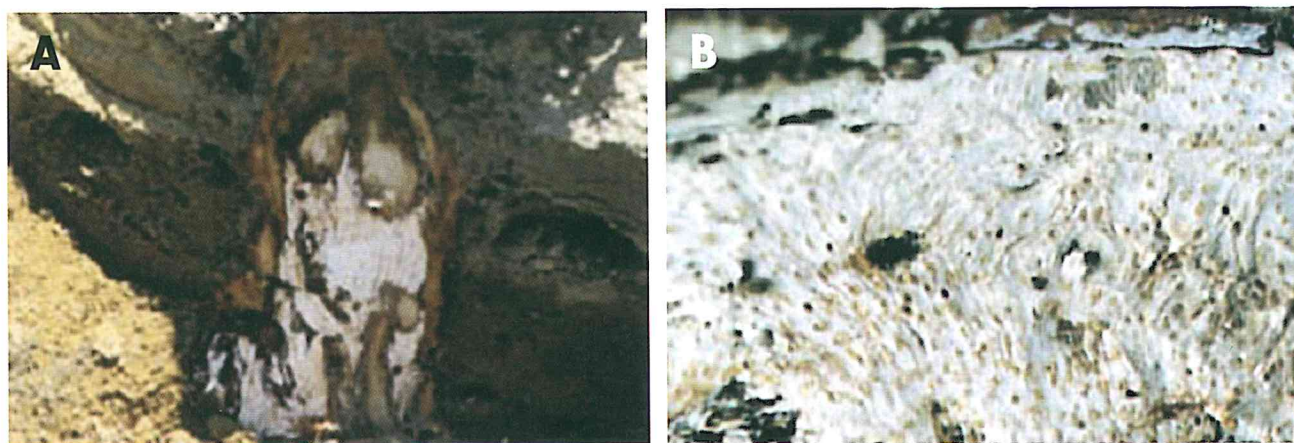


Figure 7.1.13.5. Outer bark removed from tissues of an infected peach tree to reveal the presence of mycelial sheets of *Armillaria*. (A) A large root showing mycelial sheets; and (B) a piece of crown bark showing mycelial sheet with perforations typical of *A. tabescens*.





**FIGURE 72.1.1.** Chlorotic leaves with multiple bacterial spot lesions that commonly develop in areas where moisture aggregates and evaporates slowly (e.g., at the leaf tip). Once leaves develop these symptoms, they readily drop.



**FIGURE 72.1.2.** Newly formed bacterial spot lesions. Light yellowish-green halo surrounds the water-soaked, angular-shaped, brownish-yellow center of the lesion.



**FIGURE 72.1.3.** Lesions develop a dark brown center. If the center of the lesions abscises, a shot-hole symptom develops, giving the leaf a tattered appearance.



**FIGURE 72.1.4.** An overwintering canker or spring canker on the previous year's growth. Spring cankers are first visible during bloom and develop a black, water-soaked appearance. They extend along the length of the twig from a leaf/flower bud that has failed to open.



**FIGURE 72.1.5.** An overwintering canker that developed from the terminal bud downward; such cankers have been termed *black tip*.



**FIGURE 72.1.6.** An overwintering canker soon after the shuck-off stage of fruit growth that did not completely girdle the twig. The canker color changes from black to brownish red and the outer bark begins to crack as the tissue beneath the canker grows.





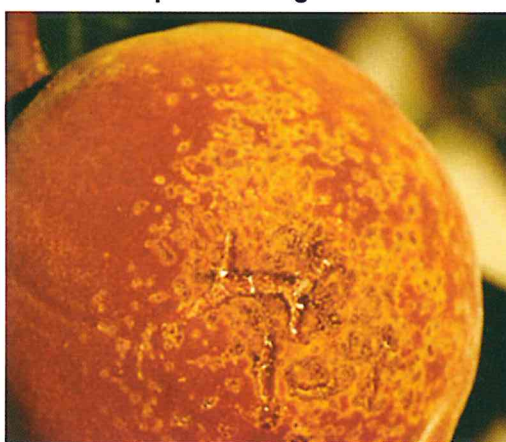
**FIGURE 7.2.1.7.** Newly formed, water-soaked lesions on fruit first visible near the time of pit-hardening. Gum also may exude from lesions.



**FIGURE 7.2.1.8.** Lesions resulting from infections occurring near the time of shuck split become black and start to extend into the fruit flesh. Gum commonly exudes from these lesions. Fruit growth stage is about three weeks after pit-hardening.



**FIGURE 7.2.1.9.** Fruit that was infected soon after bloom; lesions continued to develop throughout the season and now extend deep into the flesh. Fruit is about two weeks from harvest.



**FIGURE 7.2.1.10.** Fruit having lesions that remain near the fruit surface and do not extend deep into the flesh. Such "surface lesions" are associated with infections that occurred near or after pit-hardening rather than near or just following shuck-split.

7



◀ **FIGURE 7.2.2.2.** Leaf and flower buds failed to open (dead-bud) and branch die-back occurred. Also, note the strappy-like leaf growth on the other branches.

▶ **FIGURE 7.2.2.4.** Branch of previous year's growth that has died from bacterial canker with areas of necrotic tissue developing in the wood of older, secondary scaffold limb into which the disease has spread.







**FIGURE 7.2.2.5.** Apparently healthy shoots emerging below the areas killed from bacterial canker.



**FIGURE 7.2.3.1.** A mature crown gall that has girdled and killed a first-leaf peach tree. Image by P. F. Bertrand.



**FIGURE 7.2.3.2.** An enlarged view of an active crown gall. Image by P. F. Bertrand.



**FIGURE 7.2.4.2.** One of the major vectors of phony peach disease in the Southeast, the glassy-winged sharpshooter (*Homalodisca coagulata*), also transmits Pierce's disease of grapes. Image by Jeff Brushwein.

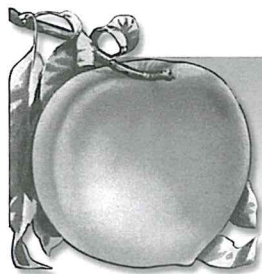


**FIGURE 7.2.4.3.** Leafhoppers have enlarged heads that house the musculature necessary to penetrate and feed against the negative pressure gradient of the xylem tissue.



**FIGURE 7.2.4.7.** Symptoms of plum leaf scald caused by *Xylella fastidiosa*.





## 7.3 NEMATODES

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**N**ematodes often cause significant tree health problems in peach orchards. Nematodes are microscopic roundworms that feed on the root systems of peach trees and other plants. This feeding may cause no damage in some cases or it may weaken or even kill the tree in other cases. The head region of a nematode contains a hollow, pointed, spearlike stylet. To feed, a nematode punctures an individual host cell with its stylet and pumps digestive enzymes into the cell. The cell contents are digested and drawn back into the nematode through the stylet. When the nematode finishes one cell, the stylet is withdrawn and a new cell is penetrated.

Nematodes that parasitize peaches can be categorized according to feeding habit as follows: (1) ectoparasites; (2) sedentary endoparasites; and (3) migratory endoparasites. Nematodes that spend their entire life cycle outside the host root, like ring nematodes, are ectoparasites. Those which feed at a permanent location within the root, like root-knot nematodes, are sedentary endoparasites. Migratory endoparasites, like root-lesion nematodes, enter plant tissues completely and carry out some part of their life cycle within the host root.

Nematodes spread very slowly under their own power, moving at most a few feet through the soil per year. They move best in coarse-textured soils that are wet, but not water logged. Nematodes are readily spread over great distances in soil clinging to farm equipment, in run-off water from rain or irrigation, or in contaminated plant material.

Several southeastern nematode species damage peach trees.

- 1. Root-Knot Nematodes** (*Meloidogyne* spp.)
  - a) Northern root-knot, *M. hapla* Chitwood
  - b) Peanut root-knot, *M. arenaria* (Neal) Chitwood
  - c) Southern root-knot, *M. incognita* (Kofoid and White) Chitwood
  - d) Javanese root-knot, *M. javanica* (Treub) Chitwood
- 2. Ring Nematode**, *Mesocriconema xenoplax* (Raski) Loof & de Grisse
- 3. Root-Lesion Nematode**, *Pratylenchus vulnus* Allen and Jensen

### ROOT-KNOT NEMATODES

Although northern and peanut root-knot nematodes can parasitize peach, problems with these two species in peaches are rare. Northern root-knot nematode is rather rare in Georgia. The major concentration of peanut root-knot nematode in Georgia is south of U.S. Highway 82 and west of Interstate 75 in the southwest corner of the state. This area is outside the major concentration of peaches. Problems with peanut root-knot nematode in this part of the state should only be expected where peaches are planted in sandier fields with a history of root-knot nematode problems on peanuts.

The parasitic nature of root-knot nematode was described on cucumber in 1855; they were dis-

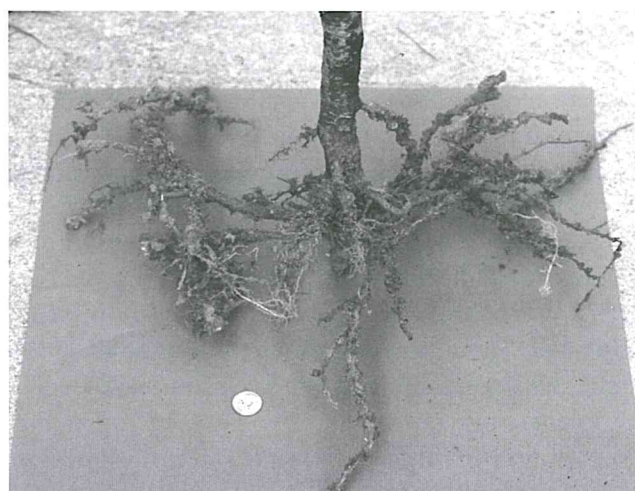




**FIGURE 7.3.1.** Stunting of 1-year-old peach trees planted into root-knot nematode-infested soil.



**FIGURE 7.3.2.** Stunting and defoliation of Lovell peach tree (left) in the presence of root-knot nematode. Check treatment on right.



**FIGURE 7.3.3.** Typical galls on peach roots caused by root-knot nematode.

covered on peaches in 1889. The most common symptom of root-knot nematode problems in peach is stunted growth of young trees. Trees infected in the nursery or transplanted into heavily infested land are often severely stunted or killed during the first year (Figure 7.3.1). Trees stunted by root-knot nematode during establishment continue to be weak growing and below average in productivity. They never recover from this weakened condition. Root-knot stunted peach trees have never been successfully rejuvenated with nematicide treatment.

Bearing trees established without any sign of stunting may or may not show any above-ground symptoms of a root-knot nematode-infested root system. Trees showing above-ground symptoms may appear short of fertilizer or water, even when these are known to be present in adequate amounts. Infected trees frequently show premature leaf drop, especially during dry seasons (Figure 7.3.2). Conditions of low fertility or drought stress may bring on above-ground symptoms that would not be evident under more optimal growing conditions. Trees established without stunting frequently, if not usually, show no above-ground symptoms whatsoever, even from rather severe root-knot nematode infection of the feeder root system. The roots of all infected trees, whether above-ground symptoms are present or not, show the galling or knotting characteristic of root-knot nematode infection (Figure 7.3.3).

The disease cycle of root-knot nematode is dependent upon temperature and moisture. After an egg hatches, the infective-stage juvenile moves along the root or through the soil and enters a susceptible root near the root tip. After entering the root, the juvenile migrates to areas of the root where food and water are transported. The developing female will not move again once a feeding site is established. Initial root penetration and feeding activities stimulate cell enlargement and cell division, which result in the familiar root galls or knots.

Under optimal conditions (77° to 86°F) the female begins to lay eggs 20 to 30 days after establishing a feeding site. The egg masses accumulate at the root surface and usually contain from 500 to 1,000 eggs/egg mass. The eggs hatch



as soon as moisture is available at temperatures above about 50°F. Egg hatch increases and length of life cycle decreases as temperatures approach 75° to 85°F. Several generations occur during a growing season.

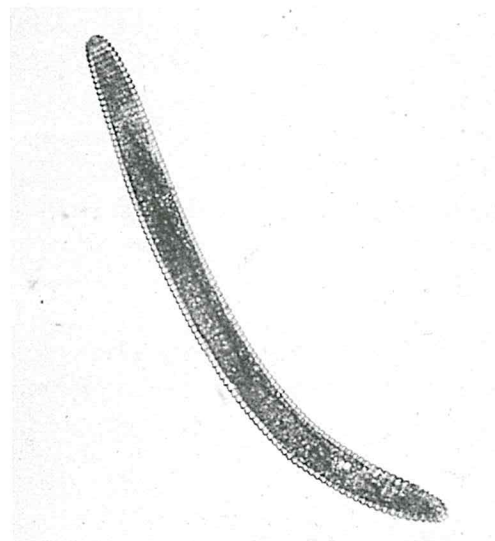
### RING NEMATODE

The ring nematode, *Mesocriconema xenoplax* (= *Criconemella xenoplax* = *Macroposthonia xenoplax* = *Criconemoides xenoplax*) (Figure 7.3.4), plays a significant role in the peach tree short life disease complex (PTSL) by predisposing trees to death from cold damage, bacterial canker, or both. Trees weakened or killed in this manner often show a proliferation of root suckers around the base of the trunk (Figure 7.3.5). *M. xenoplax* is also known to predispose peach trees to Cytospora canker. Other ring nematode species, such as *M. ornata* and *M. sphaerocephala*, are commonly found in Georgia peach orchards. These two species have no known or suspected role in PTSL. There is no convincing evidence that they damage peach roots, though they may feed incidentally on them. They are present in association with grasses and other weeds. In peach orchards, the presence of these incidental ring nematodes makes species-specific identification a critical part of ring nematode assays. Assay results that do not specifically indicate the presence or absence of *M. xenoplax* or just give a total count of ring nematodes are worthless to the peach grower.

Ring nematode problems occur most often in sandy soils and/or where peaches were previously grown, though they can occur wherever one attempts to grow peaches. Bacterial canker and Cytospora canker can occur in the absence of *M. xenoplax* if the trees are weakened by other factors. However, if ring nematode is found in high numbers in a peach orchard, especially a young orchard, producers should expect problems with one or both of these diseases. *M. xenoplax* populations tend to reach their highest levels in winter to early spring. The life cycle of *M. xenoplax* is generally completed in 25 to 34 days at 72° to 79°F. Adult females lay 8 to 15 eggs over a 2- to 3-day period. Eggs are deposited in close proximity to host roots or on the root surface. Feeding is required for juveniles to molt and for maturation of developing eggs within the adult females. Refer to the discussion of PTSL for additional information on this disease complex.

### ROOT-LESION NEMATODE

Root-lesion nematodes, *Pratylenchus* spp., were recognized as parasites of trees and vines in California in 1927. *P. vulnus* was described as a distinct species in 1951. It was first found in



**FIGURE 7.3.4.** Ring nematode (*Mesocriconema xenoplax*) that is involved in the peach tree short life disease complex.



**FIGURE 7.3.5.** Suckering at the base of a dead peach tree that originated below the soil surface in the presence of ring nematode. Typical of trees dead from bacterial canker or cold injury.



Georgia peach orchards in 1969. As is the case with ring nematodes, assays for root-lesion nematodes must identify the specific species present to be of any value. Although *P. vulnus* is a peach pest, there are other species of root-lesion nematode, not parasitic to peach, that are found in orchard samples. These incidental root-lesion nematodes feed on grasses and weeds.

Feeding by root-lesion nematodes results in reduced root systems (Figure 7.3.6) and the presence of small dead spots or lesions (Figure 7.3.7) on the

roots. Peach trees affected by root-lesion nematodes may become non-vigorous, unproductive, and/or show some dieback due to death and secondary rotting of the feeder root system. Root-lesion nematode is not a common problem in Georgia peach orchards, but losses can be significant when *P. vulnus* is present. There is evidence that *P. vulnus* reaches its highest population levels from August to December. The life cycle of root-lesion nematodes is temperature-dependent and varies between 30 (86°F) and 92 days (59°F). *P. vulnus* is more common in warmer temperature regions. *P. vulnus* penetrates roots at a faster rate and does more damage to plants growing in sandy loam (coarse) as compared with finer textured soils.

## CONTROL

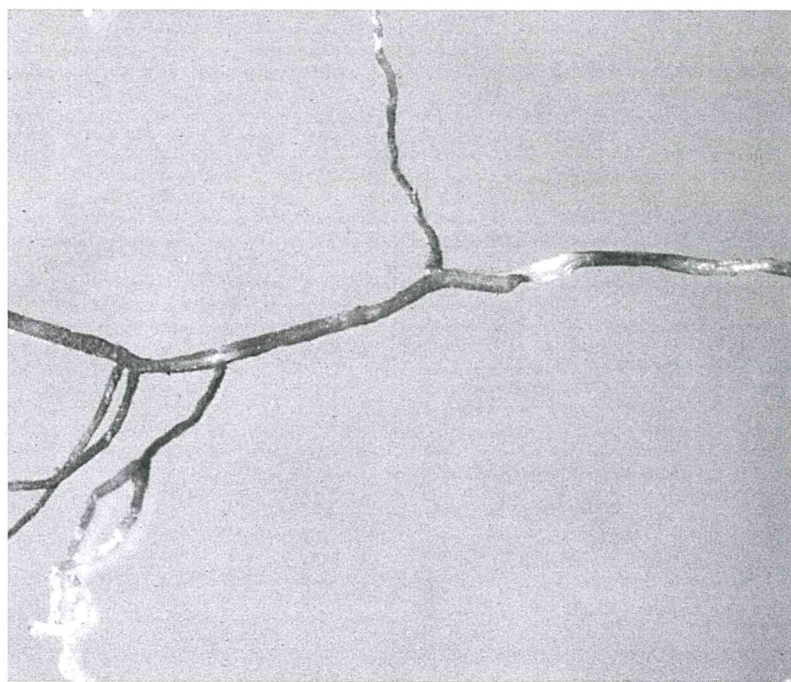
Nematode control measures for peaches are best taken before planting. An orchard is expected to bear eight or more years, usually without further nematode treatment. Because it is critical that producers use the best control measures available for their situation, the proposed site must be thoroughly sampled before planting.

## Nematode Sampling

Sampling time depends upon the crop history of the proposed site. If the site is an orchard scheduled for removal, two samples should be taken before the orchard is removed. Take the first sample in the late winter or spring (February to April). This sample is primarily for ring nematodes, which should be at their highest levels at this time. The second sample, taken in September to October, checks for root-lesion and root-knot nematodes. Both samples should include a generous amount of feeder roots. A spring sample may be all that is needed if both root-knot and root-lesion nematodes are found at this time. If they are not found in the spring sample, the fall sample



**FIGURE 7.3.6.** Root damage caused by root-lesion nematode (*Pratylenchus vulnus*) on plum (right). Image by J. Pinochet.



**FIGURE 7.3.7.** Root injury due to invasion by root-lesion nematode. Image by B. A. Jaffee.



double-checks for these species. In an old orchard site currently used for production of annual crops or pastures, spring and fall samples are also recommended. Take the spring sample before plowing or harrowing. Take the fall sample as crops mature, but before harvest. In cropland with no history of peaches, a fall sample is adequate. Take the sample as crops mature, but before harvest, which is the time of maximum root-knot nematode levels. Samples should be taken the year before trees are to be planted so the site can be evaluated prior to ordering trees. Last-minute sampling limits control options to fumigation or nothing at all.

In producing orchards, spring and fall nematode sampling should become a routine practice. Early detection of potential problems is critical for post-plant nematode control. These results will also be valuable in scheduling pruning and planning use of the land when the current orchard is removed.

Collect nematode samples from moist, but not saturated, soil. Do not sample very dry soil nor add water to samples that seem dry. Because overheating will kill nematodes and ruin the samples, take a small cooler to the field in which to place bagged samples. Dead nematodes rot very quickly and will not be seen when counts are made. In an orchard, nematode samples should be taken in the tree row through the root zone. Orchard samples should include a handful of feeder roots. Using a soil sampling tube, collect soil from random locations (zig-zag pattern) over the field. When collecting samples, first remove the top 2 inches of soil, then insert the tube to a depth of 10 to 12 inches. Each site sampled should consist of approximately a pint of soil made from a composite sample consisting of 10 or more subsamples (soil probes or cores). The number of soil cores will depend on the size of the field in question: (1) if less than 1 acre, at least 10 cores should be taken; (2) from 1 to 5 acres, take 10 to 50 cores. One sample should not represent more than 5 acres. The cores from a given area should be thoroughly mixed in a clean bucket and put into a labeled plastic bag and sealed. Because nematodes often occur in hot spots, sampling small areas separately maximizes the chances of identifying hot spots in an orchard.

Your county extension agent can assist you in sending the samples to a diagnostic clinic or a nematology laboratory for assay. Sample early in the week to ensure same-week delivery to the lab. Based on the results of these assays, one of the following control measures may be selected to best meet your needs.

### Rootstocks

Rootstocks, with very important limitations, can be useful in controlling root-knot nematode in peaches. The three rootstocks commonly available for peaches are Guardian, Lovell, and Nemaguard. Lovell rootstock has no specific resistance to any of the nematodes damaging peaches. Nemaguard rootstock has good resistance to two species of root-knot nematode, Southern (*M. incognita*) and Javanese (*M. javanica*), and can be used when these are the only damaging nematodes present. Nemaguard has no resistance to the other root-knot species or any of the other nematodes that damage peaches. Guardian, like Nemaguard, has demonstrated resistance to Southern and Javanese root-knot species (*M. incognita* and *M. javanica*), but Guardian is susceptible to peanut and northern root-knot nematode. Nemaguard rootstock should never be used if ring nematode, *M. xenoplax*, is present. Trees on Guardian rootstock are generally much more resistant to the PTSL syndrome than trees grown on Lovell or Nemaguard rootstock, whereas trees on Lovell survive longer than those on Nemaguard. If ring nematode is not present, Nemaguard rootstock can be used with relatively low risk on the lower coastal plain of Georgia (south of U.S. Highway 280). Between U.S. 280 and the fall line, Nemaguard rootstock may be used; however, it has some recognized risk of cold injury and PTSL. Use of Nemaguard in this area should be confined to cases where Southern and/or Javanese root-knot nematodes are present and *M. xenoplax* is absent. Nemaguard rootstock should not be used on the piedmont, as the risk of cold injury is too great. Wherever Nemaguard rootstock is used, a serious commitment to management, especially time of pruning, is necessary to minimize risks from winter injury. Never prune trees on Nemaguard rootstock until after February 1. Southern states vary in their recommendations of Nemaguard rootstock, and local advice from the nearest county agent should be sought whenever considering use of this root-



stock. All three rootstocks are good hosts to the root-lesion nematode, *P. vulnus*, and should not be recommended as an alternative to pre-plant chemical control for this species.

### Crop Rotation

Crop rotation is used to starve nematodes by growing crops on which they cannot feed and/or reproduce. Rotation is generally used for controlling root-knot nematodes. Rotation programs have an advantage in that the treatment can provide some income, depending on the value of the rotational crop. There are two disadvantages of crop rotation for nematode control in peaches: (1) the use of a crop rotation may delay planting the orchard two to four years and (2) there are some grass crops, such as coastal bermudagrass and bahiagrass, that will eliminate root-knot nematodes, but the reaction of the root-lesion nematodes that parasitize peach to these grasses is largely unknown. Bahiagrass is a poor host of ring nematode, *M. xenoplax*, but a three-year pre-plant rotation did not increase peach tree survival on a PTSL site as compared with pre-plant wheat. Rotating land with wheat/fallow for three years prior to establishing a peach orchard has been shown to be as effective as pre-plant methyl bromide fumigation in suppressing ring nematode and increasing tree survival on a PTSL site.

### Fumigation

Fumigation is effective against all nematodes that damage peaches. Fumigation works best in sandy or sandy loam soils and generally works poorly in heavy clays or clay loams. Clay soils have naturally small pore spaces and are difficult to dry; both factors contribute to restricted movement of fumigants. Fumigation will not work well in compacted soils of any texture. Compaction problems can usually be corrected in sandy soils by deep chiseling.

Thorough land preparation is essential to the success of any fumigation. If an old orchard is to be cleared, care must be taken to remove all roots. Roots may harbor root-knot or root-lesion nematodes, protecting them from the fumigant. Roots will also be a constant source of trouble during application of nematicides, as they tangle in the shanks of the fumigation equipment. The land must be cultivated far enough in advance of

fumigation to allow vegetation to decompose prior to treatment. Soil organic matter is not readily penetrated by fumigants. Organic matter may also bind fumigants, restricting their movement and reducing potential benefits. High organic matter may result in pockets of nematodes that survive treatment. The soil must be free of large clods, which the fumigant will channel around rather than penetrate.

Soil temperature and moisture at the time of fumigation are critical factors. For best results, soil temperatures at the 6- to 10-inch depth should be between 40° and 80°F. Soil moisture should be in the range of 6 to 150 centibars of water tension as measured by a device such as a tensiometer. Another rule of thumb would be that soil moisture for good seed germination will be about right for fumigation. In the Southeast, wet soil is a more common impediment to fumigation than dry soil.

The method of fumigation is also very important. The first decision will be whether to treat strips or broadcast the treatment over the whole field. Strip treatment can reduce costs by 1/2 to 2/3, but it leaves infested land in the field that cannot be treated later. Strip treatments have worked well for root-knot nematode control. Broadcast treatment has been more effective than strip treatment for ring nematode. Growers opting for strip fumigation must lay out the tree rows in advance. Center the fumigation over the future tree row. It is important to plant small grain or other cover crop in the drive rows to prevent nematode-infested soil from these untreated areas from eroding (washing) into the fumigated strips where trees will be planted.

For pre-plant fumigation of peaches, chisels should penetrate at least 12 inches below the final surface and be spaced 12 to 24 inches apart. After fumigation, the soil surface must be sealed with a roller, cultipacker, shallow harrow, or plastic to prevent too rapid escape of the fumigant. A harrow is the poorest choice.

Crop rotation and fumigation should not be considered as means to eradicate nematodes. The purpose of these treatments is to reduce nematodes to the lowest possible level and to allow



trees to establish healthy root systems. By doing this, the trees can withstand subsequent nematode buildup without suffering loss of production or shortened life. The long-term success of any treatment depends upon the care exercised in performing each operation.

### Sanitation

Clean nursery stock and equipment should be the first line of defense. All money and efforts will be wasted if nematode-infested trees are planted in treated soil. Growers should purchase trees only from reputable nurseries with good fumigation programs. The major nematode to watch for on nursery stock is root-knot nematode. Do not "heel-in" your trees in untreated land. This is a simple, but often overlooked, point. Farm equipment should be thoroughly cleaned before operating in a treated area. Soil left clinging to this equipment can reinfest an area that has been treated with a significant outlay of time and money.

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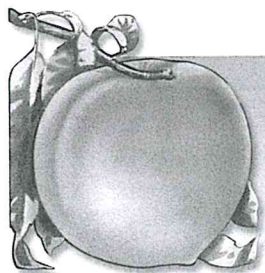
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## 7.4 PEACH TREE SHORT LIFE

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In the southeastern United States, peach tree short life (PTSL) refers to the sudden spring collapse and death of young peach trees. Generally, trees 3 to 7 years old are affected. PTSL is not caused by a single specific factor, but rather by a complex of cold damage and bacterial canker, caused by *Pseudomonas syringae* pv. *syringae*, which act together in some years and independently in other years. In any case, the final result is the same (i.e., tree death). Many other factors contribute to the PTSL complex, including time of pruning, rootstocks, orchard floor management, fertilization practices, and rapid fluctuation in late winter/early spring temperatures. The primary biotic factor responsible for predisposing peach trees to bacterial canker or cold injury or both is the ring nematode, *Mesocriconema xenoplax* (see "Nematodes" section). Cytospora canker often moves into and finally kills trees badly damaged by cold and/or bacterial canker. The role of Cytospora canker in PTSL is, however, considered secondary.

Other problems such as Armillaria root rot, stem pitting, and borers have at times been thought to be associated with PTSL, but these problems have distinct symptoms and control measures, and are discussed elsewhere in this book.

### SYMPTOMS

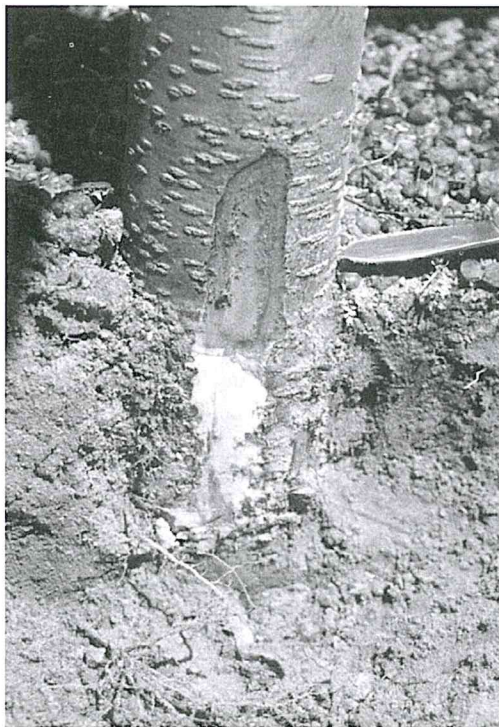
The classic symptom of PTSL is the sudden spring collapse of peach trees that were apparently healthy the previous fall. Symptoms are similar to those of any plant deprived of an adequate root system.

Cutting into the bark of these trees reveals internal browning extending to, but not below, the soil line (Figure 7.4.1). A distinct sour sap odor is often present. Water soaking of bark, or leakage, sometimes occurs in association with this internal browning (Figure 7.4.2). Individual bacterial cankers may or may not occur (Figure 7.4.3). It is usually necessary to examine trees very early in the spring (i.e., at or shortly before bud break) to determine the specific involvement of bacterial canker.

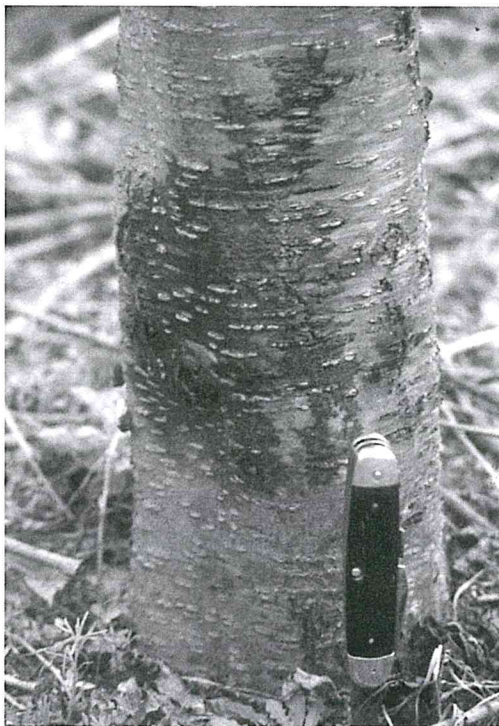
Bacterial canker of peach is generally associated with delay of bloom or leaf out of individual limbs, with such limbs usually dying by the end of summer. If the infection is severe, entire trees may collapse, with branches exhibiting alternate zones of darkened and healthy tissue having a sour sap odor. Dead trunk tissue usually does not extend beneath the soil line, thus leaving the primary root system alive. As a result, root suckers are usually produced at the base of the tree during summer (Figure 7.4.4). When cold injury is present, trees will begin to leaf out until additional water is required by the tree. At that time, leaves collapse (Figure 7.4.5) and the bark may crack and separate from the scaffold limbs and trunk (Figure 7.4.6). Trees killed or severely damaged by PTSL are frequently invaded by *Cytospora* species.

After trees have been dead for several weeks, it may not be possible to specifically separate bacterial canker from cold damage. If trees have been dead one month or more, it may not be possible to diagnose any specific cause.





**FIGURE 7.4.1.** Initially, internal browning due to peach tree short life extends only to soil line (knife blade). (color plate, page 221, Figure 7.4.1)



**FIGURE 7.4.2.** Water-soaked bark and trunk leakage often accompany internal damage to peach tree short life. (color plate, page 221, Figure 7.4.2)

## DISEASE DEVELOPMENT

Bacterial canker can cause sudden spring collapse of peach and other stone fruit trees if the trees have been weakened by factors such as ring nematode or cold damage. Even in the absence of cold damage, trees grown on Nemaguard rootstock are much more susceptible to bacterial canker than trees grown on Lovell, which in turn are more susceptible than trees grown on Guardian (BY520-9) rootstock. In the Southeast, the specific importance of bacterial canker as a factor independent of cold damage is difficult to determine. Cold damage is known to predispose trees to death from bacterial canker. Cold damage alone can also kill trees with similar symptoms. How many trees would have died without invasion of *P. syringae*, or how many would have been killed sooner or later by *P. syringae* without cold damage, cannot be determined and is of little practical importance. The important point is that PTSL is a disease complex, and the control program to be discussed later is aimed at this complex.

Observations indicate that the sudden spring-wilt syndrome of PTSL is related to vascular cambial death. In healthy trees the older wood of the xylem, the water-conducting tissue, becomes nonfunctional through time. This nonfunctionality is marked by build-up of gum in the vessel elements. Peach trees are dependent upon the yearly production of new water-carrying vessel elements. New xylem tissue is the tree's main route of water movement. New water-conducting elements are generated annually each spring from a layer of cells called the vascular cambium. The vascular cambium lies just outside the xylem, immediately beneath the spongy bark or phloem. If production of new water-carrying vessels is prevented by cold injury to the vascular cambium, the sudden increase in water consumption due to bloom and/or leaf emergence may place the tree in an overwhelming water deficit that results in collapse and death.

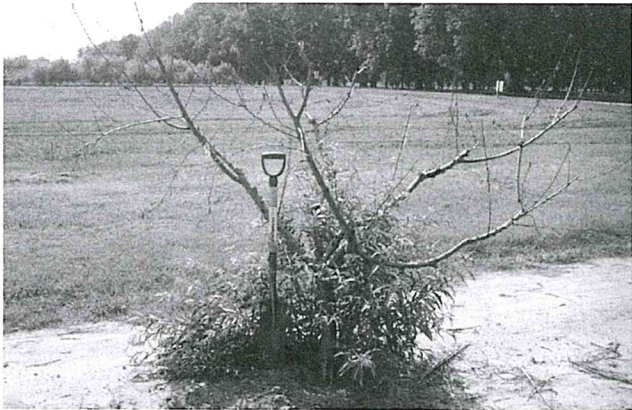
Some injured trees in a PTSL site do not collapse immediately but are weakened and decline slowly during the summer. In these trees, injury to the vascular cambium results in loss of vessel element production insufficient to cause death, but sufficient to impair the tree's water-carrying capacity. This condition results in a weakened tree that undergoes a summer-long decline. Cytospora canker often kills PTSL-weakened trees and is usually very common one or two years after an injurious winter.

The following different theories of disease development have evolved over the years.





**FIGURE 7.4.3. Bacterial canker damage associated with peach tree short life. (color plate, page 221, Figure 7.4.3)**



**FIGURE 7.4.4. Peach tree short life damage is typically confined to the above-ground portion of the tree. The surviving root system will often sucker profusely.**

### Hormone Theory

Death of the vascular cambium and the resulting failure of that tissue to produce water-carrying vessel elements in the spring appears to be due largely to cold injury. Normally, during winter the vascular cambium is dormant and highly resistant to cold damage. After the chilling requirement of the tree has been satisfied and dormancy is broken, growth and production of new vessels begin with the return of warm weather.



**FIGURE 7.4.5. Sudden collapse of developing leaves and flowers is typical of peach tree short life.**

The growing, active cambium becomes very sensitive to cold damage and can be injured by temperatures that would not have affected it earlier.

The fact that tree death from cold injury is not uniform in PTSL sites suggests that certain trees are protected from cold injury and/or bacterial canker. In many plants, the best adaptive protection mechanism from cold injury is the dormant condition. It is widely accepted that dormancy is controlled by naturally occurring growth hormones, including auxins. The auxin theory of cambial growth states that renewed cambial activity in the spring is initiated by auxin produced in the expanding portion of the crown (tips of peach branches, for example) and transported to the stem. A loss in cold hardiness accompanies the termination of dormancy. If the cambium is stimulated to become prematurely active during the time of year when cold temperatures are present, cold injury is likely. The question then becomes, what factor or factors influence dormancy?

Nematode feeding and fall pruning are factors known to be injurious to peach trees. Both nematode feeding and pruning are wounds that stress the tree. Classically, a wound stress response is seen as an increase in cambial auxin level. Fall pruning stimulates auxin levels more than winter pruning. Indeed, winter pruning does not affect auxin levels at all. Trees growing in fumigated soil showed an immediate auxin increase after fall



pruning but not after winter pruning. In non-fumigated soil, auxin levels were high initially, and subsequent early pruning did not further stimulate auxin levels in these trees. The shift toward higher auxin levels may have resulted in later entry of the vascular cambium into dormancy, earlier release from dormancy, or both. Either situation would predispose trees to cold injury.

Nematode injury alone can cause elevated auxin levels. It should be recognized that each tree and tree site varies in terms of vigor, nematode population, soil type, drainage, severity of pruning, and other factors. Such differences can affect hormone levels and release from dormancy. If the non-dormant trees are then subjected to the fluctuating cold-warm-cold temperature patterns common to the Southeast in late winter, cold injury to the vascular cambium may result. Many of the most severe occurrences of PTSL take place when the completion of the chilling requirement and release from dormancy are followed by a period of warm weather, which is subsequently followed by a bout of subfreezing temperatures. Further evidence of hormonal disruption within peach trees was shown when levels of cytokinins, another group of plant hormones, were elevated in trees grown in ring nematode-infested soil as compared with noninfested soil. The trees in the ring nematode soil eventually exhibited characteristic PTSL symptoms and died.

### **Carbohydrate-Partitioning Theory**

It has been demonstrated that Nemaguard peach rootstock (susceptible to ring nematode and PTSL) is more sensitive to ring nematode feeding than Guardian (tolerant to ring nematode and PTSL) peach rootstock. Recent work indicates that Nemaguard permits more carbohydrate reserves to be transmitted from shoot to root in response to ring nematode parasitism than does Guardian. This, in turn, depletes carbohydrate levels in the above-ground portion of trees on Nemaguard rootstocks. High carbohydrate reserves have been shown to be positively correlated with superior cold hardiness and stress resistance. Above-ground depletion of nutrients observed in trees on Nemaguard rootstock subjected to ring nematode feeding is believed to result in tree injury or death at levels of environmental and biological stresses that are innocuous to healthy trees.



**FIGURE 7.4.6. Typical peach tree short life cold injury with cracking and separation of bark from trunk and scaffold limbs. (color plate, page 221, Figure 7.4.6)**

### **ECONOMIC IMPORTANCE**

Tree loss due to PTSL varies widely from year to year in the Southeast. Losses, sometimes catastrophic, may be localized (Figure 7.4.7) or widespread; for example, nearly 200,000 peach trees were reported to have died in Georgia in the spring of 1962. It has been estimated that peach growers in South Carolina alone experience over \$6 million loss per year as a result of this disease.

### **CONTROL**

Control of PTSL in the Southeast and bacterial canker in California has been the subject of considerable research. Several practices have been shown to lessen the occurrence of this disease, and a program for control of PTSL tree losses has been developed. The various aspects of this program can be grouped into three phases of orchard





**FIGURE 7.4.7.** A mixed orchard on Nemaguard and Nemared seedling rootstocks that has been severely afflicted by peach tree short life.



**FIGURE 7.4.8.** On severe peach tree short life sites, Guardian (center) provides superior performance compared with Lovell (flanking left - dead), Boone Co. (flanking right - dead), and other tested commercial rootstocks in background.

management as follows: (A) site preparation, (B) planting stock selection, and (C) sound cultural practices.

### Site Preparation

PTSL control should begin during site preparation. Losses due to PTSL are commonly more severe on old peach land than on land newly planted to peaches. The factors that predispose virgin orchard sites to PTSL are not clear. However, root zone nutrient depletion, low pH, hardpan development, and ring nematode buildup all contribute to the occurrence of PTSL, and one or more of these factors occur in any orchard during its life. Ring

nematode buildup seems to be an extremely important factor. The time to assess the need for corrective measures is before planting. Soil sampling will determine the need for nutrients and lime. Enough lime should be added to raise the soil pH to 6.5 at a depth of 16 to 18 inches. Nutrients can be incorporated during liming.

Subsoiling to break hardpans is a second practice that improves tree survival. Sandy soils and/or dry soils will respond best to subsoiling. Wet clay soils will respond poorly, if at all.

The ring nematode, *M. xenoplax*, greatly increases severity of PTSL. Any land scheduled for planting to peaches should be tested for presence of ring nematode, and, if necessary, pre-plant fumigation should be carried out. Consult current local sources of information for updated recommendations. Pre-plant crop rotation with wheat has been shown to be comparable to methyl bromide fumigation in suppressing the ring nematode population prior to establishing a peach orchard (see "Nematode" section). Any site that cannot be sampled and prepared properly should not be planted to peaches.

### Planting Stock Selection

Good trees alone cannot assure a good orchard, but bad trees almost always assure a bad orchard. Buy trees only from nurseries with a good reputation for producing vigorous, true-to-type, disease-free trees grown in fumigated soil. The major consideration in planting stock will be rootstock selection. Trees grown on Nemaguard rootstock are much more susceptible to PTSL than trees grown on Guardian or Lovell rootstock. Nemaguard rootstock should never be used on any site where ring nematode, *M. xenoplax*, is present. Sites with a history of PTSL or old orchard sites where nematode samples were not taken should not be planted with trees on Nemaguard rootstock. Nemaguard rootstock should be used with extreme caution in Georgia in the band between U.S. Highway 280 and the fall line. Nemaguard should never be used north of the fall line. It can be used safely south of U.S. Highway 280 in Georgia in the absence of ring nematodes, where there is a commitment to proper time of pruning. Guardian rootstock has significantly better resistance to PTSL than



Lovell (Figure 7.4.8) and especially Nemaguard. Its use is recommended on sites prone to PTSL. However, Guardian is not immune to PTSL and will only perform satisfactorily in conjunction with the best management practices for suppressing the disease. Guardian has root-knot nematode resistance comparable to that of Nemaguard and can be considered as an alternative to Nemaguard in those areas of the coastal plain where this nematode is a problem. In addition, it should provide superior resistance to PTSL, which appears to be a growing problem in this area as peach land is replanted.

### Sound Cultural Practices

Time of pruning is a major cultural practice affecting the incidence of PTSL. Pruning directly affects the susceptibility of trees to cold damage. Trees pruned during October, November, December, and January are more susceptible to PTSL than trees pruned during any other time of the year. Pruning during these months should be avoided. If any pruning must be done during this period, select blocks least likely to have problems with PTSL. Choose blocks over 7 years old, blocks known to be free of *M. xenoplax*, and blocks on sites with no PTSL history. Do not prune trees on Nemaguard rootstock from October through January.

Another practice that affects the occurrence of PTSL is orchard floor management. Harrowing contributes to PTSL by damaging root systems. Use of herbicides in the tree row and sod between the rows reduces PTSL.

A sound nutrition program based on annual soil and tissue sampling will help maintain a vigorous orchard and help reduce losses from PTSL.

Weak, dying, or dead trees should be removed from the orchard. Several insects and diseases that may become a general nuisance can build up on dead or dying trees.

Obviously, PTSL has no single specific cause and control does not involve a single direct control practice. Rather, the whole package of sound, proven effective cultural practices, the details of which should make up any good orchard management program, must be considered.

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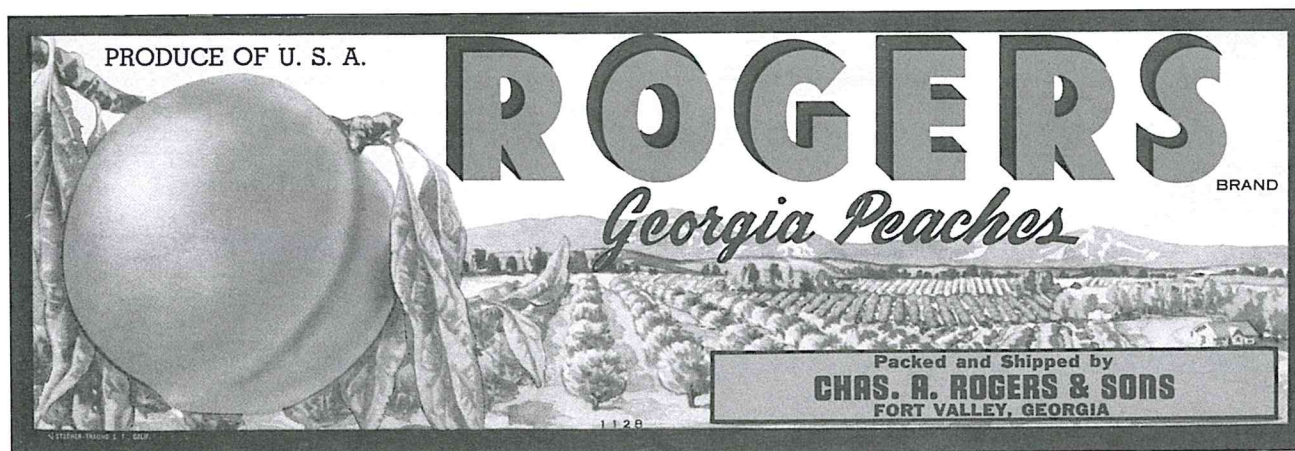
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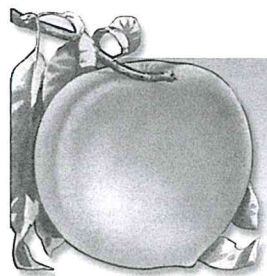
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## 7.5 VIRUSES OF PEACH

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**P***runus necrotic ringspot virus* (PNRSV) and *prune dwarf virus* (PDV) are the viruses most frequently encountered in southeastern peaches. PNRSV and PDV cause many different symptoms in peach. Both have the potential to cause considerable economic loss. Seed and scion sources for peach propagation should be screened to assure freedom from these viruses. When both PNRSV and PDV infect a tree simultaneously, they cause a distinct disease called peach stunt.

Less commonly seen in southeastern orchards are strains of *tomato ringspot virus* (ToRSV), which cause stem pitting at and above the graft union, with tree decline and death.

*Cherry green ring mottle virus* has been detected in South Carolina, but the affected orchard was subsequently removed.

*Plum pox virus* (PPV), the cause of plum pox virus disease, also known as Sharka, is the most damaging stone fruit virus worldwide; however, it is not currently present in the southeastern United States. PPV is a listed quarantine pest and all documented importations of *Prunus* germplasm into North America are subject to rigorous quarantine and testing prior to release to the importer. This quarantine process had been effective in excluding PPV from the continent for many years. However, in 1999 PPV was detected in Adams County,

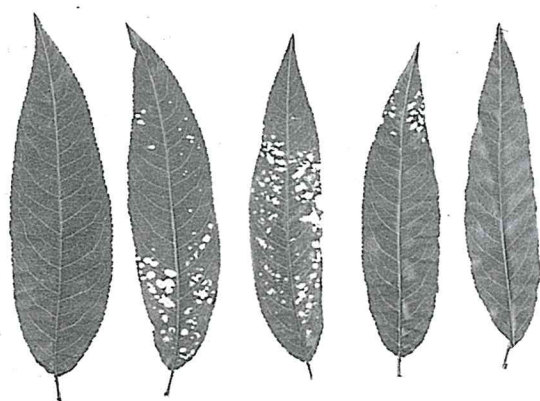
Pennsylvania, and in 2001 the virus was again detected in the peach production area of the Niagara Peninsula in Canada. No link between the two outbreaks has been demonstrated, although it is certain they are both the result of importations of propagative material (budwood) that avoided the quarantine systems. In both locations, intensive programs to eradicate the virus are underway. Because all viruses are easily transmitted by grafting and budding, screening of propagative material to preclude endemic viruses (PNRSV and PDV) should also include testing for PPV as a protection against the devastating disease caused by this virus.

### SYMPTOMS

#### **Prunus Necrotic Ringspot Virus**

PNRSV exists as numerous strains, isolates, and biotypes that vary widely in pathogenicity. Depending on the virus strain, PNRSV can produce a variety of symptoms in different stone fruit species and even within the same species. Some PNRSV strains do not produce visible symptoms and can be detected only by inoculation to woody indicator plants, serological tests, or molecular detection techniques. Other strains can induce an extensive array of symptoms both in the field and in test plants.





**FIGURE 7.5.1.** Shot holing, the classic symptom of infection with PNRSV, is temperature-dependent and not always diagnostic. These leaves were picked sequentially from a single twig, and ELISA assays indicated the presence of the virus in all leaves, not only those with shot holes. Shot holing can also be caused by excess sulfur, excess copper, or bacterial leaf spot.

PNRSV infection initially causes shock, then chronic symptoms in most woody hosts. Symptoms can be classified as chlorosis, necrosis, leaf deformity, stunting, and shot holes. Chlorotic symptoms on leaves include patterns of rings, lines, bands, spots, mottles, and mosaic. Necrosis occurs only during the initial acute stage. Buds, leaves, shoots, large branches, and roots may become necrotic. Epinasty, twisting, rugosity, and enations can be seen on infected leaves. The entire plant or portions of it may be stunted. PNRSV may cause small or large cankers on limbs and trunks. Some strains induce necrotic spots or shot holes on the young leaves during the first year of systemic infection (Figure 7.5.1), which are frequently described as the classic symptoms of infection by PNRSV. However, these symptoms are not consistently associated with the virus and can be confused with the effects of excess sulfur or copper, and with bacterial leaf spot. After the first or second year, when the chronic phase of PNRSV infection occurs, symptoms become less conspicuous and may disappear entirely. Other strains of PNRSV produce visual symptoms annually.

### **Prune Dwarf Virus**

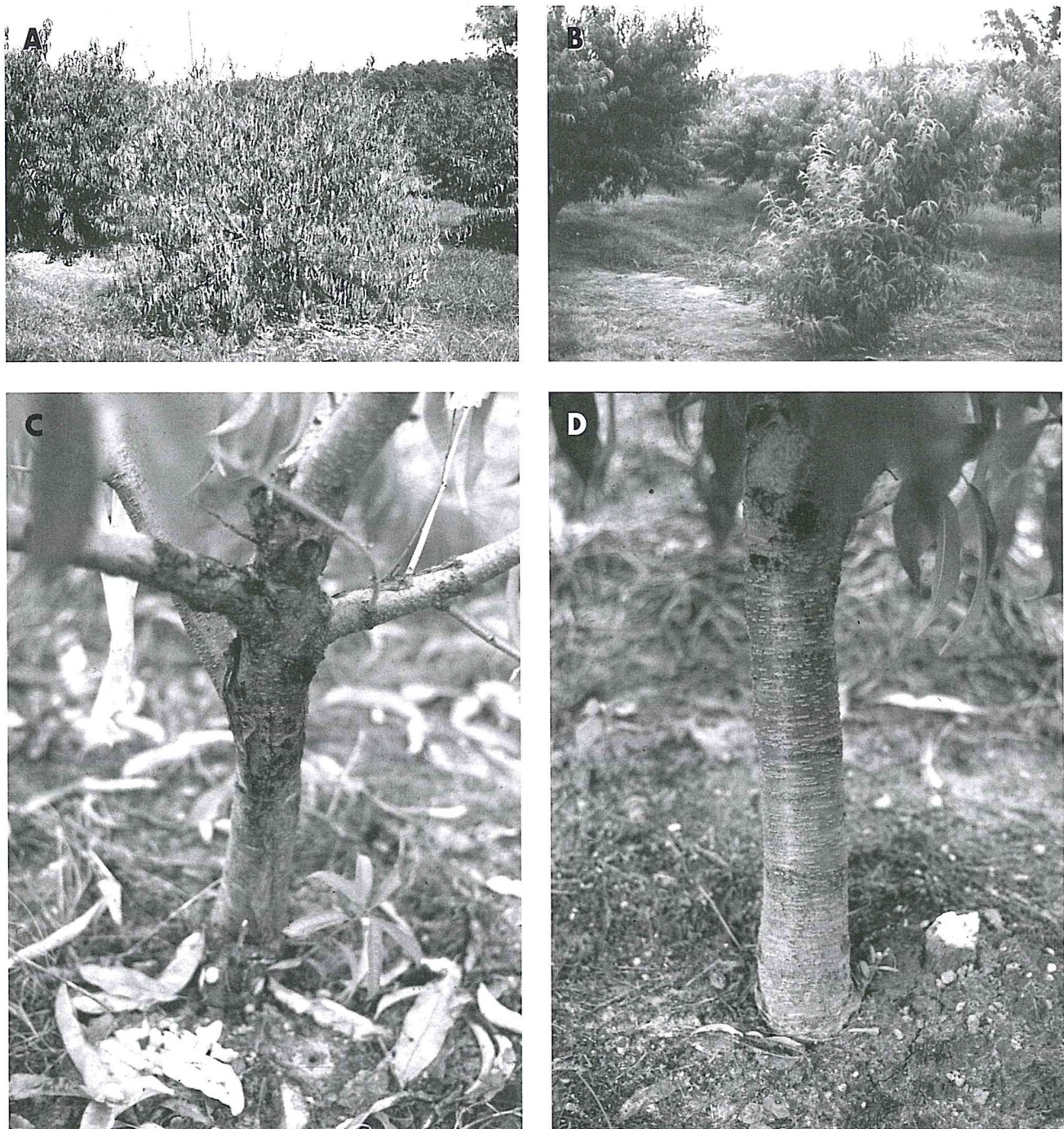
PDV also exists as many different strains that produce unique disease symptoms in different

Prunus species, although some PDV symptoms can be confused with those caused by PNRSV. Chlorosis, necrosis, leaf distortion, stunting, and gum flow may be observed during the acute phase of infection. PDV-infected peach trees exhibit mild to severe stunting of internodes, rosette formation in developing shoots, and reduction in plant growth and fruit production. Stunted plants generally do not show characteristic leaf symptoms. In the cultivar Garnet Beauty, inoculation with an isolate of PDV caused bark splitting, reduced trunk circumference, and increased watersprout production. The classic symptom from which the virus gets its name occurs in prune, where dwarfed leaves appear and the dwarfing progresses from the infection site toward the trunk of the tree.

**Peach stunt.** Trees co-infected with both PNRSV and PDV (suffering from peach stunt disease) generally display more severe symptoms than are shown with either virus alone (Figure 7.5.2). In Garnet Beauty, trees inoculated in the fall with both viruses defoliated by the end of August of the following growing season. Non-inoculated trees, and trees inoculated with PNRSV or PDV alone, showed no visible effects. Similarly, co-infected trees showed more profound reduction in trunk circumference and a doubling in production of watersprouts when compared with trees infected with either virus alone.

**Stem pitting.** Trees infected by ToRSV have a girdled appearance, fail to grow normally, and decline (Figure 7.5.3A). The leaves appear drought-stressed and leaf drop is premature. Fruit from affected trees generally ripens early, sizes poorly, and is of poor eating quality. Trees displaying such marked symptoms do not generally survive through the winter. Noticeable trunk enlargement may occur at or below the soil level. The bark in this area is two to four times thicker than comparable bark of healthy trees and may extend up the trunk in the form of an inverted V. When the thickened bark is removed, elongated pits and/or grooves may be seen in the wood (Figure 7.5.3B). The severity of the pitting varies with variety and stage of disease development. In a few severe cases, the thickening of the bark can extend well into the canopy of the tree, and scaffold limbs of affected trees are soft enough to be squeezed by



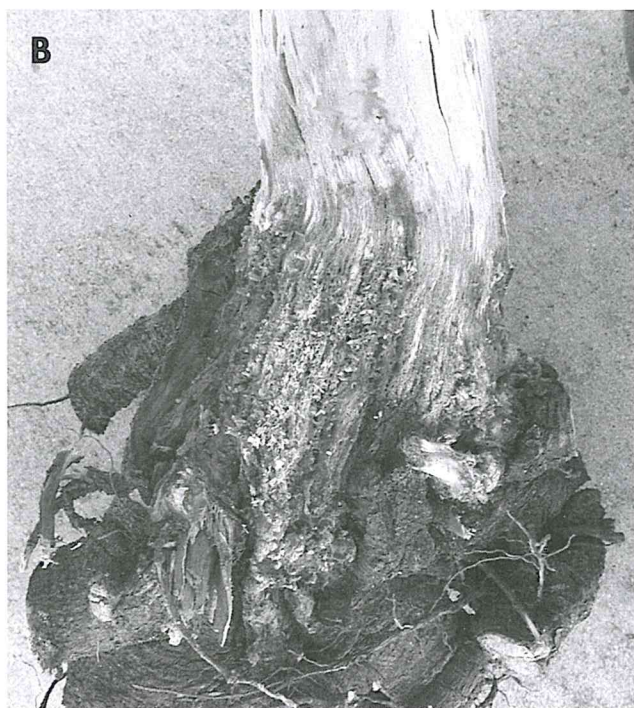


**FIGURE 7.5.2.** Peach stunt in Garnet Beauty peach. The photograph was taken in August and the tree had been inoculated with both PNRSV and PDV 10 months earlier (A). The surrounding trees are infected with PNRSV or PDV alone or are healthy. Premature defoliation was consistent through a trial with 20 replications. The tree almost died, but recovered slowly. Three years after the initial photograph, the tree survived, but produced little or no fruit (B). Other trees infected with PNRSV and PDV were less affected, but there had been an average of 55% yield loss. Bark splitting was noticeable on trees with both PNRSV and PDV (C), but absent in non-infected trees (D). (color plate, page 221, Figure 7.5.2)

hand. Affected trees frequently break off at or below the soil line due to weak wood structure caused by the pitting. This symptom should not be confused with classic graft incompatibility, where a more-or-less clean break occurs at the

bud union. Even though some peach varieties may be resistant to stem pitting, three of the commonly available rootstocks in the Southeast (Lovell, Nemaguard, and Halford) are known to be susceptible. Because there is no information





**FIGURE 7.5.3. Stem pitting.** A tree showing reduced growth, stunting, and reddening associated with stem pitting (A). Thicker than normal bark was present at the base of the trunk and when this was removed, massive pitting and grooving were revealed (B). (color plate, page 222, Figure 7.5.3)

on Guardian rootstock, it is perhaps best assumed that all of our peach trees are susceptible.

### Plum Pox Virus

Classic plum pox virus symptoms may appear on leaves or fruit, but the virus is latent in some peach cultivars. Foliar symptoms are more evident in spring when chlorotic spots, bands or rings, vein clearing, or even leaf deformation may be seen. The symptoms may be transitory and distributed unevenly throughout the tree or individual branches and

twigs. Infected fruits may show chlorotic spots or rings; symptoms are highly variable. Fruit quality and size are profoundly affected by PPV. Much of the affected fruit ripens prematurely, as much as 20 to 30 days early, and fruit are of poor flavor. Timely PPV updates and an extensive array of PPV images can be seen by referring to USDA and university fact sheets, as well as websites such as [www.apsnet.org/online/feature/PlumPox/Top.html](http://www.apsnet.org/online/feature/PlumPox/Top.html) and [www.aphis.usda.gov/ppq/plumpox/](http://www.aphis.usda.gov/ppq/plumpox/).

### OCCURRENCE AND INCIDENCE

PNRSV is found with great frequency in stone fruit orchards throughout the United States and in other regions of the world. In the 1980s, surveys of trees in 14 peach orchards in Georgia revealed that 41% of the trees were infected with PNRSV; in West Virginia, 1,264 trees were surveyed and 29.5% were found to be infected with PNRSV; in South Carolina, an extensive survey of 5,833 trees from seven cultivars in 114 peach orchards determined that incidence levels of PNRSV were 6.9% in Harvester, 10.6% in Junegold, 15.0% in Redglobe, 39.5% in Loring, 41.1% in Blake, 52.9% in Coronet, and 74.5% in Redhaven. In some Redhaven orchards, the virus was detected in all trees sampled. More recent data (2000 and 2001) indicate that PNRSV is prevalent in orchards of some of the older varieties



(Redhaven, Fay Elberta), but absent in orchards of more recently introduced varieties (Blazeprince, Summerprince).

**PDV** incidence in peach orchards is less well documented. In South Carolina in 1991, some orchards of Redglobe and Coronet were entirely infected with PDV. Ten years later, the virus was detected in only 5 out of 2,650 tested trees from 46 cultivars growing in both Georgia and South Carolina, and was not detectable in either of two orchards of Redglobe that were sampled. Again in 1991 in South Carolina, **peach stunt**, co-infections of both PNRSV and PDV, was absent in some orchards of Coronet and Redglobe, although in other orchards 80% of the trees were infected with both viruses. In 2000 and 2001, co-infections of PNRSV and PDV were detected in only 3 trees out of 2,650 tested.

**Stem pitting** can occur on peaches and other *Prunus* species wherever the trees are grown. It was observed in Spartanburg and York Counties, South Carolina, in 1968 and 1988, respectively, and in Georgia in 1978 on plums in Dooly County and in 1985 on peaches in Houston County. Although other occurrences have been reported, the disease is not common in the Southeast. The importance of stem pitting increases as one moves north through the Carolinas into Virginia and Pennsylvania, where entire orchards may be lost to the disease after five to six years.

**PPV** infections in North America presently appear confined to specific areas of Pennsylvania and Canada. Nationwide surveys of stone fruit production have not identified additional PPV-infected orchards. PPV is widely distributed in Europe, where the incidence of infestation varies with country. PPV is found in many other stone fruit production areas worldwide, including the Middle East, parts of Asia, and Chile.

## TRANSMISSION AND SPREAD

All viruses of peach are easily transmitted by grafting and budding. Natural viral spread occurs in orchards, with viruses frequently spreading to adjacent trees rather than over long distances.

Viral transmission along root grafts is also well documented.

**PNRSV** and **PDV** are transmitted through seed. In non-certified seed lots, infection rates of 16% (PNRSV) and 10% (PDV) have been documented. The number of infected seedlings that develop from infected seeds is usually considerably less. Both viruses are also transmitted through pollen. There is considerable circumstantial evidence that pollen from infected trees is blown onto plant surfaces where it is fed upon by flower thrips (*Frankliniella* spp.) that inoculate the virus into the plant in a mechanical manner. However, no finite demonstration of pollen-transmitted virus has been reported for peach. Experimental evidence and spatial patterns of natural spread of PNRSV among *Prunus* trees following the blooming period indicated that the virus infects healthy trees during the pollination process.

**ToRSV** is transmitted by the dagger nematode, *Xiphinema americanum*, which is responsible for natural spread of the virus. The nematode feeds on roots of infected plants, acquires the virus, and in subsequent feeding transfers the virus to healthy plants.

**PPV** is spread most efficiently by budding and grafting of infected plant material, with all movements of the virus over extended distances being traced to movement of infected budwood or nursery stock. Spread within and between adjacent orchards and trees is by aphids in a non-persistent manner. The distribution of infected trees in newly infected orchards is scattered as a result of infection from migratory aphids. Aphids that colonize peach are not thought to be of importance in the movement of the virus. Both infestations of PPV in North America have been shown to be caused by the D (Dideron) strain of the virus, which is inefficiently transmitted by aphids. However, epidemiological studies within the quarantine areas suggest that aphid transmission has occurred. Seed transmission has been reported for the M (Markus) strain of PPV, but is not considered to be important for the D strain. Evidence that aphids can acquire and transmit the virus from ripe fruit has been shown.



## ECONOMIC LOSSES

The effects of infection with **PNRSV** and/or **PDV** on peach are heavily dependent on the combination of the host cultivar and strain of virus involved. The deleterious effects of viral infection on tree performance and longevity are experienced even when no visible symptom of viral infection is present (i.e., the viral infection is latent).

**PNRSV** has been reported to cause reductions in tree growth of between 12% to 70%. Although bloom date may vary, fruit set may be substantially reduced, and ripening date may be altered considerably. Yield losses of 5% to 70% have been reported, with the fruit having lower soluble sugar content. Infection with **PNRSV** has also been reported to result in reduced response to fertilizer, increased susceptibility to cold, and reduced root development that leads to drought stress and tree loss in dry years.

The effects attributable to infection with **PDV** are by and large the same. **Peach stunt**, co-infection of **PNRSV** and **PDV**, has been shown to cause an average of 55% loss in fruit yield in Garnet Beauty, while at the same time increasing the number of watersprouts by 900%. In the same report, infection with **PNRSV** alone produced an average yield loss of 5% and a 410% increase in the number of watersprouts.

**ToRSV** kills trees within four to five years and, if a significant proportion of the trees within an orchard are infected, the economic lifespan of the orchard is severely reduced. In addition, the presence of **ToRSV** precludes replanting on the same site, which may be a problem if orchard sites are in short supply.

**PPV**-infected trees, and the orchards in which they are growing, are destroyed according to federal quarantine regulations to limit spread of the virus.

## CONTROL

There is no cure for a virus-infected tree. Control of viral diseases is through planting virus-tested material, removal of infected individuals, and control of the avenues by which natural spread occurs in the field.

The most critical control measure is planting orchards using virus-tested stock. Growers should purchase trees from certified programs. Ask exactly what the program certifies before committing to a purchase. Programs should propagate virus-tested budwood on virus-tested rootstocks. Virus-tested means that the material has been tested for the presence of specific viruses. It is more accurate than the previously used term virus-free, which implied that the material contained no viruses but, in fact, meant that it was only free of those viruses for which tests had been completed. In the southeastern United States, testing should focus on **PNRSV**, **PDV**, and **PPV**.

Attempts to eliminate thrips from an orchard to prevent pollen-borne transmission of **PNRSV** and **PDV** are not feasible. Thus, it has to be accepted that there may be a slow increase in the incidence of these two viruses during the life span of the orchard. Even though trees affected with these viruses may show no symptoms whatsoever, the losses that they cause are more than sufficient to offset any premium paid by the grower for certified trees.

**ToRSV** is not a major concern in much of the Southeast. However, in areas where stem pitting is observed regularly, control of the disease involves factors in addition to the use of virus-tested stock. Routine pre-plant fumigation is recommended. Peach orchards should not be planted on sites of apple orchards that have experienced union decline and necrosis, which is also caused by **ToRSV**. Some weed species (dandelion, common chickweed, and sorrel) are alternate hosts for **ToRSV** and, to the degree possible, they should be eliminated from orchards. Isolated cases of stem pitting in the orchard can be treated by immediate removal of both the diseased tree and adjacent trees. However, it would be prudent to sample soil from



the affected area and have it tested for the presence of *X. americanum*. If the nematode is present, a decision as to whether to replant must be made. The presence of *X. americanum* in soil samples does not necessarily mean stem pitting strains of ToRSV are infesting the site.

Depending on the remaining life span of the orchard, it may make economic sense not to replant young trees, as any replant is likely to succumb to the same condition in four to five years or earlier. If forced to plant on old orchard sites, it would be wise to assume the dagger

nematodes present are carrying the stem pitting virus. In this case, the land should be fumigated prior to planting and/or rotated through a series of grass or small grain crops for two to four years.

Control of PPV is dependent on testing of seed and scion sources to prevent spread via infected nursery stock. If PPV is detected, destruction of infected orchards and adjacent trees, as is mandated by federal quarantine regulations, is the only available means of limiting spread and/or eradicating the virus.

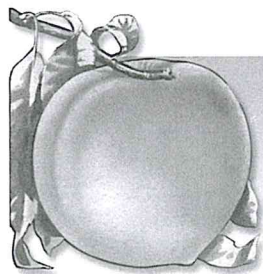
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## 7.6 DISEASES CAUSED BY PHYTOPLASMAS

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**P**hytoplasmas (previously referred to as mycoplasma-like-organisms, MLO) are cellular parasites recognized as causing diseases in many crops. Although phytoplasmas are graft transmissible and cause symptoms similar to those typically associated with infection by a virus, they are actually bacteria-like microorganisms; similar to bacteria, remission of the disease symptoms they cause can be achieved experimentally by injecting the antibiotic tetracycline.

### PEACH DISEASES CAUSED BY PHYTOPLASMAS

Peach rosette, peach yellows, little peach, and red suture are reported in peach orchards of the Southeast. However, except for peach rosette, they occur infrequently. Peach yellows disease was first observed in 1791 in Pennsylvania, rosette in 1891 in Georgia, while little peach and red suture were first seen in 1896 and 1911, respectively, in Michigan. Other diseases of peach associated with infection by phytoplasmas occur in other areas of the United States and the world. Peach yellow leaf roll, caused by the western-X phytoplasma, occurs in California. X-disease occurs in the northern United States and Canada. Although peach rosette, peach yellows, little peach, and red suture are distinct diseases, they are all caused by phytoplasmas that are very closely related to the western-X phytoplasma. In Europe, the stone fruit yellows phytoplasma (a species distinct from western-X) causes disease(s) in *Prunus*.

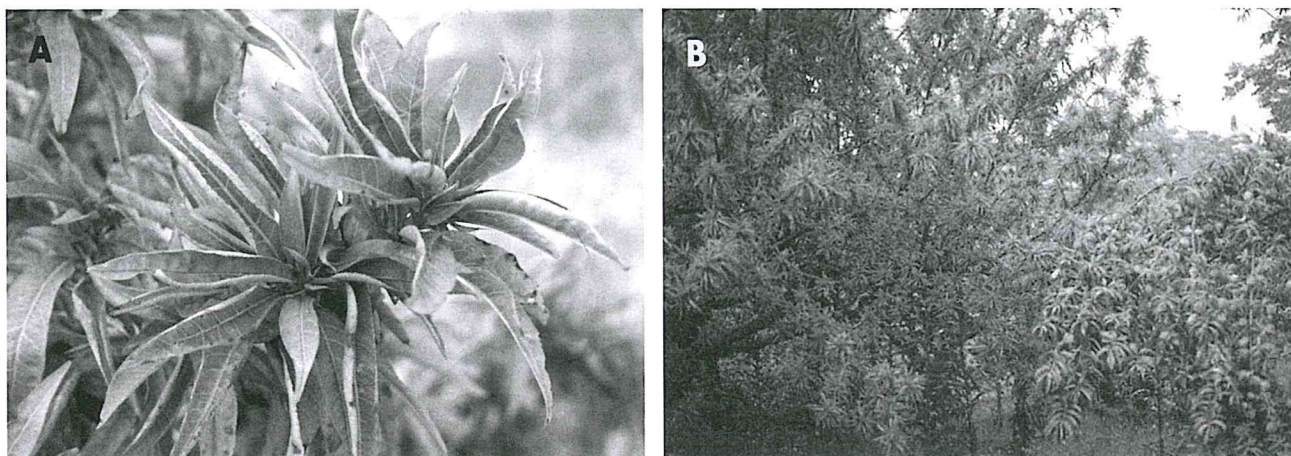
### CHARACTERISTICS OF DISEASES CAUSED BY PHYTOPLASMAS

Phytoplasmas typically cause abnormalities in growth (rosetting, willowy growth, yellowing) that may be confused with symptoms of infection by a virus, and tests to confirm the presence of a phytoplasma are therefore necessary. Unlike typical bacteria, phytoplasmas cannot be cultured on artificial media in the laboratory. However, they can be detected under the light microscope using phytoplasma-specific stains such as DAPI and Dienes' stain, and they display a characteristic morphology when thin sections of phloem cells are examined in the electron microscope.

Enzyme-linked immunosorbent assay (ELISA) and molecular techniques, including DNA probes and polymerase chain reaction (PCR), are also used to detect phytoplasmas. Symptom remission following experimental treatment with antibiotics is strong evidence that phytoplasmas are involved in the disease syndrome. However, several weeks of treatment may be necessary before remission of symptoms is observed.

The transmission of phytoplasmas from plant to plant is usually dependent upon insect vectors. Other means of in-orchard transmission, such as root grafting and parasitic weeds, are of minor importance. Unfortunately, propagation from a symptomless, but infected, tree will ensure almost 100% transmission of phytoplasmas to progeny trees. As with plant viruses, it is prudent to visually check blocks used for cutting budwood for symptoms. If orchards with suspicious trees are





**FIGURE 7.6.1. Peach rosette. (A) Compact growth with many leaves typical of rosette. (color plate, page 222, Figure 7.6.1A) (B) Trees infected with rosette are often yellower than non-infected trees. The tree on the left is displaying rosette and has no fruit, while the tree on the right shows no sign of rosette and is carrying a normal fruit load.**

used, individual trees used for budwood should be checked for phytoplasmas when they are checked for viruses. No transmission through seed is known. The insect vectors are leafhoppers, psyllids, and planthoppers. Vectors acquire phytoplasmas by feeding on an infected plant. After a latent period (days to weeks), during which the phytoplasma multiplies in the insect, it becomes able to transmit the microorganism to other plants during feeding. Nymphal stages of the vector acquire the phytoplasma more readily than adults, and the microorganism is retained through all subsequent developmental stages. Phytoplasmas are not transmitted through the insect's eggs.

### PEACH ROSETTE

Peach rosette (Figure 7.6.1A) is characterized by a lack of shoot elongation with dormant buds producing a compacted growth habit somewhat reminiscent of the basal rosettes seen in some herbaceous biennials and perennials. Shortened internodes result in a large number of leaves over a very short distance. Leaves are small in size and initially dark or normal green, then later turn yellow (Figure 7.6.1B). Normally, dormant buds break and produce rosettes. Fruit usually falls before maturity. The disease can kill a tree in a few months. When only one or two scaffold limbs are affected, two years may elapse before tree death. Specific vector species of peach rosette are unknown. Natural spread does occur.

### PEACH YELLOWS

Peach yellows (Figure 7.6.2A, B) is first recognized by off-color, yellowing trees. Leaves near tips of young branches show vein clearing. The newest expanding leaves are sickle-shaped instead of being in their normal upright position. Frequently only one or two branches are affected. After the disease becomes well established, many thin, upright shoots are apparent along affected branches. Typically, fruit on affected trees or branches ripens prematurely. The disease is lethal in two to five years. Natural spread does occur in the Southeast.





**FIGURE 7.6.2. Peach yellows.** (A) A tree showing both small yellowy growth of yellows and normal growth. (B) The branch on the left shows yellow growth as compared with the one on the right. (color plate, page 222, Figure 7.6.2B) Image by Eric Boa, CABI Bioscience.

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### LITTLE PEACH

Little peach symptoms (Figure 7.6.3) may resemble some aspects of the symptoms of yellows and rosette and, like rosette and yellows, only one or two branches of whole trees may be affected. Apical dominance is lost and all buds on an infected limb develop thin, willowy shoots with small leaves. The shoots are longer than on rosette-affected trees but shorter than on yellows-affected trees. Shoots are upright in growth habits as with yellows-affected trees. No fruit is produced on limbs displaying little peach symptoms. Fruit maturity is delayed and fruit is smaller than normal. Death occurs several years after symptoms appear. The vector(s) of little peach is unknown.

### FIELD SYMPTOMOLOGY

The yellowing, differences in leaf size, and extent of rosetting in little peach, peach rosette, and peach yellows vary from infection to infection. A disease reported as peach yellows by one observer might be described as little peach by another observer and peach rosette by a third observer. As little is known of the epidemiology of these diseases, it is better to indicate that the tree is infected with a phytoplasma and recommend the appropriate treatment rather than attempting to definitively identify the causal agent.





**FIGURE 7.6.3. Little peach.** (A) A seedling tree with the prolific, willowy growth typical of little peach. The leaves are usually much smaller than normal. (B) The contrast between growth in infected trees and normal trees is most noticeable in dormant trees.

## RED SUTURE

Red suture (Figure 7.6.4) may appear as a dark red suture on fruit that ripens prematurely, with the flesh in the suture soft and watery. In other instances, a prominent red suture that softens is observed on an otherwise green fruit. The tree, except for fruit, is symptomless at this point. After several years, an infected tree or branch may have symptoms similar to little peach-affected trees. An infected tree may survive for a number of years, but the fruit is inedible. The vector(s) of red suture is unknown.

## OCCURRENCE AND SPREAD OF PHYTOPLASMAS

Phytoplasma-associated diseases typically infect only a few trees within an orchard. Historically, infections of peach yellows reached epidemic proportions in the late nineteenth and early twentieth centuries. More recently (late 1970s), an unprecedented epidemic of peach yellow leaf roll occurred in northern California. No specific insect species has been identified as transmitting peach rosette, little peach, or red suture. One known vector of peach yellows is the plum leafhopper (*Macropsis trimaculata* (Fitch)). There are numerous leafhopper vectors of western-X, some of which are known to be present in the Southeast, including the sharp-nosed leafhopper (*Scaphytopius acutus* (Say)), the speckled leafhopper (*Paraphlepsius irroratus* (Say)), and Flor's leafhopper (*Fieberiella florii* (Stål)).

However, it should be pointed out that considerable differences in the specificity of transmission of phytoplasmas by different vector species are known, and extrapolation from one disease/vector combination to another may not be valid. Peach trees are "dead end" hosts for the phytoplasmas; their presence leads to rapid tree death, and, as the trees are dormant during the winter, they are not a host for the vectors year-round. Thus, the vectors and the phytoplasmas must overwinter in alternate hosts (possibly weed species or other native woody species). New infections occur when leafhoppers leave the alternate winter hosts, move out into the orchard, and feed on the trees. The



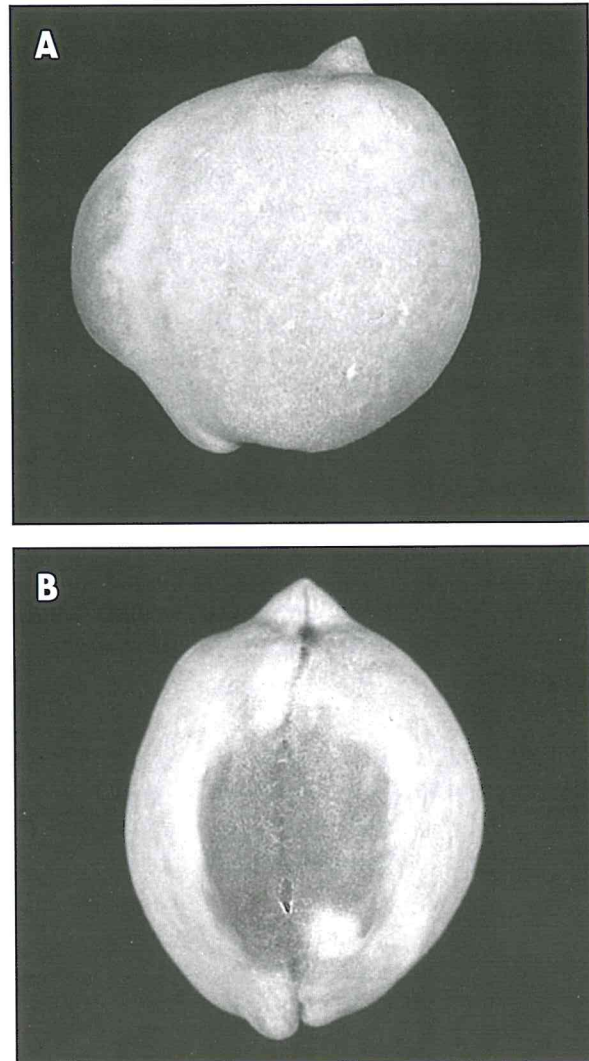
phytoplasma associated with peach rosette has been detected in wild plums (*Prunus angustifolia*) growing adjacent to peach trees displaying rosette symptoms. Infected individuals of this species survive from year to year and may act as an alternate host and reservoir for peach rosette. However, the correlation between the occurrence of infected wild plum and the incidence of new infections in adjacent peach orchards is not absolute, suggesting that other alternate hosts exist.

### GENERAL PRINCIPLES OF CONTROL

There are several control tactics for phytoplasma-associated diseases:

- (1) Eradicate known diseased trees as soon as they occur. Removal of trees eliminates sources of infection within the orchard.
- (2) Select propagating material from sources known to be free of disease or indexed free of disease.
- (3) In cases where the insect vector is known and the time of its occurrence established, insecticide programs may be of value when directed at the vector before it becomes established in the orchard. Typically, insecticide sprays in orchards are of limited value since migrating vectors may transmit the phytoplasma before the insecticide kills them.
- (4) The eradication of known alternate hosts has been effective when the alternate hosts are limited in species and number.

Antibiotics, applied by tree injection, have potential for control of phytoplasma diseases. However, antibiotic treatment is expensive and labor-intensive. The best tactic is to maintain an effective eradication program.



**FIGURE 7.6.4. Red suture.** Two views of an immature fruit showing the prominent suture and premature reddening around the suture typical of the disease. In some instances, the red area may soften well before the remainder of the fruit is ripe. (color plate, page 222, Figure 7.6.4)

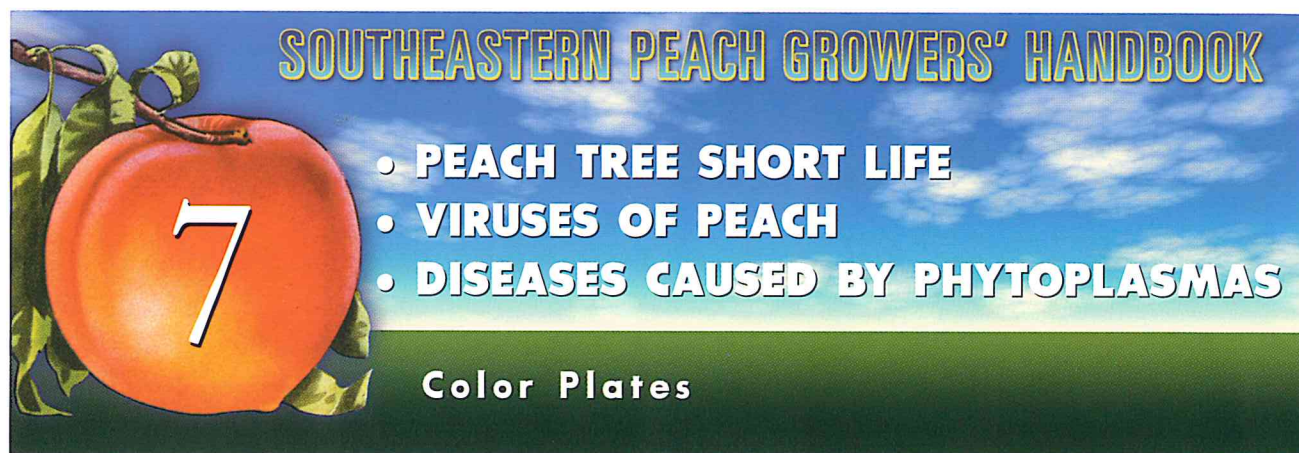


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**FIGURE 7.4.1.** Initially, internal browning due to peach tree short life extends only to soil line (knife blade).



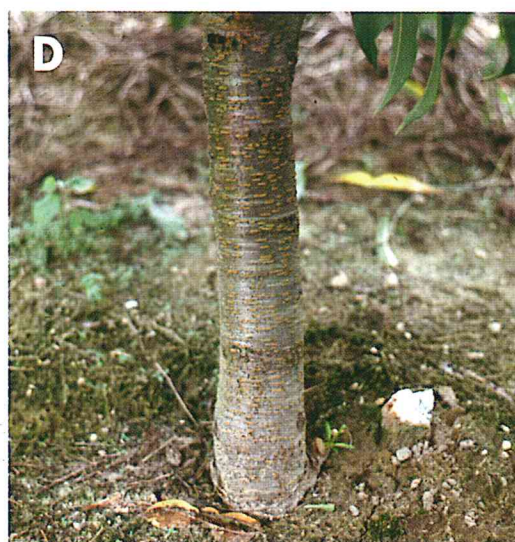
**FIGURE 7.4.2.** Water-soaked bark and trunk leakage often accompany internal damage to peach tree short life.



**FIGURE 7.4.3.** Bacterial canker damage associated with peach tree short life.



**FIGURE 7.4.6.** Typical peach tree short life cold injury with cracking and separation of bark from trunk and scaffold limbs.



**FIGURE 7.5.2.** Peach stunt (PNRSV plus PDV) infected trees suffered noticeable bark splitting (C). Healthy tree, uninfected by peach stunt (D).





**FIGURE 7.5.3. Stem pitting.** A tree showing reduced growth, stunting, and reddening associated with stem pitting (A). Thicker than normal bark was present at the base of the trunk and when this was removed, massive pitting and grooving were revealed (B).



**FIGURE 7.6.1A. Peach rosette.** Compact growth with many leaves typical of rosette.

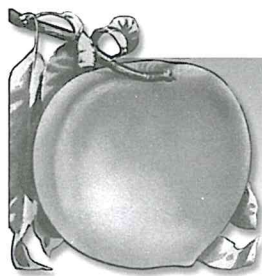


**FIGURE 7.6.2B. Peach yellows.** The branch on the left shows yellow growth as compared with the one on the right. Image by Eric Boa, CABI Bioscience.



**FIGURE 7.6.4. Red suture.** Two views of an immature fruit showing the prominent suture and premature reddening around the suture typical of the disease. In some instances, the red area may soften well before the remainder of the fruit is ripe.





## 7.7 INSECTS AND MITES

### 7.7.1 Aphids

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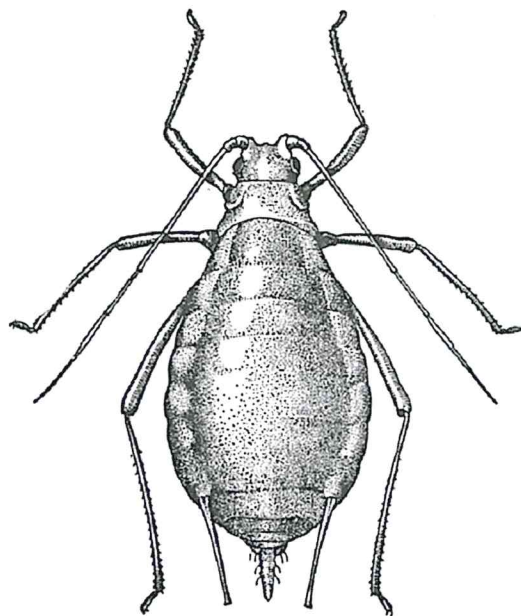
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Aphids are incidental pests that seldom do meaningful damage to peaches in most of the Southeast. Aphids injure peach primarily by feeding on succulent vegetative growth. Black peach aphids can stunt or even kill young trees. In most of the region, years lapse between outbreaks of this severity.

Aphids are important vectors of plant viruses in many other crops. Only one important peach virus present in North America is aphid vectored. Plum pox virus, a devastating pathogen that limits stone fruit production in many areas of the world, had until recently been excluded from North America. Plum pox virus-infected orchards were discovered in Adams County, Pennsylvania, in 1999 and on Ontario's Niagara Peninsula in 2001. Infected budwood is the most important means of plum pox virus transmittal. Aphids, the virus' natural vectors, are responsible for local movement of the pathogen within or to adjacent orchards. Migratory aphid species, such as green peach aphid, are felt to pose a greater vector potential than aphids that colonize peach. The presence of plum pox virus in North America has greatly heightened interest in the aphid fauna of peach. Peach aphid complexes in North America, particularly the Southeast, are poorly understood and studied. The black peach aphid, the green peach aphid, and the rusty plum aphid are among the more common aphids in southeastern peaches.

#### DESCRIPTIONS

Generically, aphids (Figure 7.7.1.1) are small, tear-drop shaped, soft-bodied insects with long antennae. They seldom exceed 1/10 inch (2.5 mm) in length. Most have a pair of tubules or cornicles resembling tail pipes near the rear of the abdomen. Aphids typically live in colonies and reproduce very rapidly. Nymphs, immature aphids, resemble adults but are smaller and lack wings. Winged and wingless adults occur.

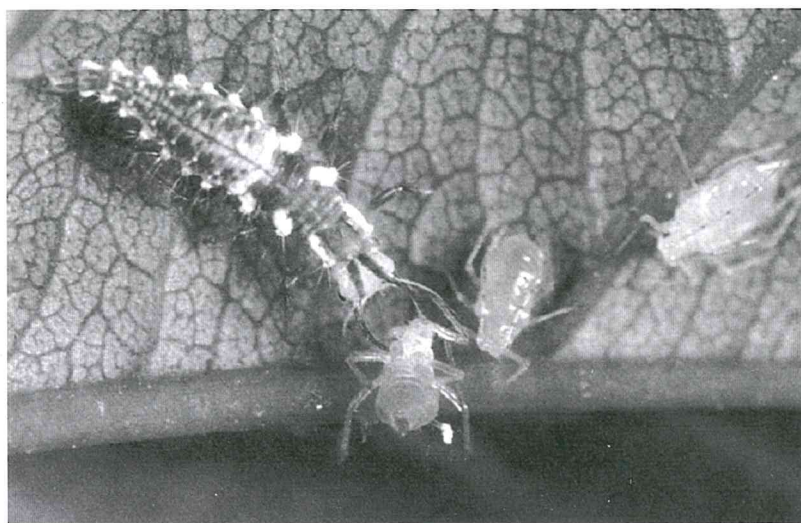


**FIGURE 7.7.1.1. Aphid.**



Black peach aphid adults, *Brachycaudus persicae* (Passerini), are shiny black and about 1/12 inch (2 mm) long. Nymphs are reddish-brown in color. In the Southeast, black peach aphid is seldom damaging, but it has considerable pest potential. Black peach aphid forms colonies on the foliage. However, much of its pest potential is attributable to year-round, root-infesting colonies. It can stunt or, in worst-case scenarios, kill young trees. Black peach aphid occurs throughout the eastern United States. Its severity as a peach pest increases from south to north, being more often cited as damaging to peach in Middle Atlantic production areas. Peach and plum are among its preferred hosts.

Green peach aphid, *Myzus persicae* (Sulzer) (Figure 7.7.1.2), is found worldwide on a great variety of host plants. Green peach aphids are small, about 1/12 inch (1.8-2.3 mm) long, light to dark green or pink in color, with red eyes. Wingless forms are usually yellowish-green during the summer, but may be pinkish-red in the early spring and fall. Winged forms are generally brown with a yellowish abdomen bearing an irregular dark blotch. Green peach aphid is frequently migratory, moving from host to host. In the Southeast, green peach aphid is insignificant as a direct pest of peach. However, it is an abundant, cosmopolitan, migratory aphid with documented potential as a plum pox vector in other areas of the world. In most cropping systems, insecticidal control of migratory aphids to mitigate spread of plant viruses has been ineffective. In some



**FIGURE 7.7.1.2. Green peach aphids with lacewing larvae predator.**  
(color plate, page 273, Figure 7.7.1.2)

instances, the irritation of sub-lethal insecticide exposure seems to make migratory aphids more active, which can increase their vector potential.

Rusty plum aphid, *Hysteroneura setariae* (Thomas), occurs throughout eastern North America. It is often abundant in the Southeast, but it is seldom damaging to peach. It feeds on peach, plum, cherry, and various small grains. Rusty plum aphids are rusty brown in color with white markings at the base of the antennae, on the legs, and on the abdomen. It is about 1/15 inch (1.7 mm) long.

## PLANT INJURY

Aphids suck plant juices from leaves, blossoms, and twigs. Heavy infestations can cause leaf curl and stunted terminal growth. When aphids are abundant, leaves frequently become coated with a sticky excretory product called honeydew. Honeydew often supports the growth of a black sooty mold, which can coat leaves and reduce photosynthesis.

Aphids are generally most important in early spring, when they feed on developing buds, opening blooms, and young fruit. Heavy infestations can slow tree growth and reduce fruit set. Typically, less damage occurs as the season progresses. The black peach aphid also attacks the roots of peach trees. Root-infesting forms are present throughout the year. Black peach aphid is most damaging to nursery stock and newly set trees. Older trees apparently suffer little injury from root feeding.

## SEASONAL HISTORY AND HABITS

In the Southeast and other warm areas, green peach aphid seldom produces sexual forms; the aphids overwinter as nymphs and adults on a variety of host plants. Continuous reproduction by unmated females may occur. There are numerous generations per year.



In cooler areas of the United States, green peach aphids overwinter as eggs on peach in the axils or on twigs. The eggs hatch in early spring, and emerging nymphs begin feeding at once on opening buds, unfolding blossoms, and tender twigs. Nymphs develop into wingless female adults that give birth to living young without mating. The young are likewise all females that reproduce without mating. Succeeding generations are produced in the same manner. After two or three generations, winged females are produced that migrate to summer food plants, including many vegetables and ornamental plants. At the onset of cold weather, winged migrants move back to peach, and sexual forms, males and females, are produced. These mate, and overwintering eggs are laid.

The life history of the rusty plum aphid is similar to that of the green peach aphid.

The black peach aphid's wingless form lives throughout the year on peach roots. Feeding may continue through the winter. In late winter and early spring, individuals migrate to new growth above-ground. They start new colonies on twigs

or shoots, and increase rapidly. Like other aphids, their reproduction is parthenogenic, with unmated females giving birth to living young. After several generations, winged forms are produced, probably in response to overcrowding. Winged adults migrate to other trees or plants. Above-ground, black peach aphids usually disappear by mid-summer. There are numerous generations of black peach aphids per year.

## CONTROL

In the Southeast, aphids of peach are commonly controlled by insecticide applications aimed at other insects. They are seldom of economic importance in commercial orchards. However, aphids are easily detected and a watch should be maintained. If aphid infestations develop, they should be controlled before they become abundant enough to cause leaf curl or honeydew buildup. Above-ground forms of the black peach aphid should be controlled when first detected. They are much easier to control than root-infesting forms. This is especially important on first-year peach trees.

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## 7.7.2 Thrips

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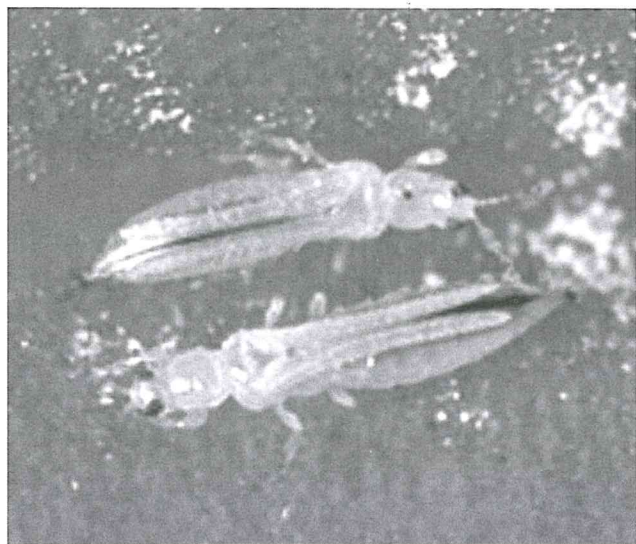
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Thrips, *Frankliniella* spp. and others, make use of a broad range of host plants, including nectarine, peach, and plum. Adult thrips are slender, yellow to black insects, less than 1/12 inch (2 mm) long (Figure 7.7.2.1). Adults have four feathery wings and are usually very active. Nymphs are smaller and wingless. Both nymphs and adults feed by rasping or scraping plant tissue with their mouthparts and sucking up plant juices.

Injury to stone fruit, particularly nectarine or plum, occurs when flower thrips feed and lay their eggs in the buds, blossoms, and small fruit in the early spring, causing shallow brown scarring or russetting of fruit surfaces (Figure 7.7.2.2). Peaches are rarely injured by thrips. Russetting is commonly seen on nectarines in the Southeast. On peaches russetting occasionally develops following warm, dry winters that seem to favor high numbers of western flower thrips. Thrips can also cause silvering, a normally superficial injury to nearly mature fruit. Silvering is much more readily seen



**FIGURE 7.7.2.1. Western flower thrips.** (color plate, page 273, Figure 7.7.2.1)

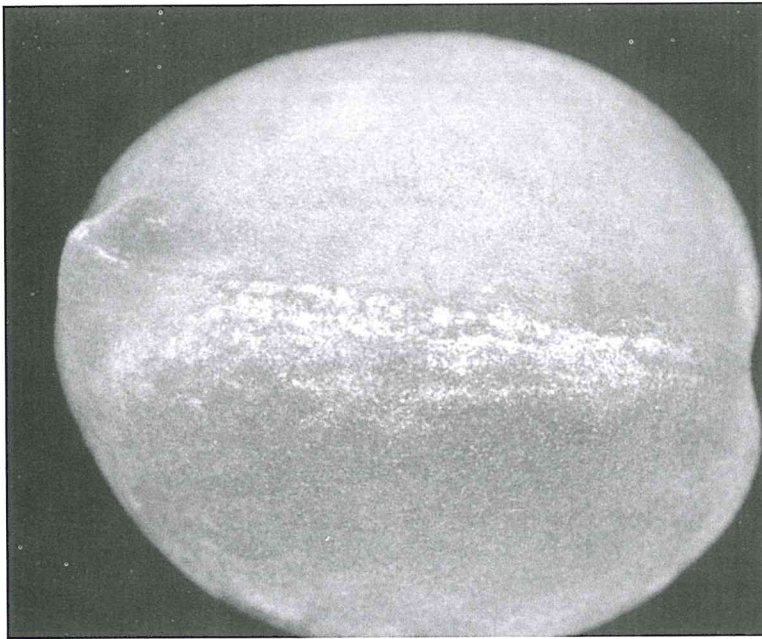


**FIGURE 7.7.2.2. Russetting from early-season thrips injury, primarily during bloom.** Image by J. A. Payne. (color plate, page 273, Figure 7.7.2.2)

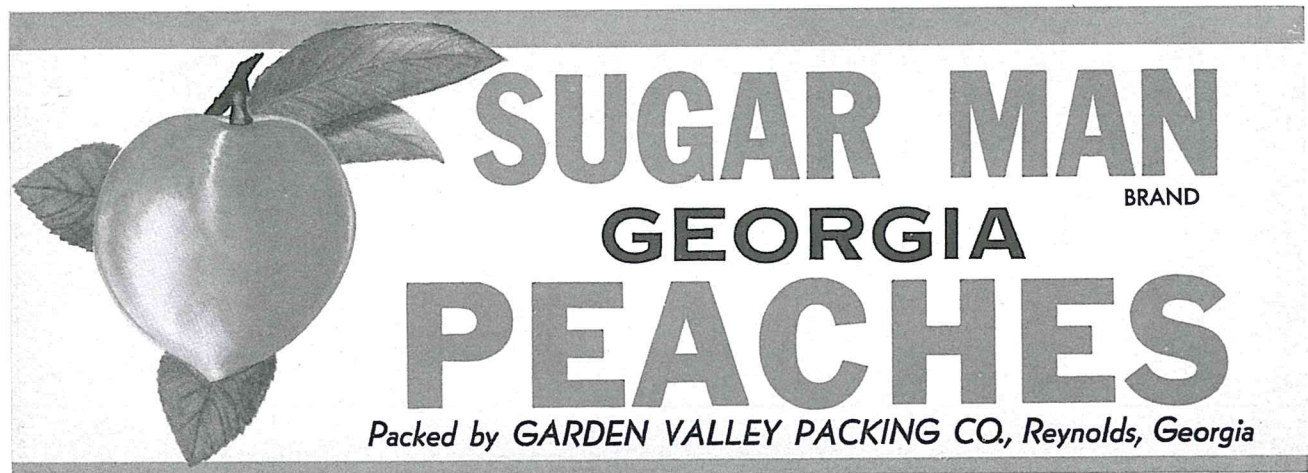
on highly colored cultivars. Silvering is a light, to colorless, stippling on the fruit surface (Figure 7.7.2.3). Silvering is typically an inconsequential injury that is seldom recognized as insect related. Thrips also feed on peach foliage, but damage is insignificant.

Thrips deposit their eggs in plant tissue. Young thrips hatch in two or more weeks. They pass through five developmental stages including egg, two active larval stages, an inactive pre-pupal stage, and adult. Developmental time depends upon species and weather. Most species have multiple generations per year. Thrips may invade peaches from nearby crops or the orchard floor cover as these hosts dry down and become unacceptable. Nectarines and some plums are much more susceptible to thrips injury, especially during bloom. Spraying at pink bud and again at petal fall typically controls flower thrips.





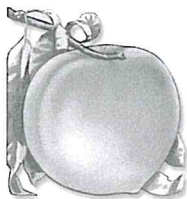
**FIGURE 7.7.2.3. Silvering caused by thrips feeding on maturing fruit.**  
Image by J. A. Payne. (color plate, page 273, Figure 7.7.2.3)



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## 7.7.3 Cankerworms

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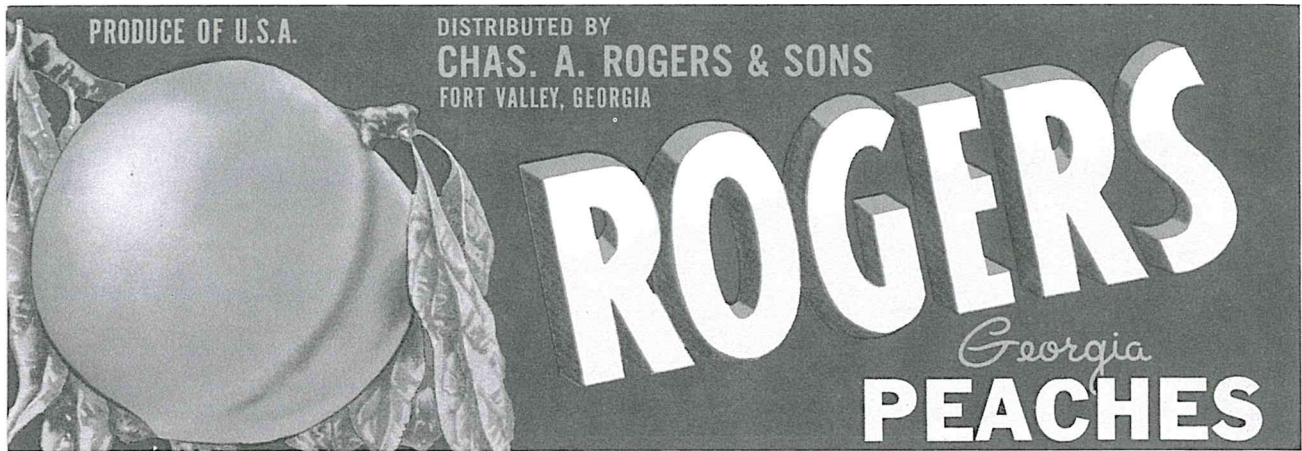
Cankerworms (fall cankerworm, *Alsophila pometaria* (Harris); spring cankerworm, *Paleacrita vernata* (Peck)) are foliage feeders of many forest, shade, and fruit trees. The larvae are called measuring worms, inchworms, or loopers because they arch their bodies when crawling. In poorly sprayed orchards, cankerworms occasionally cause significant defoliation. Serious damage can occur, even in commercial orchards, if high populations of larvae are present in early spring before insecticide sprays are applied.

The spring cankerworm is the most common species in the Southeast. It overwinters as a pupa in the soil. Moths begin to emerge in February. Wingless female moths generally crawl up the tree trunk, mate, and lay masses of eggs under

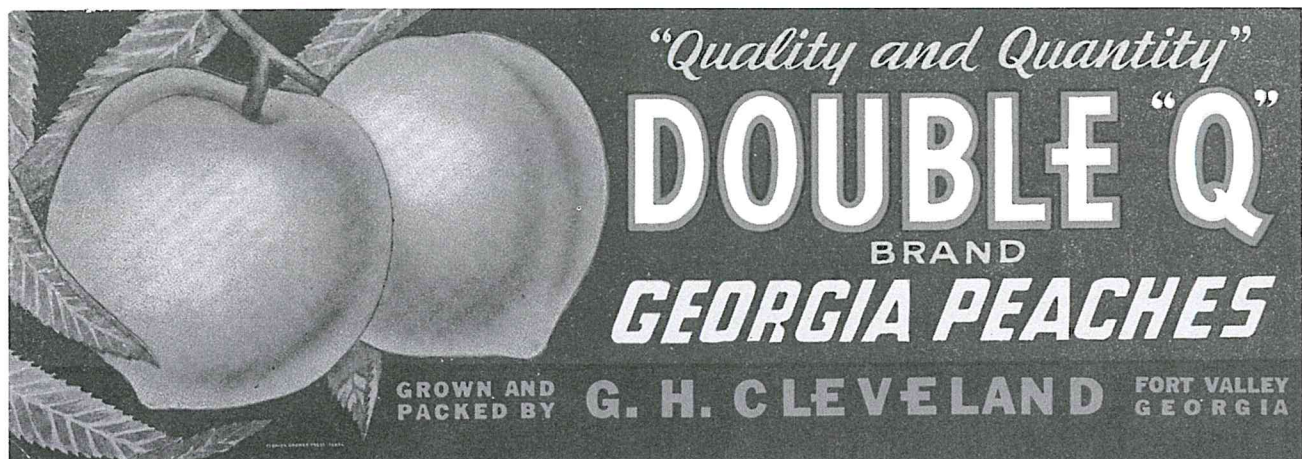
loose bark or in other protected places. Larvae hatching from the eggs immediately move to and feed on unfolding buds or foliage. Substantial injury to flower buds and blooms can occur if high numbers of cankerworms are present and uncontrolled. They feed for three to four weeks, crawl to the ground, and change to the pupal stage, where they remain until the following year. There is only one generation per year. On the rare occasions when damaging levels of spring cankerworm are likely, an insecticide spray in the pink bud stage may be needed. In small plantings, egg laying can be reduced by placing sticky bands around tree trunks in late January to capture emerging wingless female moths. The bands should be left in place until May.



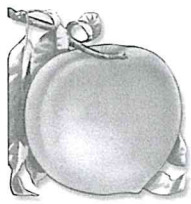




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## 7.7.4 Scale Insects

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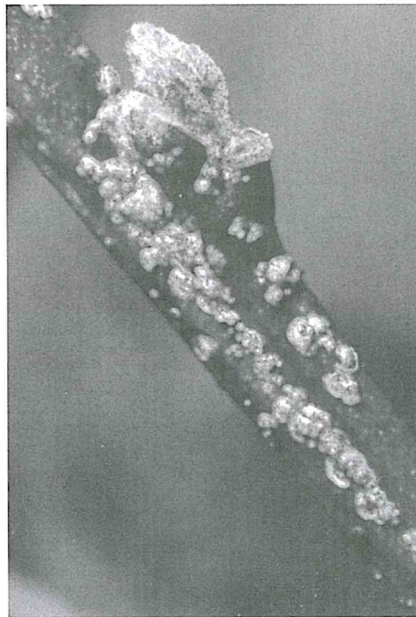
**S**cale insects infest an enormous variety of plant hosts worldwide and are important pests of peaches and virtually all orchard trees.

Scientists typically recognize 18 families of scale and several thousand species. Most common scale pests are from three families: the armored scales (Diaspididae) (Figures 7.7.4.1 and 2), the soft scales (Coccidae) (Figure 7.7.4.3), and the mealybugs (Pseudococcidae) (Figure 7.7.4.4). San Jose and white peach scale, the key scale pests of southeastern peaches, are armored scales.

Armored scales are generally flat in appearance and are usually cryptic or well camouflaged. Armored scales tend to be small (2-3 mm long). Except for the adult males and crawlers, armored scale live inside a protective covering made of waxes and previously molted skins. This covering helps protect scale from natural enemies, pesticides, and desiccation. The soft scales are generally convex in shape and are larger (5-10 mm) than armored scales. Soft scales secrete a layer of wax that covers their bodies. As with the armored scale, this wax layer protects them from natural enemies, pesticides, and desiccation. Mealybugs are recognized by the mealy wax and waxy projections emerging from their bodies. Unlike the armored and soft scales, which are generally mobile only in the crawler stage, mealybugs are mobile in all life stages. Scale damage plants by direct feeding injury or indirect means such as production of honeydew by soft scale and

mealybugs. Scale feed by inserting their piercing/sucking mouthparts and withdrawing nutrients. In peaches, feeding damage can cause leaf chlorosis and twig or limb die-back, even death of trees if scale populations reach high levels. Feeding injury to peach fruit, primarily from San Jose scale, produces small, red, measles-like lesions on the skin. Indirect plant damage, such as honeydew production and buildup of sooty mold from soft scales and mealybugs, is rare in southeastern peaches.

Scales have unusual life cycles; females have incomplete metamorphosis (egg-immatures-adult), whereas the males have complete metamorphosis (egg-immatures-pupal state-adult). Not all scales have both male and female sexes. Some species are made up entirely of females. Most scales overwinter as adults or immatures that have almost



**FIGURE 7.7.4.1. Armored scale insect (San Jose peach scale). (color plate, page 274, Figure 7.7.4.1)**



**FIGURE 7.7.4.2. Armored scale insect without protective covering. (color plate, page 274, Figure 7.7.4.2)**

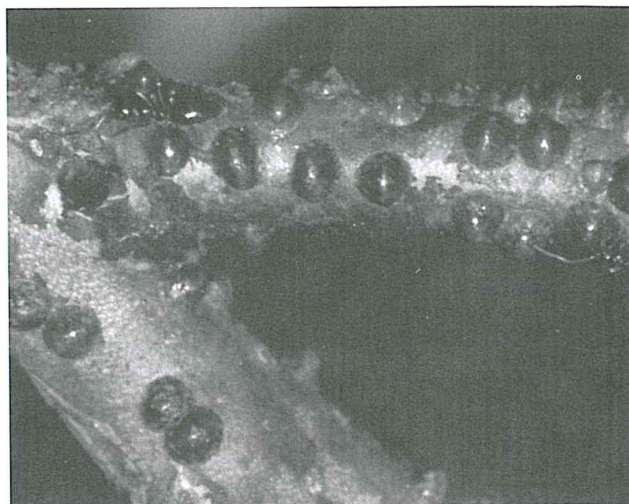


reached adulthood. In early spring, adults mature and begin laying eggs that generally hatch in two to four weeks. Mobile immature scale are known as crawlers (Figure 7.7.4.5). Crawlers are highly vulnerable to pesticides and oils because they have yet to produce any protective outer covering. Crawlers quickly find a suitable settling site on the host. After settling, crawlers start feeding and producing protective waxes. Within two weeks of settling, crawlers molt to the second instar (equipped with a protective covering). Second instars molt after about two more weeks. In similar fashion, third instars emerge as adults in roughly two weeks. In the Southeast, armored scales may have as many as seven generations. Most soft scales have only one or two generations per year.

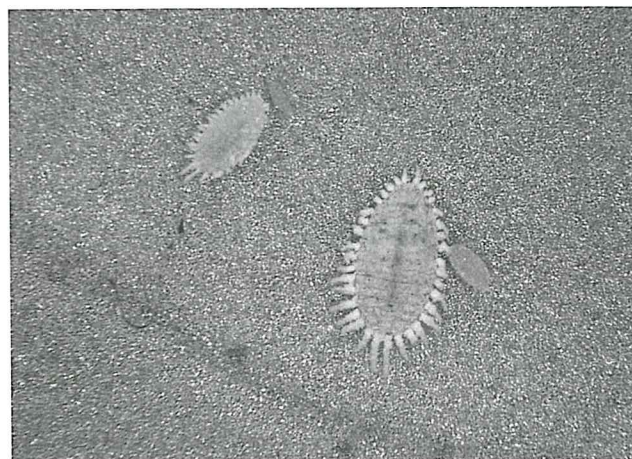
In Georgia and South Carolina, two armored scales are key pests of peaches: San Jose scale (*Quadraspidiotus perniciosus*) and the white peach scale (*Pseudaulacaspis pentagona*). Other scales that occasionally infest peaches in the Southeast include: terrapin scale (*Mesolecanium nigrofasciatum*) (soft scale); European fruit lecanium (*Parthenolecanium corni*) (soft scale); cottony hydrangea scale (*Pulvinaria hydrangeae*) (soft scale); walnut scale (*Quadraspidiotus juglansregiae*) (armored scale); latania scale (*Hemiberlesia lataniae*) (armored scale); Forbes scale (*Quadraspidiotus forbesi*) (armored scale); mining scale (*Howardia bicalvis*) (armored scale); camphor scale (*Pseudaonidia duplex*) (armored scale); cottony cushion scale (*Icerya purchasi*) (margarodid scale); Comstock mealybug (*Pseudococcus comstocki*); and taxus mealybug (*Dysmicoccus wistariae*).

### ● SAN JOSE SCALE

San Jose scale, *Q. perniciosus* (Comstock), is a damaging pest that must be managed aggressively to avoid serious losses in productivity and orchard longevity. San Jose scale was introduced into the United States in the San Jose valley of California in 1870. It is a pest of peaches, nectarines, plums, and other deciduous tree fruits including apple and pear. The origin of this scale is China, perhaps on peach. San Jose scale now inhabits most of the United States. The scale is capable of tremendous damage. In 1922, San Jose scale killed 1,000 acres



**FIGURE 7.7.4.3. Soft scale insect (terrappin scale).** (color plate, page 274, Figure 7.7.4.3)



**FIGURE 7.7.4.4. Various instars of Comstock mealybugs.** Image by Juang-Horng Chong. (color plate, page 274, Figure 7.7.4.4)



**FIGURE 7.7.4.5. Recently settled white peach scale crawlers; females (translucent cream), males (pink).** (color plate, page 274, Figure 7.7.4.5)



of mature apple trees in southern Illinois. San Jose scale can be found on a number of alternate hosts including persimmon and roses. The Forbes scale (*Q. forbesi* (Johnson)) is similar to San Jose scale in appearance, habits, and distribution.

## DESCRIPTION

Adult females of the San Jose scale are yellow, circular, sac-like, legless insects. They secrete and live beneath a protective covering. The covering is round, gray-brown, and made up of concentric rings surrounding a raised nipple near the center (Figure 7.7.4.6). The circular female covering is about 1/16 inch (1.5 mm) in diameter. Adult males are tiny, golden-brown, two-winged insects, about 1/25 inch (1 mm) long with a narrow, dark band across the abdomen (Figure 7.7.4.7). They mature under elongate oval scale coverings, about 1/24 inch (1-2 mm) long with the raised nipple near one end. Nymphs or crawlers have six legs, are yellow, somewhat oval, about 1/100 inch (0.3 mm) long, and resemble tiny larval mites.

## SEASONAL HISTORY AND HABITS

San Jose scale overwinter primarily in immature life stages that are nearing adulthood beneath

their protective coverings. The scale remains inactive until sap flow begins in the spring. Development resumes as temperatures reach 51°F. In warmer Southeast winters, mature females also overwinter. In fact, all San Jose scale stages may be present throughout the year, except during the coldest winter weather. Some overwintering nymphs develop into males and some into females. Females remain stationary beneath their scale covering throughout their lives. In central Georgia, males emerge from beneath their scale covering in April. Males are tiny, winged insects that search out female scales and mate. Four to five weeks after mating (sometime in May), females give birth to living young (crawlers). Females produce crawlers, about 10 per day for two to three weeks, depending upon temperature. Crawlers emerge from under the female scale and move to new sites of infestation on bark, leaves, or fruit. The crawlers can walk considerable distances (2-4 m) or be blown by the wind. It is possible for scale crawlers to be wind blown into orchards from adjacent hedgerows, wooded borders, or orchards. Within one day after emerging, crawlers settle, insert their mouthparts into a host, and begin to feed. Within two to three days of settling, crawlers begin to secrete their protective coating. The coating is enlarged (waxes and molted skins) as the insect grows. There are four or more generations of San Jose scale per year in much of

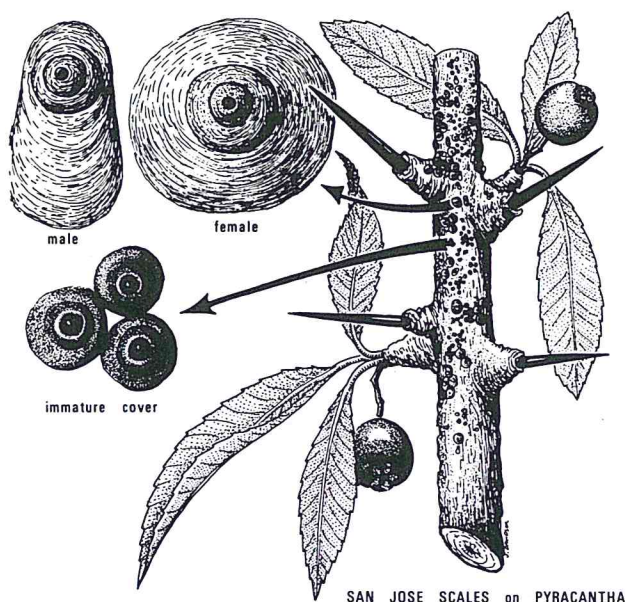


FIGURE 7.7.4.6. San Jose scale adult and immatures.

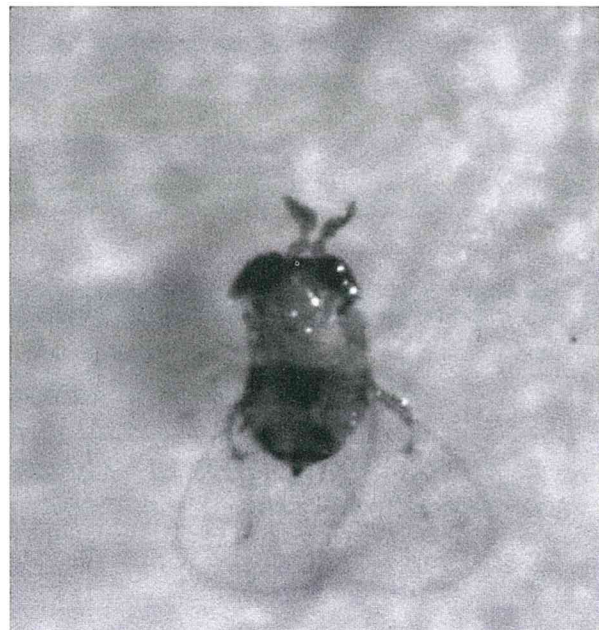


FIGURE 7.7.4.7. San Jose scale adult male.



Georgia, with only two generations in Arkansas. San Jose scale has a very high reproductive potential. Serious infestations can develop between harvest and the onset of winter. This is especially true when abundant late-summer rainfall promotes succulent growth favorable for scale development.

## CONTROL

Trees and fruit should be inspected frequently for the presence of scale insects. Scales blend in well with peach bark and are generally hard to see. Controls are suggested when scale lesions were present on fruit the previous year or when scales are found on wood during pruning. Most southeastern peach orchards should receive one dormant oil application every year, primarily for scale control. A second oil application, dormant or delayed-dormant, is advised if orchard history suggests a need. Mark heavily infested trees so you can readily monitor scale development. Pruning out infested branches or suckers can modestly reduce scale abundance. Careful tree training also opens the canopy, which facilitates better spray coverage.

The most common and effective scale control options are two oil applications made during dormancy to kill overwintering scales. Complete coverage with dilute sprays is critical because the oil must coat the scales to kill them. Further in-season scale control is achieved by insecticide sprays targeting the first crawler generation in May. In mid-March, place a San Jose scale pheromone trap in the upper half of each of three scale-infested trees. Monitor traps for male (Figure 7.7.4.7) capture twice weekly. Once you notice captured males, begin accumulating degree-days (developmental base of 51°F). Crawler emergence occurs 400 to 700 degree-days after initiation of male emergence (early May). Wrap scale-infested branches with double-sided sticky tape (or black electrical tape coated with petroleum jelly) and check tape for scale crawlers twice per week. Spray insecticide promptly when the yellow crawlers appear on the tape and continue sprays every 10 days until no crawlers are captured (usually two sprays are adequate). These sprays should be applied with sufficient volume to wet the wood. In some cases where heavy

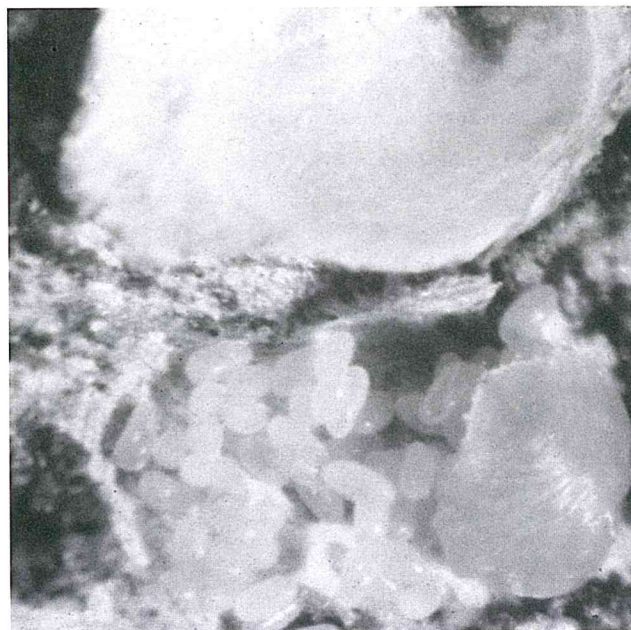
infestations exist, post-harvest applications may be required and repeated for several years.

## ● WHITE PEACH SCALE

White peach scale, *Pseudaulcaspis pentagona* (Targioni-Tozzetti), is a key pest of southeastern peach. White peach scale is a native of the Orient, but is now found worldwide. The white peach scale was reportedly introduced into the United States in the late 1800s by a nurseryman at Thomasville, Georgia. White peach scale attacks several hundred plant species, but is very common on peach, privet, chinaberry, mulberry, and persimmon. It is a serious pest of peach. In the early 1900s, thousands of peach trees were lost to white peach scale in Florida and South Georgia.

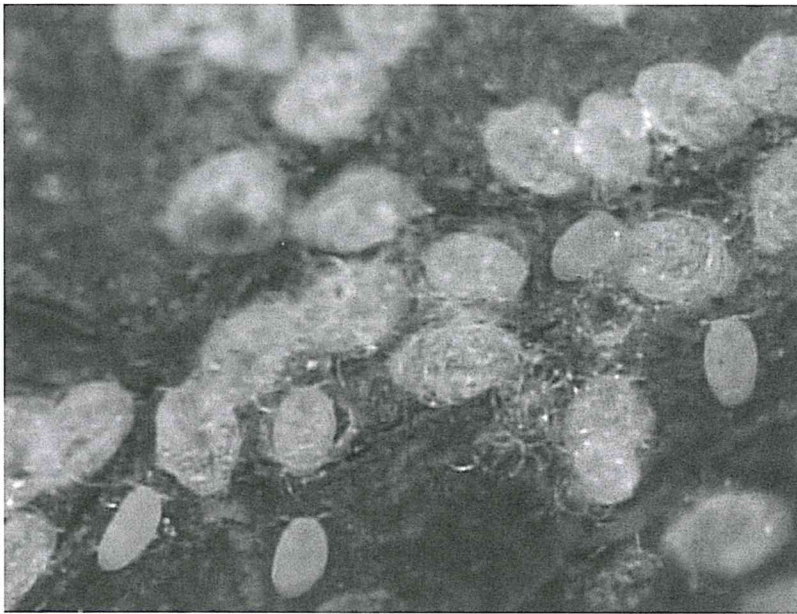
## DESCRIPTION

Adult females of the white peach scale are creamy-white to reddish-orange, oval to circular, sac-like insects, about 1/30 to 1/25 inch (0.8 to 1.0 mm) in diameter. Females live beneath a waxy scale covering (Figure 7.7.4.8) which is oval to circular, grayish to brownish-white, convex, and about 1/12 to 1/10 inch (2.0 to 2.5 mm) in diam-



**FIGURE 7.7.4.8. Female white peach scale cover with eggs. (color plate, page 274, Figure 7.7.4.8)**





**FIGURE 7.7.4.9. White peach scale crawlers (males pink, females translucent). (color plate, page 275, Figure 7.7.4.9)**

eter. White peach scale females produce yellowish eggs beneath the scale covering.

Adult males are tiny, yellowish, two-winged insects about  $11/36$  inch (0.7 mm) long, with a wing-spread of about  $3/50$  inch (1.5 mm). They are rarely seen. Male white peach scale coverings are elongate, snowy white, about  $3/50$  inch (1.5 mm) long, and commonly found in clusters, typically on the lower branches.

Nymphs or crawlers are tiny, oval, whitish to orangish insects with six legs (Figure 7.7.4.9).

### SEASONAL HISTORY AND HABITS

White peach scale overwinter primarily as fertilized females beneath scale coverings. Overwintering females begin laying eggs in February and March. They first lay orange-colored eggs that will become females, then pinkish eggs, which will become males. Eggs are laid underneath the scale covering. Each female lays 100 to 150 eggs, usually over an 8 to 15 day period. Eggs hatch within two to five days.

Upon hatching, crawlers immediately leave the protection of the parent scale and move to new sites to settle. Crawlers frequently do not move far from their parent, some even anchor under

the parent scale. Male white peach scale crawlers locate in clusters on older, lower portions of the tree. Female crawlers are generally more active than male crawlers and may disperse throughout the tree, although they are seldom seen on terminal, green wood, or fruit. Crawlers soon anchor at a new site, insert their slender mouthparts and begin to feed. About seven to nine days after hatching from the eggs, anchored crawlers molt and begin forming their own scale covering. The scale covering is cemented firmly to the bark and is relatively impermeable.

A third molt gives rise to the adults.

Adult females remain under their scale throughout their life. Winged adult males emerge from beneath their scales, seek out females, and mate. Males do not feed and die shortly after mating. Mated females soon begin to lay eggs. Females usually die following oviposition. A complete white peach scale generation, from egg to egg, takes 50 days at 75°F. Developmental time is temperature dependent and varies considerably in the field.

### CONTROL

Several parasites and predators attack white peach scale, but in commercially managed peaches, natural enemies seldom provide acceptable control. Insecticide applications specifically for scale control are usually required. Armored scales are difficult to kill with insecticides. The mainstay of control is application of two dormant oil treatments ideally at two-week intervals. These treatments provide a reasonable degree of control. Well-timed insecticide applications aimed at the unprotected crawlers provide good control. Both methods should be used where white peach scale infestations are chronic or heavy.

Crawlers are unarmored and susceptible to insecticides for only seven to nine days, so identifying the periods of egg hatch and crawler activity is critical to the proper timing of crawler sprays.



These periods vary with season and location. To pinpoint crawler activity, identify infested trees and check scale development twice a week. To monitor crawler emergence of either white peach scale or San Jose scale, find a limb heavily infested with scale. Be sure you have a vigorous infestation with mostly live scale. Check by carefully picking the scale covers off of adults with a pocketknife. Use a hand lens to examine the scale you uncover. Live scale are moist, creamy white to reddish-orange in color, whereas dead scale are shriveled and either black or gray. Once you locate a vigorous infestation, wrap the limb with double-sided sticky tape or black electrical tape coated with petroleum jelly. When crawler emergence begins, the tiny crawlers will be caught crossing the tape. Monitor tapes twice weekly. With a hand lens, crawlers are easily seen against the tape. Spray as soon as feasible after you find scale crawlers. If emergence continues, spray again a week later. Thorough coverage is essential. Dilute airblast application with at least 150 gals/acre will work, but handgun application does a better job, especially against white peach scale. Approximate peaks of white peach scale crawler generations are based on observation and the references cited.

*Middle Georgia* (Yonce and Jacklin 1974): April 21, July 1, August 5, October 5

*South Georgia* (Kuitert 1967, Van Duyn and Murphy 1971): March 21, May 5, July 15, September 21

Two or more crawler generations may develop each year after harvest. Make special efforts to detect and control these late season crawlers. Crawlers of the third generation are known to be very important in the spread of white peach scale. In middle Georgia, the August borer spray normally provides an important component of overall white peach scale control. In south Georgia, borers should be treated immediately after harvest. A special scale treatment applied between mid-September and late October is very valuable for scale and helps with borer control. Always monitor for crawlers and time sprays accordingly. If post-harvest crawler generations are not controlled, a heavy scale infestation may be carried

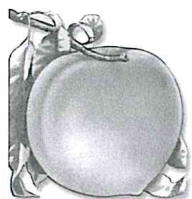
into the winter, making control even more difficult the following year.

Spray coverage is also critical for good control. To be effective, both dormant oils and crawler sprays must be applied with sufficient volume and pressure to thoroughly cover the woody portions of the tree.

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## 7.7.5 Plant Bugs and Stink Bugs

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Plant bugs and stink bugs feed on peaches, other stone fruit, and a wide array of wild and cultivated plants, including numerous horticultural and agronomic crops. These hemipterous (sucking) bugs are significant pests throughout the United States. Some hemipterous insects known to attack peach include: *Lygus* spp., primarily the tarnished plant bug, *L. lineolaris* (Palisot de Beauvois); the leaffooted bug, *Leptoglossus phyllopus* (Linnaeus); *Euschistus* spp., primarily the brown stink bug, *E. servus* (Say); the green stink bug, *Acrosternum hilare* (Say); the southern green stink bug, *Nezara viridula* (Linnaeus); and *Thyanta* spp. stink bugs.

### DESCRIPTION

Sucking bug pests of peach vary greatly in color, size, and shape. Sucking bugs are hemipterans; all have certain characters in common. The front half of the forewing is leathery, the back half membranous. Mouthparts are of the piercing-sucking type; the beak is three or four segmented, arises on the front of the head, and is held below the body, between the legs, when not in use. Antennae are usually long, and four or five segmented. Compound eyes are normally large. Nymphs (immature stage) are generally similar to adults, but do not have wings.

Tarnished plant bugs (Figure 7.7.5.1) are small, oval, fragile-looking insects that are green to dark-brown in color, flecked with white, yellow, reddish-brown and black markings and a yellow

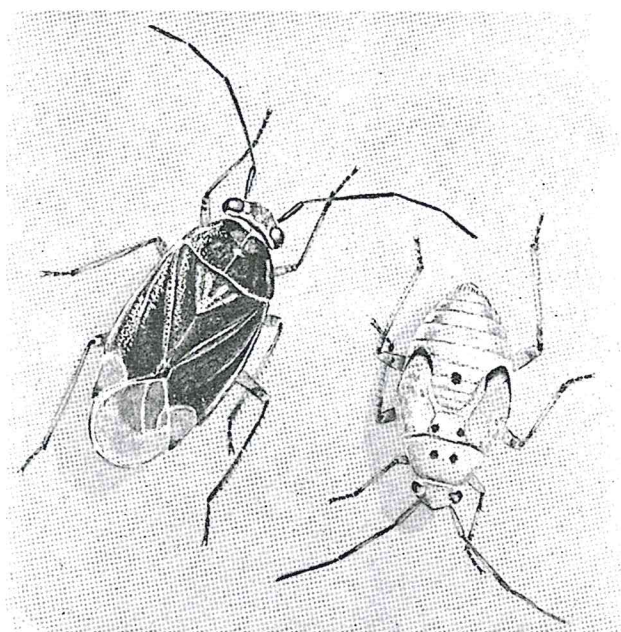


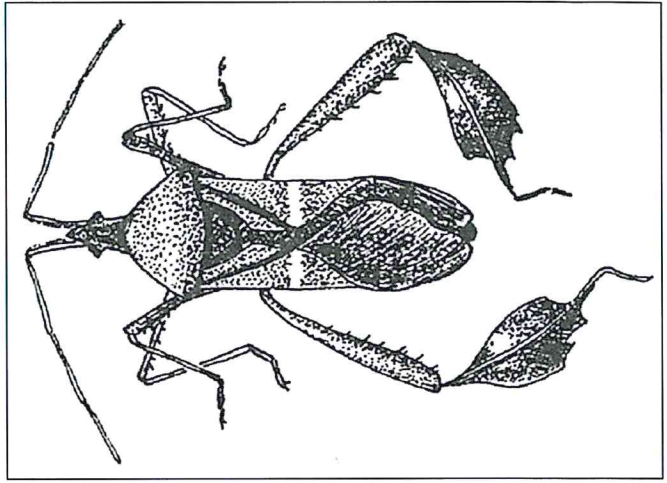
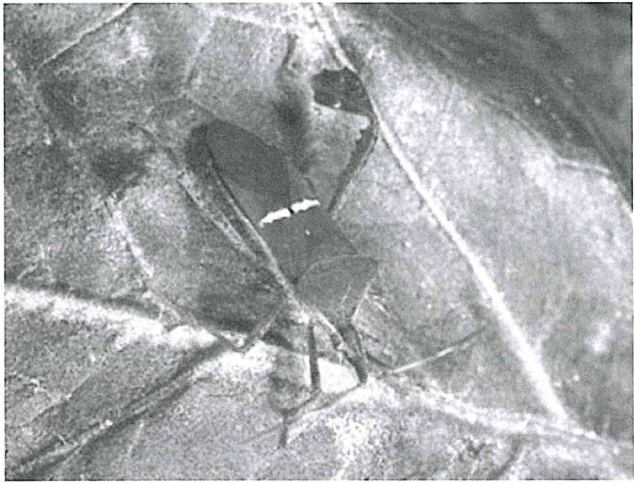
FIGURE 7.7.5.1. Adult and immature tarnished plant bug.

"V"-shaped marking on the triangular portion of its back. Nymphs are pale-yellow to green, black dots may be visible on the back (Figure 7.7.5.1). Adults are about 1/5 to 1/4 inch (5 to 6 mm) long.

The leaffooted bug (Figure 7.7.5.2) is large, up to 3/4 inch (19 mm) long, slender, shield-shaped, and flatbacked. It is brownish-black in color with two transverse whitish-yellow lines across the back. The lower portion of the hind legs is expanded and leaf-like. Nymphs are orange.

Stink bugs (Figure 7.7.5.3) are broadly shield-shaped, flattened, with a narrow head, and rather





**FIGURE 7.7.5.2. Adult leaffooted bug. (color plate, page 275, Figure 7.7.5.2)**



**FIGURE 7.7.5.3. Stink bugs. Images by J. A. Payne. (color plate, page 275, Figure 7.7.5.3)**

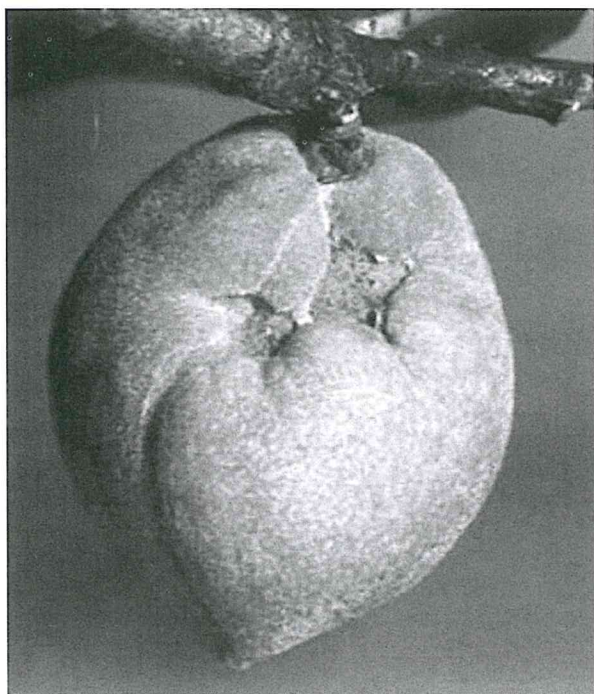
short legs. The green stink bug is bright green, sometimes with a visible yellowish-orange to reddish border. On the underside, the first ventral body segment behind the back pair of legs is pointed. The point extends forward between the hind legs. Green stink bugs are about 1/2 inch (12-13 mm) long. The southern green stink bug is similar in size and appearance. It is uniformly light green, and the first ventral segment behind the back legs is rounded and does not extend forward between the back legs. Many *Thyanta* spp. stink bugs are also green, frequently with red shoulders; they are smaller, usually only about 3/8 inch (9-10 mm) long. *Euschistus* spp. stink bugs are light grayish-brown to brown, marked with dark brown to black speckles. The brown stink bug, *E. servus*, is often the most common stink bug on southeastern peaches. The brown stink

bug frequently has slightly pointed shoulders. It is about 3/8 to 1/2 inch (10 to 12 mm) long.

### PLANT INJURY

Sucking bugs feed by sucking sap from plants. They inject a salivary secretion into the plant when feeding to break down plant tissues. Sucking bugs feed on a great diversity of host plants, moving from one host to the next to feed on the best available food source. They prefer to feed on maturing flower buds, blooms, and fruit, but if no reproductive tissues are available, they feed on succulent vegetative growth. Feeding injury is very destructive to fruiting bodies and other tender plant parts, but wounds are confined to the small areas actually fed on. Earliest injury





**FIGURE 7.7.5.4. Catfacing damage.**

to peaches is caused by the tarnished plant bug, other *Lygus* spp., and possibly stink bugs that are active in the early spring. Tarnished plant bugs can be present in high numbers when peaches start to grow in the spring. Before fruit set, plant bugs feed on swelling fruit and leaf buds and then blooms, causing the buds and blooms to dry up and abort. This injury is insignificant if flower bud numbers are within normal healthy ranges. In peach, injury from tarnished plant bug is most severe immediately following bloom, from petal fall until the peaches are 1/2 to 3/4 inch in diameter. Feeding on young fruit causes fruit deformation. Cells are destroyed in the small area around the feeding site, inhibiting fruit development and producing localized scarring. Surrounding tissues are unaffected and continue to grow and expand (Figure 7.7.5.4). This normal growth around the small feeding wound is called “catfacing” injury. Cold weather, hail, and plum curculio can also cause injury that is very similar in appearance. By cutting thin slices across the wounded area, it is sometimes possible to see the round, symmetrical wound channel left by sucking bugs. Cold injury tends to be irregular, often with internal gum pockets. After pit hardening (May), plant bug or stink bug feeding causes less scarring and distor-

tion of the fruit; more often, beads or strings of clear gum (ooze) exude from the pinprick-size feeding wound. These wounds may develop into dry, corky, shallow, sunken areas in the fruit.

## SEASONAL HISTORY AND HABITS

All sucking bugs that attack peaches overwinter as adults in protected places, such as in ground debris or between folds or cracks in bark. Adults may become active periodically on warm days during the winter. Time of emergence from hibernation in the spring varies with species, but many emerge in early spring.

Sucking bugs are very mobile. They are particularly attracted to orchards with blooming or fruiting broadleaf weeds in the orchard floor. Trees on the edges of orchards bordering woodlands, fencerows, or fields are usually the first and most severely damaged.

Tarnished plant bugs are typically present in peach orchards by the time buds begin to swell. They feed on the flower buds of peach and of numerous other plants. Plant bugs are strongly attracted to orchards with winter annual weeds in bloom. Egg laying begins shortly after adult emergence. Eggs are laid primarily in the tender shoots or flower heads of herbaceous weeds, vegetables, and legumes. Few eggs are laid in peaches. Eggs hatch in about 10 days and emerging nymphs begin to feed. The nymphal stage lasts about a month. There are several generations of tarnished plant bugs each year, but the bugs normally begin to leave peaches shortly after petal fall and move to other hosts. Populations in peaches usually decline significantly by shuck fall.

Feeding by stink bugs may occur at almost any time during the growing season. Red shouldered stink bugs, *Thyanta* spp., are often the first stink bugs to attack peaches. They have been reported to be present in peaches from the late-bloom through shuck fall stages. Most leave for other hosts within a month after shuck fall. In most years, brown stink bug, *E. servus*, is the most common stink bug on southeastern peaches. Normally brown stink bug numbers peak within six weeks after shuck fall, but they may be



abundant into July. The summer stink bug generations may reappear in late May in Florida, extending to the upper South in June and July. Green and southern green stink bugs frequently increase in number after mid-June. Stink bugs have two or more generations per year, depending upon species. The species and number of sucking bugs present in peach trees at a given time during the season are greatly dependent upon weather, surrounding vegetation (alternate host plants), orchard history, and other factors. Bugs normally are most abundant in peaches from bud break until about eight weeks after bloom.

## CONTROL

Sucking bug control begins with cultural practice. Orchard floor management, in the form of chemical mowing to suppress broadleaf weeds, especially the winter annuals, renders orchards less attractive to sucking bugs.

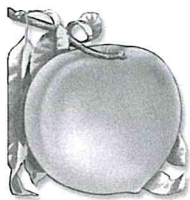
Begin checking weekly for plant bugs by bud swell. Trapping can be very useful. White traps are particularly good for tarnished plant bug. Yellow traps are attractive to the full range of plant bugs and stink bugs. White rectangular sticky traps may be hung from the lowest scaffold limbs along the orchard perimeter nearest woods or fencerows. Change to yellow sticky traps along the orchard perimeter at petal fall. Bait the yellow sticky traps with *Euschistus* spp. aggregation pheromone (methyl 2,4-decadienate). Check traps weekly for stink bugs and replace bait. Growers can also jar stink bugs from trees over a ground sheet as for plum curculio.

Appropriate management for catfacing insects includes suppression of broadleaf weeds with early season insecticide applications. Legumes such as clover and vetch should be avoided as cover crops. Insecticide applications at shuck split and possibly two additional sprays at 10- to 14-day intervals typically provide good control. In blocks where flower bud numbers are low, sprays during pink bud can be helpful if plant bugs are abundant.

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## 7.7.6 Plum Curculio

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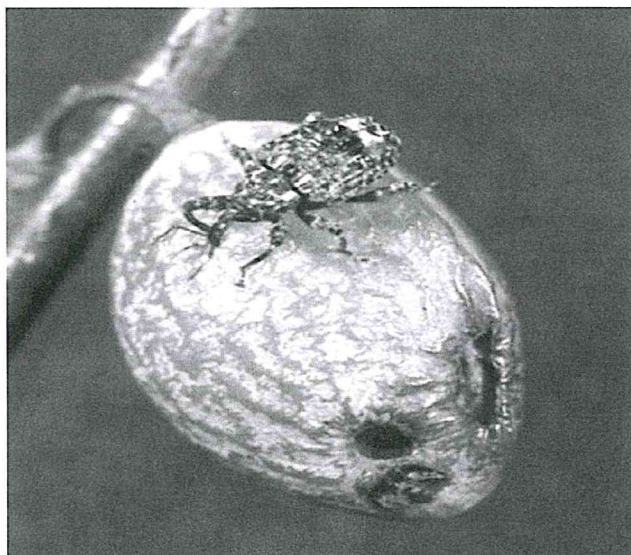
**P**lum curculio, *Conotrachelus nenuphar* (Herbst), is a native American insect found east of the Rocky Mountains in the United States and Canada. Its original hosts included wild plum, crab apple, cherry, and similar plants. It is the key fruit-attacking insect pest of peaches and other stone fruit in the southeastern United States. Plum curculio is also a pest of pome fruit and blueberries.

### DESCRIPTION

Adult plum curculios (Figure 7.7.6.1) are small brownish-black snout beetles, about 1/4 inch (4-6 mm) long, mottled with lighter gray or brown markings. The mouthparts are at the end of a moderately curved snout that is about one-fourth the length of the body. Their backs are roughened and bear two prominent humps and two smaller humps. Larvae are slightly curved, yellowish-white, legless, brown-headed grubs, about 3/8 inch (6-9 mm) long when fully grown (Figure 7.7.6.2).

### PLANT INJURY

Both the adult and larval stages of the plum curculio damage fruit. On nectarines and plums, adult damage consists of tiny circular feeding punctures or small crescent-shaped oviposition wounds made by females immediately adjacent to egg-laying punctures. On peaches, it is more common to see a 1/8-inch area of shiny fuzz. Teasing away the fuzz will expose a feeding or



**FIGURE 7.7.6.1. Adult plum curculio. (color plate, page 275, Figure 7.7.6.1)**



**FIGURE 7.7.6.2. Larval plum curculio. (color plate, page 275, Figure 7.7.6.2)**



oviposition scar, possibly an oval white egg or brown larval tunnel into the flesh. These feeding and oviposition sites cause conspicuous scarring and malformation as the fruit develop and can provide entry for the brown rot fungus. Feeding damage by adults appears obscure in April but, as the fruit enlarges, plum curculio feeding looks like the injuries caused by catfacing insects or cold. The larvae tunnel and feed in developing fruit, usually boring to the pit. Most peaches infested by plum curculio early in the season drop prematurely. Female curculios will deposit eggs whenever fruits are available, but they prefer small, young peaches or peaches within two weeks of harvest. Larger peaches, infested after pit hardening begins, generally stay on the tree until ripe, but these wormy fruit are of no value due to the flesh damage and/or presence of the grubs.

### SEASON HISTORY AND HABITS

Plum curculio overwinters as an adult in ground litter or other protected places, both in and around orchards, particularly in nearby woods or fence rows. Overwintered adults become active when mean temperatures reach 50° to 60°F for three to four days, and begin moving toward orchards when the maximum temperature reaches 70°F for two or more days. This series of temperature events often takes place shortly before or as peaches bloom, especially in the middle and upper South. Plum curculio are reluctant fliers when it is cool. Most adults probably walk to the trees when temperatures are under 70°F, whereas flight may be more commonly seen when temperatures exceed 70°F. Initially, overwintered adults feed on succulent buds, foliage, and blooms. A pre-oviposition period following emergence from hibernation may vary from six to seventeen days, depending upon temperature. As the most mature peaches reach shuck split, the female begins depositing eggs singly in a hole that she eats in the fruit. On peach, feeding and egg-laying sites often appear as shiny areas of disturbed fuzz on the fruit. On nectarines, plums, and sometimes on peach, the round feeding scars and the crescent-shaped egg laying scars will be evident (Figure 7.7.6.3). The egg hatches in two to twelve days; the average is about five days. The larva feeds in the fruit for eight to twenty-two days.



**FIGURE 7.7.6.3. Egg deposition by plum curculio on peach. "Silvering" of the fruit surface is pre-harvest thrips injury. Image by J. A. Payne. (color plate, page 275, Figure 7.7.6.3)**

The full-grown larva tunnels out of the peach, enters the soil and constructs a small earthen cell, usually one to three inches below the surface. After about two weeks (12 to 16 days) in the soil, the larva transforms into a white pupa, then to an adult. First generation adults usually emerge about four weeks (30 to 35 days) after larvae enter the soil. The complete life cycle, from egg to emerged adult, requires five to eight weeks, depending upon climatic conditions. In the Southeast, there are usually two generations and possibly a partial third generation each year.

Emerging overwintered adults may deposit eggs (first generation eggs) as soon as young peaches reach shuck split. Emergence and oviposition may continue for a period of six to eight weeks following shuck split. The next adult emergence (first generation adults) usually occurs from late May through July. These adults begin egg laying (second generation eggs) in early June. Second generation larvae may be found in peaches at harvest time. Second generation adults normally appear in late July or August. Both first and second generation adults feed on foliage or fruit until cool weather, when they seek overwintering sites.

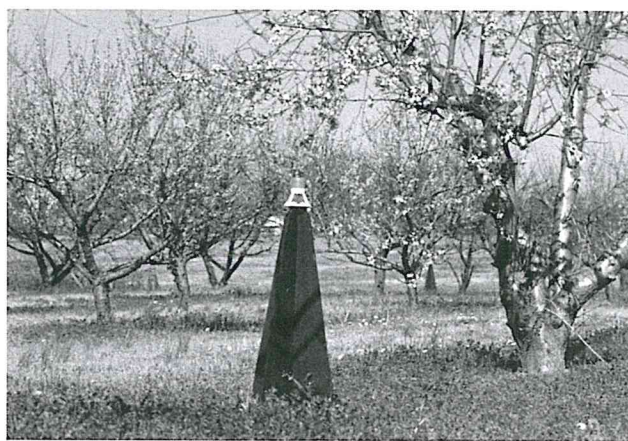
Annual variations in the seasonal history of the plum curculio occur, depending upon weather conditions. The overwintering populations may be made up mostly of second generation adults. A portion of second generation adults may mate and produce a partial third generation.



## CONTROL

Plum curculio is the key fruit-infesting insect pest of southeastern peaches. Its lengthy emergence and egg-laying periods mandate diligent control, but existing control programs work well and plum curculio is seldom damaging in well-managed orchards. Adult populations are suppressed in the spring by well-timed applications of effective insecticides. Keeping the orchard floor closely mowed after harvest affords less protective cover to adults that overwinter in the orchard. Destruction of nearby plum thickets, abandoned peach blocks, and other alternate hosts is suggested to reduce plum curculio migration into orchards from outside sources.

Plum curculio control programs are intense. Sprays provide a protective barrier to prevent overwintering adults from laying first generation eggs. Sprays for plum curculio control are normally initiated at shuck split. Two or possibly three additional sprays at 10- to 14-day intervals are needed to assure control of the overwintered population. Sprays targeting the overwintered plum curculio generation also provide control of oriental fruit moth and suppress stink bugs moving into the orchard. If the egg-laying adults are not effectively controlled, additional applications will be necessary to prevent wormy fruit from second generation larvae that mature from early June through harvest. In infested orchards, special attention should be given to mid- and late-season cultivars by applying insecticide sprays at six, four, and two weeks before harvest.



**FIGURE 7.7.6.4. Pyramidal weevil trap for monitoring plum curculio. Image by J. A. Payne.**

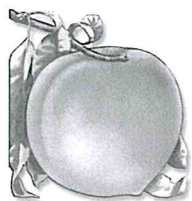
An improved knowledge of plum curculio biology is allowing greater refinement of control efforts. Once maximum daily temperatures reach 70°F for two consecutive days from February to early March (Florida or Georgia) or March to early April (Alabama, Arkansas, Oklahoma, South Carolina, North Carolina), begin accumulating daily degree days (DD). At pink stage, position two to four pyramid traps per block in the outer row of peach trees adjacent to woodlots or fence rows (Figure 7.7.6.4). At petal fall, begin checking pyramid traps twice weekly for plum curculio adults. At the same time, inspect 100 fruit along the orchard perimeter for plum curculio feeding damage. After accumulating 50 to 100 DD (about shuck split), growers should expect to start catching plum curculio adults in pyramid traps or see the first feeding damage on fruit. An insecticide application is recommended if the traps exceed 0.1 adults per trap per day or if damage exceeds 1%. Adult emergence can also be monitored by jarring peach trees along the perimeter over a ground sheet or beating tray. Jar trees in the early morning when the plum curculio adults are less active and more easily dislodged. Migration of adults into the orchard continues from 50 to 500 DD, so this is the period when fruit should be protected by insecticide sprays (most of March in Florida and southern Georgia, most of April in the central Georgia and more northern areas). Summer adults emerge from the soil after 1,000 DD (from sometime in late May through harvest).



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## 7.7.7 Oriental Fruit Moth

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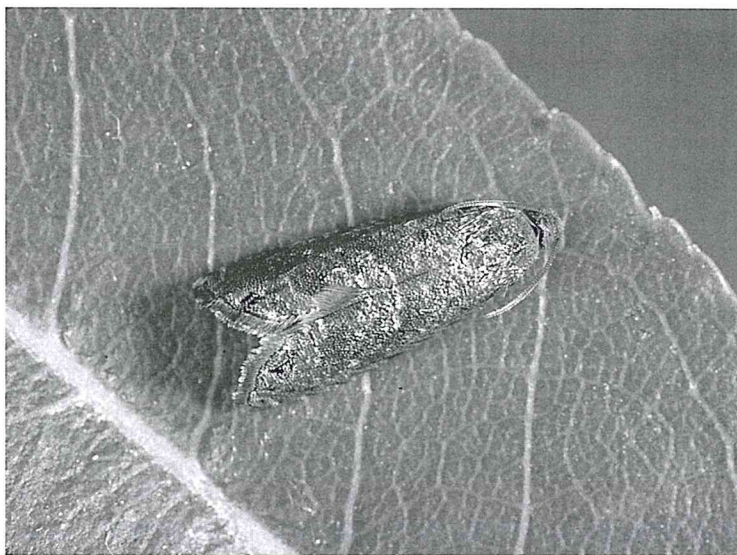
The oriental fruit moth, *Grapholita molesta* (Busck), is a cosmopolitan pest that is present in major tree fruit production areas worldwide. It was inadvertently introduced into North America from Japan around 1913. Oriental fruit moth is an established pest of stone and pome fruit in most of the peach-growing areas of the United States. Oriental fruit moth attacks practically all orchard fruits, but is of particular importance as a pest of peach.

### DESCRIPTION

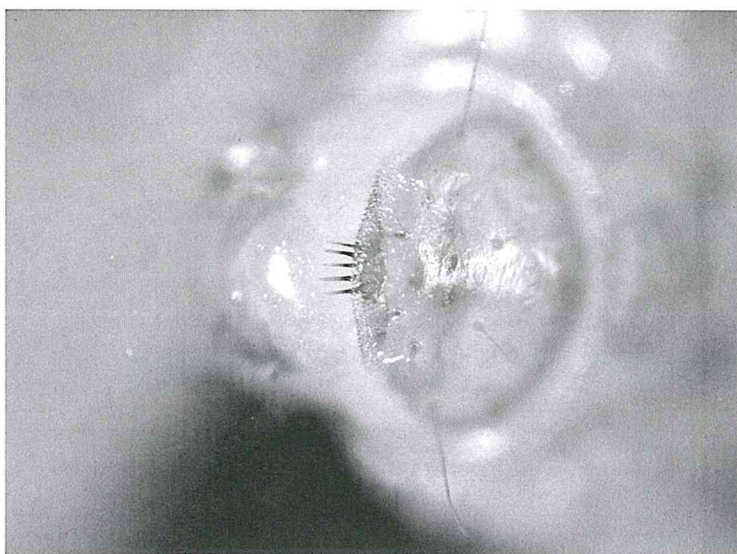
Moths are gray, about 1/4 inch (6-7 mm) long, with dark-brown bands on their wings (Figure 7.7.7.1). They have a wingspread of about 1/2 inch (12 mm). Larvae are pinkish-white, brown-headed caterpillars, about 1/2 inch (10-12 mm) long when fully grown, with a black anal comb on the top of their last body segment (Figure 7.7.7.2). Oriental fruit moth larvae have three pairs of true legs and fleshy prolegs on abdominal segments three, four, five, and six.

### PLANT INJURY

Oriental fruit moth's larval stages tunnel in succulent vegetative shoot growth or in fruit. Moths of the overwintered generation lay their eggs on succulent growth around bloom. Larvae burrow into tender, rapidly growing terminals. The larva enters a tender twig at a leaf axil near the tip, feeding down the central core of the



**FIGURE 7.7.7.1. Adult oriental fruit moth. Image by Jack Kelly Clark. (color plate, page 276, Figure 7.7.7.1)**



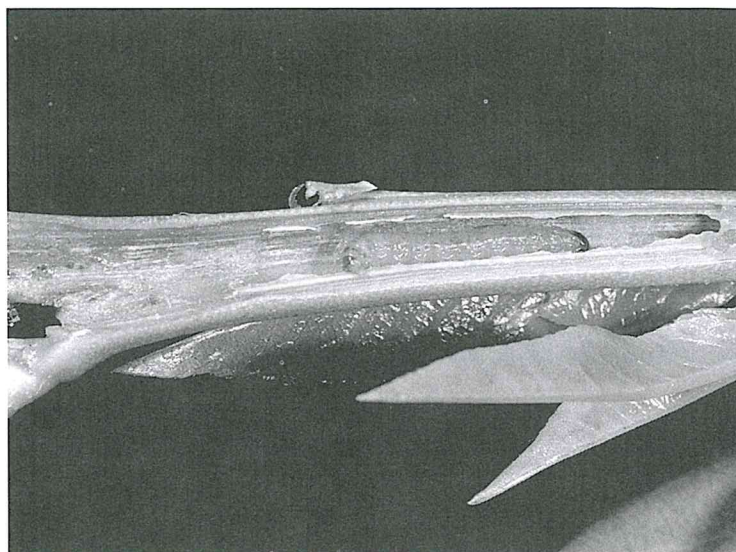
**FIGURE 7.7.7.2. Anal comb of oriental fruit moth larva. Image by Jack Kelly Clark. (color plate, page 276, Figure 7.7.7.2)**





**FIGURE 7.7.7.3. Flagging damage by oriental fruit moth larvae. (color plate, page 276, Figure 7.7.7.3)**

shoot for two to six inches, resulting in wilting and death of the terminal, which is said to be “flagging” (Figure 7.7.7.3). Feeding patterns vary, an individual larva may attack only one terminal (Figure 7.7.7.4) or it may enter several stems or fruit to complete its development. When terminals are killed, lateral shoots are stimulated to develop below the dead area, so heavily infested trees may have a compact, bushy growth habit. Larvae of later generations may feed on terminals or peaches. Fruit feeding (Figure 7.7.7.5) increases dramatically as the season progresses, perhaps in response to hardening of terminal growth. Larvae attacking fruit often enter near the stem, leaving little or no external signs of entry. They also may enter where two peaches touch or from the side of an individual fruit. Tiny, dark spots exuding gum sometimes indicate larval entries. Once inside the fruit, larvae feed to the pit in a fashion similar to the plum curculio. The presence of



**FIGURE 7.7.7.4. Oriental fruit moth larva in stem. Image by Jack Kelly Clark. (color plate, page 276, Figure 7.7.7.4)**



**FIGURE 7.7.7.5. Fruit damage by oriental fruit moth larvae. Image by Jack Kelly Clark. (color plate, page 276, Figure 7.7.7.5)**

distinct legs on oriental fruit moth caterpillars distinguishes them from legless plum curculio grubs. Oriental fruit moth larvae typically exit the peach through readily visible holes in the sides of fruit, from which considerable gum and dark frass may exude. Infested fruits break down rapidly and are unfit for consumption. In the Southeast, early- and even some mid-season cultivars may escape fruit damage by this pest. After harvest is complete, fruit moth larvae may again develop in the terminals if a late season vegetative growth flush is produced.



## SEASONAL HISTORY AND HABITS

The oriental fruit moth overwinters as a fully-grown larva in a silken cocoon on the tree, in a dried-up peach, in leaves or stems on the ground, or other protected sites such as stacked fruit bins. In the late winter, the larva transforms into a pupa and then to a moth. Oriental fruit moth adults typically begin to emerge shortly before peaches bloom. Emergence of the overwintering flight may continue for several weeks. After mating, female moths lay flat, whitish eggs on twigs or the underside of leaves near the tips of twigs. Normally, egg laying begins two to five days after adult females emerge. Adults live for about two weeks, during which time a female may lay up to 200 eggs. Cool temperatures may extend the egg stage to several weeks. Eggs hatch in less than a week in summer. First generation larvae primarily attack terminals. Larvae complete development in one to eight weeks, depending upon temperature, chewing their way out of the twig or fruit and spinning cocoons in which to pupate. Summer cocoons may be found in ground trash, under the bark on a tree, in the axils of leaves, or on fruit. The insect normally spends about two weeks in the cocoon before emerging as a moth.

There are six or more generations per year in central Georgia and five or more further north in Arkansas and North Carolina. Generational overlap, moths of two or more generations present at the same time, becomes more common as the season progresses.

## CONTROL

Optimal control of oriental fruit moth using conventional insecticides can be facilitated by monitoring moth activity with pheromone traps. First-brood fruit moths are normally controlled by insecticides applied for plum curculio. Adequate suppression of the first brood (adults developing from overwintered larvae) may give control for the entire season if orchards are not reinfested from untreated orchards nearby. The summer generations from May to mid-August can be controlled with insecticide applications or

pheromone mating disruption. Mating disruption is most often employed by placing mating disruption dispensers in the orchard (ca. 100/acre) just before second flight begins. The dispenser saturates the orchard atmosphere with a volatile, synthetic mimic of the pheromone oriental fruit moth females produce to attract males. Saturating the orchard atmosphere with pheromone confuses the males, preventing mating and reproduction.

Timing management decisions for spraying or using mating disruption is best done by use of pheromone trap monitoring. At pink, set out three pheromone traps in each orchard. Check twice weekly for first catch of moths. On the first day moths are caught, begin accumulating daily degree-days (DD) using Table 7-7-7-1. Locate the daily minimum temperature in the left column and move horizontally to the right until it intersects the vertical column below the daily maximum temperature. The value at this intersection (from 0 to 40) is the daily DD. Add DD values together daily until it totals 400 DD. At 400 DD, oriental fruit moth eggs have experienced enough warmth to begin hatching, and insecticides should be applied. Insecticides are required from 400 to 700 DD (typically April to May) to prevent infestation by oriental fruit moth larvae. The second oriental fruit moth generation hatches between 1300 to 1700 DD (June), the third generation occurs from 2300 to 2700 DD (July) and overlaps with later generations until late September. Peaches should be sprayed to protect against oriental fruit moth hatch whenever 5 or more moths are caught per pheromone trap since the last insecticide application.

Good orchard sanitation is also important in reducing oriental fruit moth populations. Prompt removal and destruction of dropped and cull fruits from the orchard and packing shed destroy any larvae infesting these fruit. To the degree possible, all fruit should be removed at harvest. Unharvested and mummied fruit should be removed during pruning. Flailing of pruning debris helps reduce an orchard's overwintering oriental fruit moth population. Plant litter and other ground debris on the orchard floor should be kept to a minimum to reduce sites favorable for pupation and overwintering.



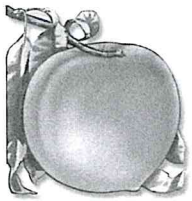
Max Min	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96
20	1	1	2	2	3	4	4	5	6	7	8	9	9	10	12	12	13	14	15	16	17	17	18	19
22	1	1	2	2	3	4	4	6	7	7	8	9	10	11	12	12	13	14	15	16	17	18	18	19
24	1	2	2	2	4	4	5	6	7	7	8	10	10	11	12	12	14	15	15	16	16	18	19	20
26	1	2	2	3	4	5	5	6	7	7	8	10	10	11	13	12	14	15	16	16	18	18	19	20
28	1	2	3	3	4	5	5	6	7	8	9	10	10	11	13	13	14	15	16	17	18	19	20	20
30	1	2	3	3	4	5	5	6	7	8	9	10	10	12	13	13	15	16	16	17	19	19	20	21
32	1	2	3	3	4	5	6	6	8	8	9	10	11	12	13	14	15	16	17	18	19	19	20	21
34	1	2	3	3	4	6	6	7	8	8	10	11	11	12	14	14	15	17	17	18	19	20	21	21
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44	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
46	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
48	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
50	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
52	-	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
54	-	-	9	10	11	12	16	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
56	-	-	-	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
58	-	-	-	-	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
60	-	-	-	-	-	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
62	-	-	-	-	-	-	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
64	-	-	-	-	-	-	-	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
66	-	-	-	-	-	-	-	-	21	22	23	24	25	26	27	28	29	30	31	32	33	34	36	36
68	-	-	-	-	-	-	-	-	-	23	24	25	26	27	28	29	30	31	32	33	34	35	36	36
70	-	-	-	-	-	-	-	-	-	-	25	26	27	28	29	30	31	32	33	34	35	36	37	37
72	-	-	-	-	-	-	-	-	-	-	-	27	28	29	30	31	32	33	34	35	36	37	38	38
74	-	-	-	-	-	-	-	-	-	-	-	-	29	30	31	32	33	34	35	36	37	38	39	39
76	-	-	-	-	-	-	-	-	-	-	-	-	-	31	32	33	34	36	36	37	38	39	40	40

**TABLE 7-7-7-1. Oriental fruit moth degree days (45°F lower base) at various daily maximum and minimum temperatures.**

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## 7.7.8 Peach Twig Borer

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**P**each twig borer, *Anarsia lineatella* Zeller, was introduced from Europe. It now occurs throughout the peach-growing areas of the United States. Peach twig borer is an important pest in the West. In well-managed orchards in the Southeast that make regular use of organophosphate insecticides, peach twig borer is a minor seldom-seen pest.

### DESCRIPTION

Adult peach twig borers are small, inconspicuous, gray to dark gray moths with a wingspread of about 2/5 to 1/2 inch (10 to 12 mm). Larvae (Figure 7.7.8.1) are reddish-brown to chocolate-brown caterpillars with black heads. They often have creamy-white bands extending around their bodies and they reach 2/5 inch (10 mm) long when mature.

### PLANT INJURY

In early spring, peach twig borer caterpillars burrow and feed in the pith of new shoots, causing wilting and die-back similar to that caused by the oriental fruit moth. One larva may destroy several shoots. Later generations of larvae feed in fruit, often penetrating completely to the pit. Late maturing peach cultivars normally sustain more fruit damage. After harvest, larvae of late-season generations again bore and feed in terminal growth.

### SEASONAL HISTORY AND HABITS

Peach twig borer overwinters as a partially grown larva in a hibernaculum, a silk-lined cell or cavity (Figure 7.7.8.2). Hibernacula are usually constructed under loose bark or in the folded bark in the crotch of younger branches. Overwintering larvae become active in the early spring when new twig growth starts. About the time leaves begin to appear, overwintering larvae leave their hibernacula, move up the tree, and burrow into tender new growth. When mature, larvae exit the shoots, migrate to larger branches, and pupate in loose silken cocoons in rough places in the bark or in curled leaves. Moths soon emerge, mate, and begin laying eggs that hatch in four to seven days. Emerging first generation larvae also feed primarily on shoot growth. Fruit are apparently unattractive to peach twig borer larvae until after the pit-hardening stage. Some fruit feeding by first generation larvae may occur on early varieties.



**FIGURE 7.7.8.1. Peach twig borer larva. Image by Jack Kelly Clark. (color plate, page 276, Figure 7.7.8.1)**

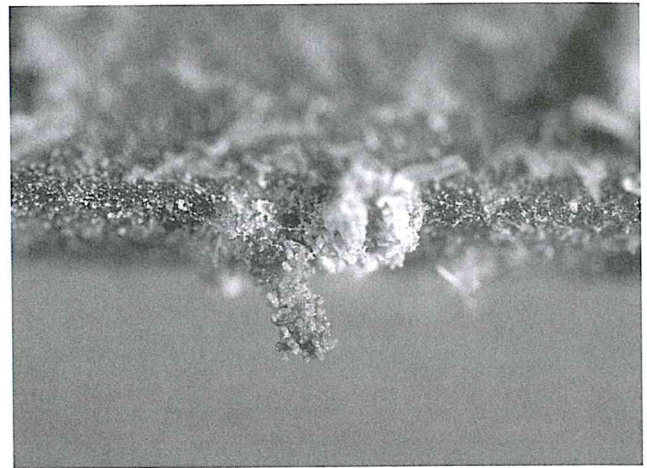


Larvae feed and grow for about three weeks, at which time they pupate and give rise to first generation moths. The life cycle repeats throughout the season. There are normally four complete generations per year in the Southeast. Larvae of the second and succeeding generations feed increasingly on maturing fruit, as long as fruit is present.

The time required for a given generation of peach twig borer to complete its development varies, depending upon weather and location. Normally, there is an overlapping of generations in late season, and fruit or terminals may be infested by larvae from more than one generation. Overwintering larvae may also be from different generations.

### CONTROL

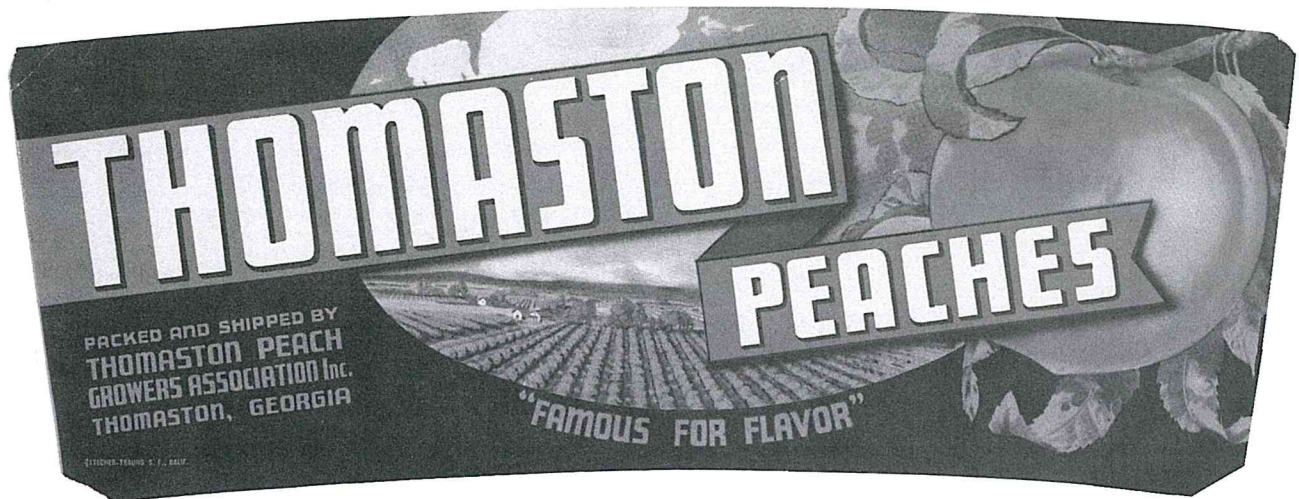
Insecticide applications for catfacing insects and plum curculio normally provide peach twig borer control. Delayed dormant sprays for scale insects may also kill many of the overwintering larvae. Season-long control of peach twig borer can usually be obtained by insecticide applications at petal fall and shuck fall.



**FIGURE 7.7.8.2.** Peach twig borer hibernaculum, a silk-lined cell in which larvae overwinter. Image by Jack Kelly Clark. (color plate, page 277, Figure 7.7.8.2)

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Sorenson, C. J. and F. H. Gunnell. 1955. Biology and control of the peach twig borer (*Anarsia lineatella* Zeller) in Utah. Utah State Agr. Exp. Stn. Bull. 379. 19p.







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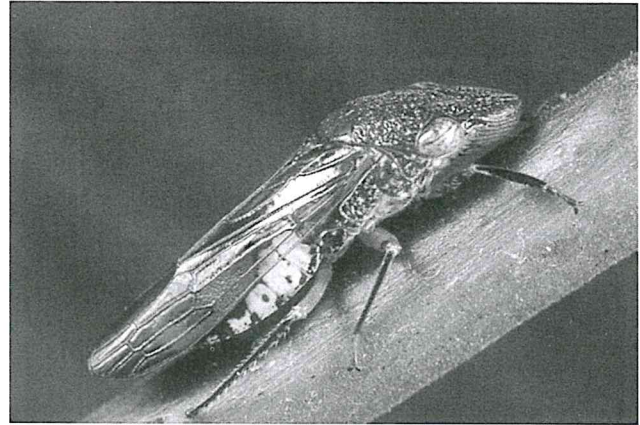
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Leafhoppers, often called sharpshooters, vector numerous plant diseases, including phony peach disease and plum leaf scald. Leafhoppers are abundant insects and they are very strong fliers. Key species in southeastern peaches readily move in and out of orchards. Phony peach and plum leaf scald, caused by the bacterium *Xylella fastidiosa*, are important diseases, especially in the Southeast's warmer production areas. Phony peach and plum leaf scale can be key factors in premature orchard decline. These leafhopper-vectored diseases limit stone fruit production in the Southeast's lower coastal plain. The leafhopper *Homalodisca coagulata* (Say), often called the glassy-winged sharpshooter, is a key vector of phony peach disease. *Oncometopia orbona* (Fabr.) and *Graphocephala versuta* (Say) are probably next in importance. *Cuerna costalis* (Fabr.) and *Homalodisca insolita* (Walker) are principally grass feeders and are considered to be less important in the transmission of phony peach.

### DESCRIPTIONS

Leafhoppers are slender, elongate insects with round or pointed heads. The forewings are slightly thickened and frequently are held roof-like over the abdomen. Adults of the two most important species on peach, glassy-winged sharpshooter and *O. orbona*, are rather large, being about 1/2 inch (11-13 mm) in length. The glassy-winged sharpshooter (Figure 7.7.9.1) is generally gray-brown in color with a reddish tint when newly emerged and with an orange underside marked with black. An ivory-colored blotch is usually visible at the base of the abdomen when the insect is viewed from the side. *O. orbona* is greenish-blue with irregular dark spots; it is orange and black underneath. The legs are orange with sparse black



**FIGURE 7.7.9.1. Glassy-winged sharpshooter, *Homalodisca coagulata*. Image by Jeff Brushwein. (color plate, page 277, Figure 7.7.9.1)**

markings. *G. versuta* is a smaller leafhopper, about 1/5 inch (5 mm) long. Adults are generally green with reddish-orange stripes. *H. insolita* is brown to black, slightly less than 1/2 inch (10-11 mm) long, with a longitudinal ivory stripe on each side of the body.

### PLANT INJURY

On peaches and plums, leafhoppers are important only as vectors of *X. fastidiosa*, which causes phony peach disease or plum leaf scald. Direct leafhopper injury to peaches and other stone fruit is insignificant. Leafhoppers inject saliva and suck plant juices while feeding. All important leafhopper species on peach are stem feeders that have specialized to feed on the nutrient-poor xylem fluid, likely because of the near absence of plant defensive components in xylem fluid. *X. fastidiosa* is a xylem-limited pathogen. The glassy-winged sharpshooter is a key vector of phony peach disease and plum leaf scald. It feeds on a variety



of woody and herbaceous host plants. Plums and crapemyrtle, *Lagerstroemia indica* L., are favorite summer hosts. Glassy-winged sharpshooters are sensitive to minor changes in the amino acid concentrations of nutrient-poor xylem fluid. They feed very selectively, moving from tree-to-tree or to-and-from orchards in response to xylem nutrients. On peach, leafhoppers feed selectively and aggressively during May and June when concentrations of key amino acids are highest.

Leafhoppers aggregate on healthy, uninfected trees that have high levels of glutamine and asparagine in their xylem fluid. Levels of these amino acids are suppressed in phony trees. *X. fastidiosa* infections advanced enough to produce the diagnostic visual symptoms of dark foliage and shortened internodes have already begun to render these trees unattractive to leafhoppers.

Removal of phony trees is recommended primarily to remove unproductive, weed trees. Root suckers from infected trees that have been cut are very attractive to leafhoppers.

### SEASONAL HISTORY AND HABITS

Leafhoppers of peach generally overwinter as adults in wooded areas. They become active and feed extensively during warm winter periods. Some feeding, and possibly even reproduction, may continue throughout warm winters in the Southeast's lower coastal plain. Activity increases in early spring; considerable numbers of leafhoppers may be seen by March and April. They feed on peach twigs and on stems of other trees (hollies, *Ilex* spp., appear to be especially important), shrubs, and grasses. Leafhoppers normally feed head-down, moving rapidly to the opposite side of the stem when disturbed. Adults mate and females lay masses of eggs in plant stems or leaves. Herbaceous plants are generally favored for egg laying, although leafhoppers will oviposit in peach. Eggs normally hatch in one to two weeks. Emerging young (nymphs) pass through five growth stages (instars) before becoming adults.

The primary vectors of phony peach, the glassy-winged sharpshooter and *O. orbona*, are particularly active as vectors in May to June. Crapemyrtle and hollies are two of their favorite summer hosts. Glassy-winged sharpshooter is known to feed on

over 100 plant species. Later in the summer, they feed primarily on herbaceous, broadleaf weeds. In the fall, when herbaceous weeds and field crops begin to dry up, these leafhoppers move back to woody plants, including peaches. *G. versuta*, *H. insolita*, and *C. costalis* feed primarily on broadleaf weeds and grasses, although they may be found in association with peach trees and other woody perennials throughout the year.

Leafhopper vectors of phony peach are quite abundant in the Southeast's coastal plain. The lower abundance of glassy-winged sharpshooter in cooler regions, particularly upper piedmont and mountain sites, is felt to be a key factor in the low incidence of phony peach disease in the Southeast's cooler production areas. Leafhopper abundance fluctuates with climate. High populations are common in summers following warm winters. High winds associated with summer thunderstorms are thought to be important in spreading leafhoppers and *X. fastidiosa*. Cold winters, especially those with warm periods followed by sudden, severe cold, can significantly reduce overwintering leafhopper populations. The abundance and species of leafhoppers in orchards during the summer appear to be influenced by the vegetation in and around the orchards. Well-maintained, closely mowed orchards with low broadleaf weed levels generally harbor fewer leafhoppers. Clean orchard culture may discourage vector movement into orchards. Diminishing the attractiveness of orchards to leafhoppers by cultural practice is important because the incidence of phony peach disease is usually directly related to the abundance of leafhopper vectors in orchards.

### CONTROL

Insecticides applied to peaches and other crops through the season probably reduce leafhopper populations. However, because of the leafhoppers' mobility, broad host ranges, and abundance on a variety of host plants, insecticidal control is impractical as a means of suppressing spread of phony peach disease.

Good cultural practices are the best means of reducing leafhopper populations in peach orchards. Orchard floor management practices that sup-



press broadleaf weeds and strong-stemmed, upright grasses such as johnsongrass and Texas panicum are recommended. Keep other grasses and vegetation on the orchard floor short. Remove succulent green peach suckers, as they frequently attract large numbers of leafhoppers.

Remove phony infected trees each year. Although phony trees are themselves less attractive to leafhoppers, vigorous regrowth from phony stumps is quite attractive to leafhoppers and may create an important source of infection. If phony

trees are chain sawed, leaving stumps, it is important to either treat stump suckers with an herbicide or push out the stumps before they sucker. It is also helpful to remove or kill all wild plums within 300 yards of orchards; within one-half mile if possible. Plums are a favored host for both the phony peach organism and its leafhopper vectors. Plums serve as a constant reservoir of infection for nearby peaches. Cultivated plums are also excellent disease and vector reservoirs, so do not grow domestic plums near peaches in phony areas.

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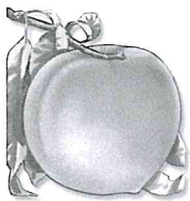
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## 7.7.10 Mites

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The twospotted spider mite, *Tetranychus urticae* Koch, and the European red mite, *Panonychus ulmi* (Koch), are the principal mite pests of peach. The twospotted spider mite is native to North America and may be found on almost any type of broadleaf plant. The European red mite was first found in the United States about 1911. It is now a serious pest of tree fruits throughout North America.

### DESCRIPTIONS

Mites are close relatives of insects (Figure 7.7.10.1). Adults are minute, eight-legged, appear to have only one body segment, and are frequently oval and spiny. Color is variable. Newly hatched young, larvae, have only six legs. The two immature stages that follow are referred to as nymphs. They have eight legs. Immature mites are similar to adults in general appearance.

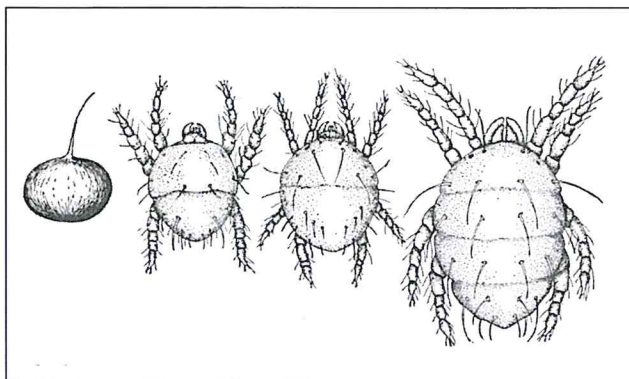


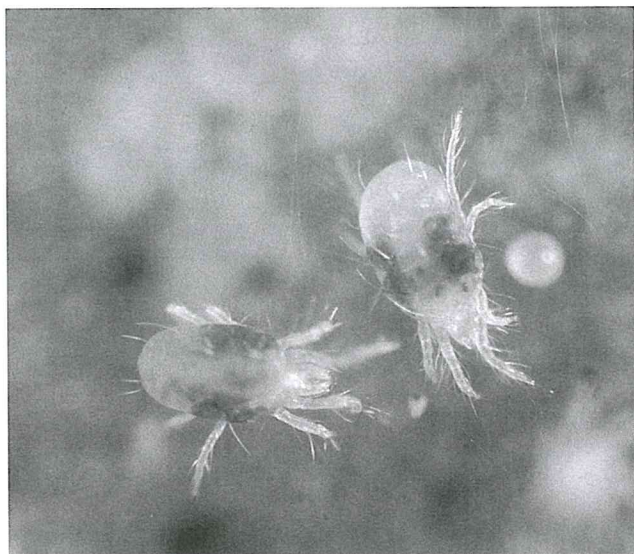
FIGURE 7.7.10.1. European red mite: egg, larva, nymph, adult stages.

European red mite females (Figure 7.7.10.2) can be easily distinguished from other mites. Female red mites are elliptical, brownish-red, about 1/65 inch (0.3-0.4 mm) long, and have four rows of conspicuous, white, spine-bearing tubercles on their backs that are clearly visible with a 10x lens. Males are smaller, football-shaped, about 1/90 inch (0.28 mm) long, lighter in color, with less conspicuous spines. The eggs are red with a hair sticking out of the top. European red mite does not spin silken threads on the leaves, but will disperse from leaves by a silken thread.



FIGURE 7.7.10.2. European red mite female. Image by Jack Kelly Clark. (color plate, page 277, Figure 7.7.10.2)





**FIGURE 7.7.10.3. Twospotted spider mite summer coloration.** Image by Jack Kelly Clark. (color plate, page 277, Figure 7.7.10.3)

Twospotted spider mite (Figure 7.7.10.3) females may range in color from orange to green to yellow, depending upon their age and host. The feeding stages are usually yellowish-green with two dark spots on each side of the body; they are about 1/60 inch (0.4 mm) long. Males are smaller, about 1/80 inch (0.32 mm) long, with a narrower body and a pointed abdomen. The eggs are clear and round. Adult mites may web leaves by spinning silk threads on the leaf surface.

## PLANT INJURY

Mites pierce leaf cells with tiny stylet-like mouthparts and ingest the cell contents, including the chlorophyll, which results in mottled, off-color foliage that may later appear gray or bronzed (Figure 7.7.10.4). Extensive webbing may be evident when twospotted spider mites are the major problem (Figure 7.7.10.5). Severely injured leaves often fall. Peaches can tolerate relatively high mite levels. Heavy, persistent mite infestations that begin in early season hurt fruit size and quality. Prolonged defoliation can result in low tree vigor, a decline in general tree health, and lower fruit yields the following year.

Mite infestations at harvest can be a very serious problem, because mites inadvertently get on the pickers, which can cause dermal irritation.



**FIGURE 7.7.10.4. Leaf damage caused by mites.** Bronzing on the top, light damage on the center, and a normal leaf on the bottom. (color plate, page 277, Figure 7.7.10.4)



**FIGURE 7.7.10.5. Webbing caused by twospotted spider mites.** (color plate, page 277, Figure 7.7.10.5)



Mite-induced work stoppage of pickers is perhaps the grower's greatest mite-related fear.

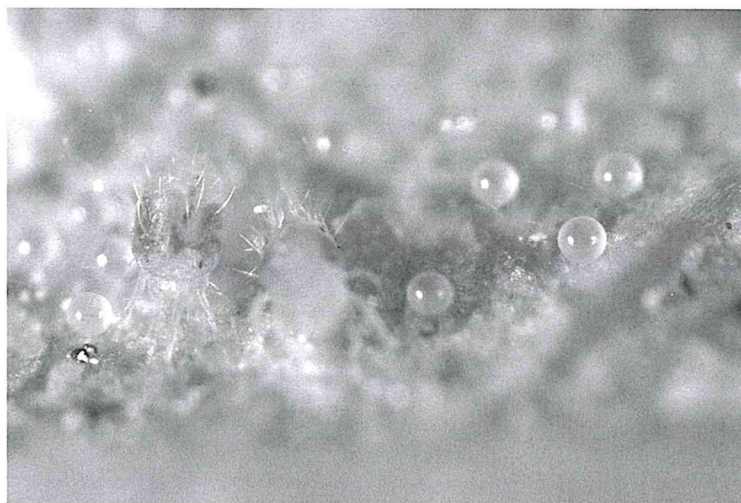
### SEASONAL HISTORY AND HABITS

The life history and habits of the European red mite and twospotted spider mite are similar, but there are differences that are of importance from a management perspective. The European red mite overwinters in the orchard as a fertilized egg. The overwintering eggs are bright red and are typically found in groups on the underside of twigs or branches (Figure 7.7.10.6). Overwintering eggs normally hatch shortly before peaches bloom. Newly hatched young have six legs and are called larvae. They pass through two nymphal eight-legged stages and become adults. Development time from hatching to adult ranges from four to 20 days, depending on temperature and other factors. Adult females live for about 18 to 20 days and lay about 20 eggs per female. Eggs are usually laid on the underside of leaves. Eggs from unmated females develop into males; eggs from fertilized females develop into both sexes, mostly females. The length of time for a complete life cycle varies, but averages about three weeks. There are multiple (six to nine) generations per year in the South.

The twospotted spider mite overwinters as an adult female in ground debris on the orchard floor, occasionally under loose bark on the trees (Figure 7.7.10.7). It becomes active in early spring and lays round, straw-colored eggs on weeds and other ground vegetation or on the lower, inner leaves of trees. Eggs are usually webbed to the underside of leaves. Eggs hatch and the young pass through a larval and two nymphal stages before becoming adults. Unfertilized eggs give rise to male mites; eggs from mated females produce both sexes, but mainly females. Twospotted spider mites develop from egg to adult in five to ten days under favorable conditions; there are numerous generations per year.



**FIGURE 7.7.10.6. European red mite eggs around a dormant bud.** Image by Jack Kelly Clark. (color plate, page 278, Figure 7.7.10.6)



**FIGURE 7.7.10.7. Twospotted spider mite overwintering coloration.** Image by Jack Kelly Clark. (color plate, page 278, Figure 7.7.10.7)

Because European red mites overwinter and reside primarily in the trees, they are typically the most numerous mites in early season. Twospotted spider mites reside primarily on herbaceous vegetation in the orchard floor until early summer, when they migrate into the trees. Time of movement to trees depends upon population levels and how long the orchard floor vegetation remains succulent and acceptable as a host. Twospotted spider mite populations often increase in fruit trees as the orchard floor vegetation dries down or following herbicide use in May or June. Mixed populations of European red mites and twospotted spider mites are commonly present, but twospotted



spider mites generally predominate by mid-season. The potential for mite damage normally is greatest from June through August, when mite numbers often increase rapidly.

## CONTROL

Peaches are generally more tolerant of mite infestations than other deciduous fruits, including plums. Except for preventative application of dormant oil(s) for scale and European red mite, mites in peaches seldom warrant pest management actions beyond regular scouting after mites are seen. The development of high populations of European red mites and twospotted spider mites is favored by hot, dry weather, and use of or timing of pesticide applications that decimate predators. Mite outbreaks in peaches are often thought to be attributable to pesticide use or selection. Applications of the fungicides thiophanate-methyl and captan, or any of the pyrethroid or carbaryl insecticides, have been associated with increased mite numbers in several deciduous fruits.

Because mites rapidly develop resistance to miticides, treat only as-needed and alternate miticides in a given season. When miticide applications are necessary, it is common to need two treatments at a 7- to 10-day interval. It is important to make subsequent miticide applications using another miticide(s) that has a different mode of action.

Twospotted spider mite populations in peach can be reduced by suppressing broadleaf weeds, such as vetch, in the orchard floor. A dormant oil spray should be standard as an effective tool to aid in control of scale insects and the European red mite. Twospotted spider mites are largely unaffected by dormant oil applications, as they overwinter primarily on herbaceous hosts on the orchard floor.

Targeted, in-season miticide applications should be made strictly on an as-needed basis, as peaches are more tolerant of mite injury than most other fruit crops.

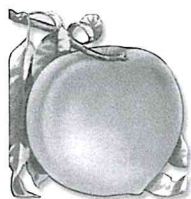
Weekly monitoring of general orchard performance and pest abundance should be standard and sufficient to detect mites before infestations become problematic. Once mites are observed, scout specifically for them at least weekly. Mites are quite small, a 10 to 15x hand lens or jeweler's visor is quite helpful for mite scouting. Generally, a sample consisting of 10 leaves from 10 trees (100 leaves) per orchard is considered adequate. If 80 percent of these leaves have mites present (ca. 7.5 mites/leaf), a miticide application is probably in order.

Mite populations appear largely unaffected by organophosphate cover sprays. Mite outbreaks are favored by hot, dry weather and the use of pesticides detrimental to the mite's natural enemy complex.

Mite resistance to miticides may vary from orchard to orchard, but resistance is a serious concern that should be avoided or, as necessary, considered in making miticide choices. Mite outbreaks require targeted miticide application(s), seven to ten days apart, to bring populations under control because, except for the ovicides, most miticides do not control eggs.

Nimblewill (*Muhlenbergia schreberi* J.F. Gmelin) is a short-statured perennial grass that has many desirable attributes for an orchard floor cover. If established in an orchard, nimblewill is an almost ideal orchard floor cover. It tolerates drought, grows well in partial shade, does not harbor twospotted spider mites or catfacing insects (stink bugs or tarnished plant bugs), inhibits populations of ring nematodes (*Mesocriconema xenoplax*), and survives winter weather with little injury. Nimblewill also successfully crowds out most weed species, but its season of growth avoids competition with peach trees for water and nutrients, even when growing directly under the tree canopy. Unfortunately, nimblewill is difficult to establish and seed are frequently unavailable.





## 7.7.11 Japanese Beetle

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The Japanese beetle, *Popillia japonica* Newman, is a minor pest of peaches. However, if adults are abundant and feeding on fruit, they should be controlled. Japanese beetle is a destructive introduced pest that was first found in the United States in New Jersey in 1916. In its native Japan, where the beetle's natural enemies keep its populations in check, Japanese beetle is not a serious plant pest. In the United States, the Japanese beetle found a favorable climate and an abundant food supply with a near absence of its natural enemies. It infests much of the southeastern United States.

### DESCRIPTION

The life stages of the Japanese beetle are typical of white grubs. The white oval eggs are usually about 1/16 inch (2 mm) long. Eggs are placed in the soil where they absorb moisture, become rounder, mature, and hatch. The larvae are white grubs that can be separated from other soil-



**FIGURE 7.7.11.1. Adult Japanese beetle.**

dwelling white grubs by the presence of a V-shaped series of bristles on the abdomen or raster. First instar larvae are 1/16 inch (2 mm) long, while the mature third instars are about 1-1/4 inch (32 mm) long. The pupae are light reddish brown, about 1/2 inch (13 mm) long and 1/4 inch (6 mm) wide. The adults (Figure 7.7.11.1) are a brilliant, metallic green color, generally oval in outline, 3/8 inch (9 mm) long and 1/4 inch (6 mm) wide. The wing covers are copper brown, and the abdomen has a row of five tufts of white hairs on each side. These white tufts are diagnostic. The males have a sharp tip on the foreleg tibia, while the female's tibia has a long rounded tip.

### SEASONAL HISTORY AND HABITS

The Japanese beetle overwinters as a partially grown grub in the soil. This beetle completes one generation each year. Larvae mature from late April to late May. They pupate, and the adult beetles emerge from mid-May through July, with a peak in July. On warm sunny days, the new beetles crawl onto low growing plants and warm for a while before taking flight. Adults live four to six weeks. The first beetles out of the ground seek out suitable food plants and begin to feed as soon as possible. These early arrivals release an aggregation pheromone (odor). This odor attracts additional adults, which gather in masses to feed. In cool weather, the adults may feign death by dropping from the plants when disturbed, but normally they will take flight. Newly emerged females release a sex pheromone to attract males. Mating is common in pastures and on the food plants. After feeding for a day or two, the females leave feeding sites in the afternoon and burrow into the soil to lay eggs at a depth of 2 to 4 inches. Females may lay 1 to 5 eggs scattered in an area



before moving. Egg-laying females may leave the following morning or linger for a day or two before returning to feed and mate. This cycle of feeding, mating, and egg laying continues until the female has laid 40 to 60 eggs. Most of the eggs are laid by mid-August. If the soil is sufficiently moist, eggs will swell in a few days. Egg development varies from 8 to 30 days. Larvae dig to the soil surface where they feed on roots and organic material. Where Japanese beetle larvae are abundant in grasses, their tunneling creates a soft, spongy feel underfoot. Generally, grubs are in the third instar by early fall and are ready to dig into the soil to hibernate. Grubs can burrow up to 4 to 8 inches into the soil in colder regions. Grubs are closer to the surface when soil temperatures are moderate. Grubs can be expected at the surface when surface soil temperatures reach 60°F. Grubs continue development in the spring, forming pre-pupae from May into June. The pre-pupa voids its gut contents and has a translucent appearance. The pupa is formed in the split skin of the pre-pupa in an earthen cell 1 to 3 inches beneath the soil surface.

## PLANT INJURY

Japanese beetles feed on over 400 species of broad-leaved plants, but some 50 species seem to be preferred. Adults are primarily leaf skeletonizers; they eat the leaf tissue between the veins, leaving the veins behind. Attacked leaves are lace-like, and often wither and die. The adults also attack flower buds and fruit. Commonly attacked hosts include peach, cultivated and wild grapes, raspberry, plum, rose, apple, cherry, corn, soybean, Virginia creeper, hibiscus, marshmallow and Indian mallow, hollyhock, dahlia, zinnia, elm, horse chestnut, linden, lombardy poplar, willow, crapemyrtle, bracken and sensitive fern, elder, evening primrose, sassafras, and smartweed. The grubs will feed on a wide variety of plant roots, including grasses, ornamental trees and shrubs, and garden and truck crops. Japanese beetle larvae especially relish tall fescues, perennial ryegrasses, Kentucky bluegrass, and bent grass. The grubs can kill small seedling plants, but most of their damage occurs in grasses. Heavily infested turf feels spongy underfoot and can be easily

pulled back like old carpet to reveal the grubs. Large populations of grubs kill the turf in irregular patches.

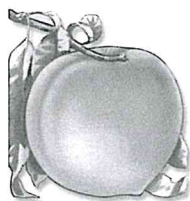
## CONTROL

Japanese beetle adults are easily seen. The lace-like appearance of foliar feeding and the occasional fruit feeding are also easy to detect. Regular orchard monitoring for cultural and pest evaluations should detect Japanese beetles before serious injury occurs. When Japanese beetles are readily evident, begin checking fruit for damage. Apply insecticide sprays if significant new damage is present and repeat sprays if additional fruit damage continues. Cover sprays are typically helpful in controlling or suppressing Japanese beetles. It may be necessary to apply additional insecticide if feeding Japanese beetles are abundant.

Traps are of limited value because they capture beetles from up to a mile away. To assure reliability, traps must be emptied every other day to prevent rotting beetles from releasing ammonia, which actually repels Japanese beetles.

Several parasitic wasps, especially *Tiphia popillivora* and *T. vernalis*, and the winsome fly, *Hyperecteina aldrichi*, have been imported and are now established in several eastern states. Unfortunately, these parasites do not seem to be reliable in reducing Japanese beetle populations below damaging levels, although the *Tiphia* appear to be more efficient in southern states.





## 7.7.12 Green June Beetle

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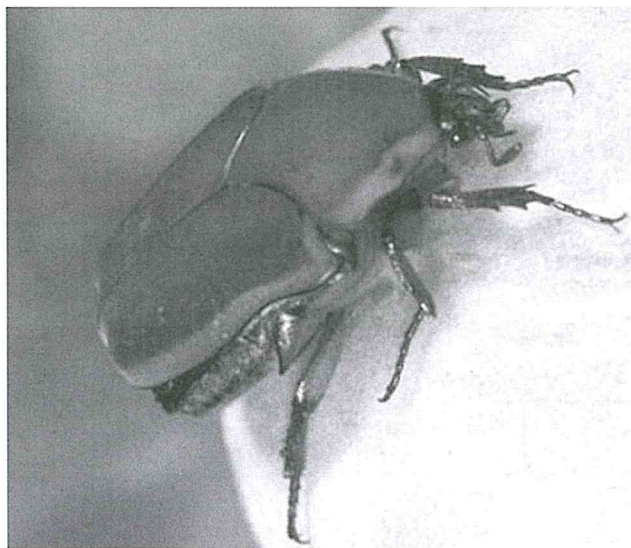
**G**reen June beetle, *Cotinis nitida* L., adults feed with enthusiasm on ripening stone fruit. Green June beetle is native to the United States in an area bounded by Texas, Nebraska, New York, and Florida. The insect was first described as a pest of tobacco and truck crops in the early 1900s. Green June beetles lay their eggs in the soil, preferring soils rich in decaying organic matter, which makes up a large part of the grub's diet. Manures of all sorts and high organic matter soil amendments encourage green June beetle infestations. The fruit-feeding adults are typically most abundant where highly fertilized pastures are adjacent to orchards. Although green June beetle grubs prefer to feed on decaying organic matter, their surface-burrowing behavior also damages grasses and turf.

### DESCRIPTION

Green June beetle adults are velvet green with orange- or rust-colored stripes along the outer margins of the wing covers (Figure 7.7.12.1). Beetles may be nearly 1 inch (25 mm) long. Green June beetle grubs are white, have six legs, grow up to 2 inches (51 mm) long, and about 1/2 inch (13 mm) thick. Grubs have the unique behavior of crawling on their backs as they work their way into and through the soil. This movement easily distinguishes them from other white grubs in the soil at the same time of year. When disturbed, the grubs curl up into a C-shape, typical of the grubs in their family, the scarab beetles.

### SEASONAL HISTORY AND HABITS

The green June beetle completes one generation each year. It overwinters as a partially grown larva. Grubs can burrow as deep as 10 inches in the soil, but they are frequently active at the surface when the surface soil temperatures reach 60°F. Surface feeding may occur in January or February from Alabama to Georgia and as late as April in Arkansas. Disturbed soil surface, with excrement similar to mouse droppings, may be visible in lush grassy areas where manure piles have decomposed. Grub activity increases as spring weather becomes consistently warmer. In May and June, larvae form a soil cell at a depth of 2 to 6 inches. They pupate inside and remain in the pupal stage for 2 or 3 weeks. Adults mature, but remain in the soil cell for an additional week or two. From late June through July, waves of adult emergence occur after rains soften the soil. As they emerge, females release sex pheromone (calling) to attract males from mid-morning to



**FIGURE 7.7.12.1. Adult green June beetle. (color plate, page 278, Figure 7.7.12.1)**



mid-afternoon. Adult males fly in a zigzag fashion waist-high over pastures in search of females. After mating, the female flies close to the turf surface and selects a moist site with high organic matter, such as decomposed manure piles or decomposed hay. She digs 5 inches into the soil, constructs a walnut-sized ball of soil and inserts 10 to 30 eggs into the ball. Eggs are initially oblong. If the soil is sufficiently moist, eggs will swell, become round, and double in size to about 1/16 inch (2 mm) diameter. The cycle of feeding, mating, and egg laying continues until the female has laid up to 100 eggs. Eggs hatch in about 2 weeks. Newly hatched grubs are about 3/8 inch (9 mm) long. Young grubs tunnel to the surface where they feed on organic matter at night and move down the tunnel during the day. As the soil cools in the fall, grubs move into the soil and overwinter.

## PLANT INJURY

Adult green June beetles mate, lay eggs, and feed on sap and ripe fruits. Beetles feed in groups that readily devour fruit (Figure 7.7.12.2). Beetle excrement fouls fruit. Green June beetles most often reach economically damaging levels where pastures are adjacent to orchards. Feeding on fruit extends adult longevity and results in

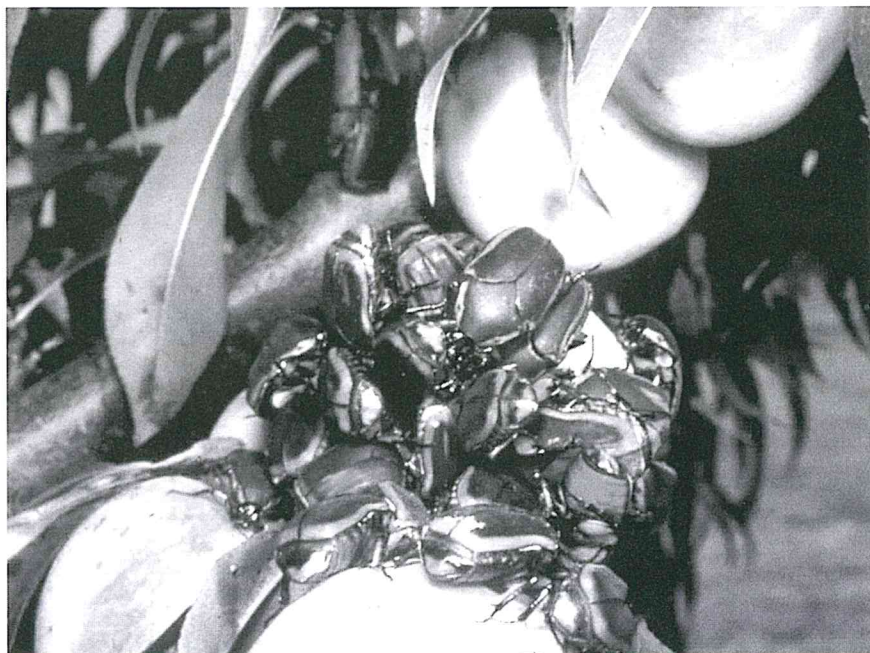
increased egg-laying capacity. Once a sweet food source is located, the adults feed and emit an aggregation odor that attracts more adults to feed as a group. It becomes difficult to prevent fruit damage because adults continuously move into a fruit planting. Control is necessarily dependent on insecticides with short pre-harvest intervals before beetle populations reach critical levels.

Grubs feed on organic matter at the soil surface. A small amount of green June beetle tunneling helps aerate the soil; however, extensive tunneling can be quite harmful to turf and seedling plants.

## CONTROL

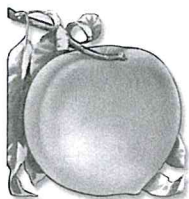
Normal orchard monitoring readily identifies green June beetle infestations in peaches. When adult green June beetle flights begin in adjacent pastures in late June or July, it is prudent to begin checking ripening peaches for beetle feeding. Some will find it useful to monitor for adult beetles by placing trays of fermenting fruit or watermelon on the orchard perimeter. Once adult June beetle flights begin, check several times a week for fruit feedings. Apply an insecticide when beetle attack first begins, and reapply if beetles continue to enter the orchard. Border sprays can be a valuable control option. Insecticide use must be carefully

timed to conform to pre-harvest intervals. Use of insecticide-treated fermenting fruit trays, placed every 50 feet around the orchard perimeter, can significantly reduce the number of beetles entering the orchard to damage peaches. It is, however, important to take care to avoid poisoning non-target species.



**FIGURE 7.7.12.2. Green June beetles on peach. Image by Clyde S. Gorsuch.**





## 7.7.13 Driedfruit Beetle

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**D**riedfruit beetle, *Carpophilus hemipterus* (Linnaeus), and other nitidulids are sap beetles (Family: Nitidulidae). Sap beetles are attracted to wounds in trees or fruits, where they feed on plant juices associated with wounded tissue. Sap beetles can be very abundant if injured, very ripe, or decaying fruit is common. Driedfruit beetles are secondary invaders; they attack peaches where the fruit's skin has been damaged by disease, other insects, or mechanical injury. They can spread disease by transporting fungi, bacteria, or other rot-producing organisms on their bodies. Adults are black, about 1/8 inch (3 mm) long, and have reddish legs. Their wing covers are short, exposing the rear portion of the abdomen. Each wing cover has a tan spot near its tip and a smaller spot near its base. Adults are strong fliers that readily move about to find injured or fermenting fruit in which to lay eggs. Females lay perhaps 1,000 eggs, which hatch in about two days. Larvae are slender, white, active grubs with brown heads that grow for one to two weeks, attaining a length of about 1/4 inch (6 mm). They leave the fruit and pupate in the soil. Sap beetles can complete a generation, from egg to adult, every three weeks under favorable weather conditions. Therefore, numbers can increase rapidly in infested areas.

In peaches and other fruits, driedfruit beetles and other nitidulids are most problematic when blocks are being picked the last time, owing to the diminishing of the last pre-harvest insecticide application. If high populations develop, additional sprays may be necessary. Control focuses on the adult beetles, as there are no controls for the internal feeding larvae. Baits are also used. Several applications at weekly intervals may be needed to kill adults as they emerge. Insecticides are only moderately effective if ripe fruit is constantly available. Sanitation in the form of picking, along with removal and destruction of infested fruit, drastically reduces sap beetles.





## 7.7.14 Shothole Borer and Ambrosia Beetles

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The shothole borer, *Scolytus rugulosus* (Müller), sometimes called the fruit tree bark beetle, is a native of Europe, but now occurs throughout the United States. It attacks a wide variety of deciduous tree fruits and other trees. Shothole borer infestations are usually associated with stressed trees; frequently, trees that are attacked are visibly stressed. Drought, disease, borers, scale, and other stresses predispose peaches to shothole borer attack. Enormous numbers of shothole borers can develop in the large limb piles (Figure 7.7.14.1) sometimes stacked adjacent to orchards.

Several species of ambrosia beetles attack peach trees. The four most common species attacking peach trees are *Xyleborinus saxeseni*, *Xylosandrus crassiusculus*, *Monarthrum fasciatum*, and *Ambrosiodmus tachygraphus*. *X. saxeseni* and *X.*

*crassiusculus* are introduced pests. *X. saxeseni* arrived from Europe in the early 1900s, and *X. crassiusculus*, a native of east Africa and southern Asia, was first reported in the United States in 1974 from Dorchester and Charleston Counties, South Carolina. The other two species are native to the United States. Ambrosia beetles also attack trees under stress. Stress factors associated with ambrosia beetles include low soil pH, poor fertility, cold injury, plant parasitic nematodes, and poor drainage. Ambrosia beetles may also develop in limb piles adjacent to the orchard. However, *X. crassiusculus*, frequently referred to as the Asian ambrosia beetle, very often attacks young trees with no apparent stress factors.

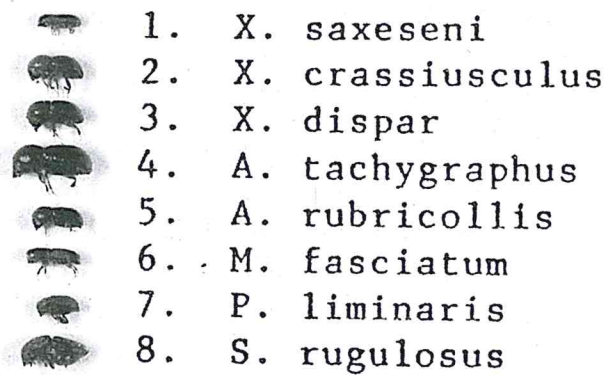
### DESCRIPTION

Adult shothole borers and ambrosia beetles are dark brown to black beetles. The shothole borer is blunt on both ends and about 1/10 inch (2.5 mm) long. The tips of the antennae, legs, and wing covers are reddish-brown. Wing covers are striated with rows of shallow punctures. The ambrosia beetles are similar in appearance, but are more rounded at the rear end than the shothole borer. Sizes range from slightly less than 1/10 inch (2.5 mm) to about 1/7 inch (3.8 mm). The larvae are similar, with a white body and a reddish head, legless, and about 1/8 inch (3.2 mm) long when fully grown. Adult ambrosia beetles and bark beetles are shown in Figure 7.7.14.2.

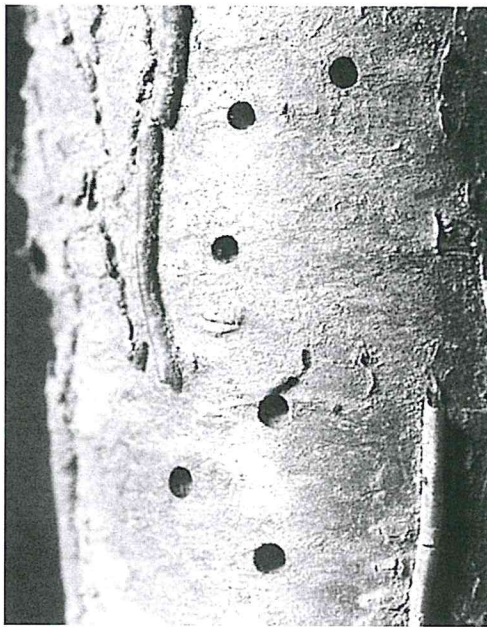


FIGURE 7.7.14.1. Shothole borer breeding site.





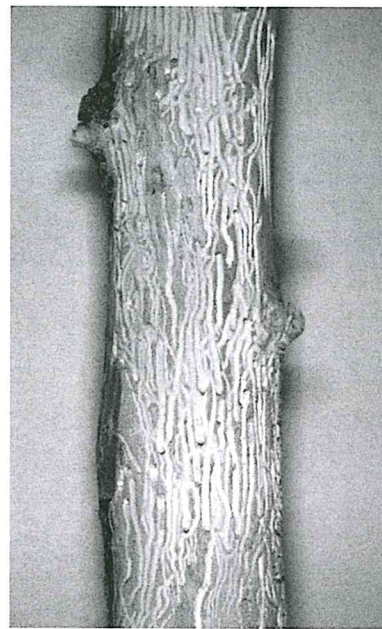
**FIGURE 7.7.14.2.** The common ambrosia beetles and bark beetles associated with peach trees. Image by Clyde S. Gorsuch.



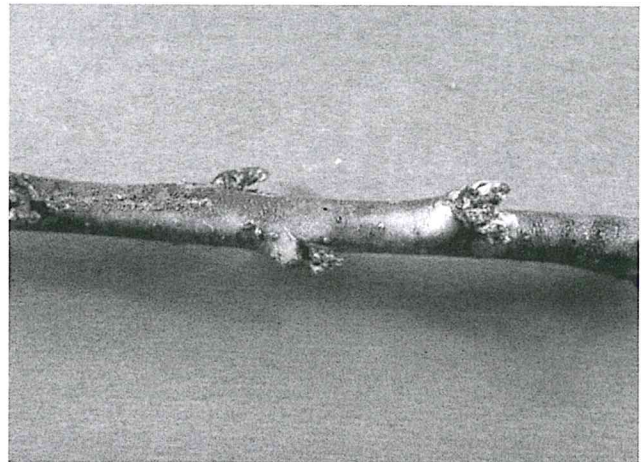
**FIGURE 7.7.14.3.** Shothole borer entry and exit holes, old wood.

### PLANT INJURY

Adult shothole borers drill holes, such as might be made by small birdshot, in the bark and wood of twigs, branches, and trunks of infested trees. The holes usually occur in clusters and may be either entrance holes or exit holes (Figure 7.7.14.3). Entrance holes are often near a lenticel and thus can be identified. Adults feed and reproduce beneath the bark. Shothole borer females create small tunnels about two inches in length, which usually run parallel with the grain (Figure 7.7.14.4). Larval galleries leave the main tunnel and radiate out across the grain. Galleries are



**FIGURE 7.7.14.4.** Shothole borer, adult galleries under the bark, parallel to grain. Image by Clyde S. Gorsuch.



**FIGURE 7.7.14.5.** Shothole borer will attack apparently healthy trees when beetles are very abundant, green wood is attacked at the buds, which often gum.

easily visible when the bark of infested trees is removed.

Shothole borer attacks are usually limited to visibly weak, declining trees. Infestations frequently hasten tree or limb death, but shothole borers are rarely the primary cause of tree death. However, where borers are very abundant, they will occasionally attack apparently healthy trees nearby. Attacks on healthy trees may be evident on small twigs where adults bore in or around buds (Figure 7.7.14.5). This injury usually is indicated by small droplets



of gum exuding from the tiny, round feeding sites. Buds are often destroyed and twig die-back can result.

Ambrosia beetles differ from bark beetles by boring through the bark and into the wood (Figure 7.7.14.6). Entry is usually at a lenticel. Galleries are excavated and, in the process, the female pushes sawdust-like particles from the entry hole. At times the sawdust forms strands that protrude from the hole like a toothpick (Figure 7.7.14.7). The female beetle carries a special fungus that is spread on the walls of the gallery. As the fungus colonizes the gallery walls, the female and the larvae feed on the fungus. The fungus also spreads into the xylem causing staining of the wood. Fungal growth can also plug the xylem, causing the limb or tree to die. In the spring, healthy, vigorous trees may produce enough sap to drown the female beetle and larvae. Many of these trees ultimately recover.

## SEASONAL HISTORY AND HABITS

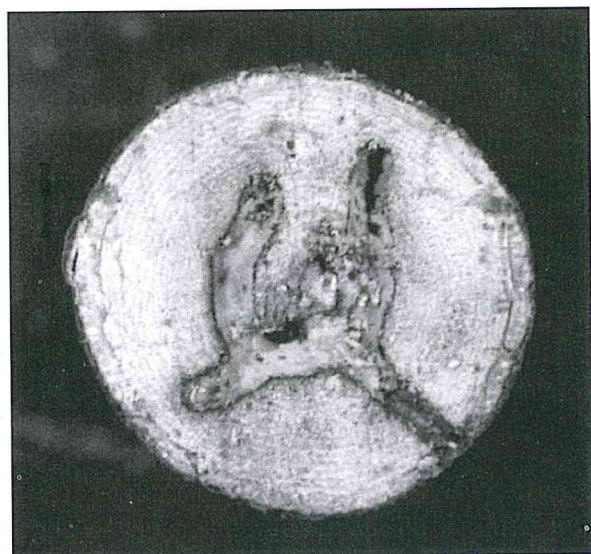
Shothole borers overwinter as larvae beneath the bark. They pupate in early spring and adults emerge, usually in April to May in the Southeast. Adults can fly considerable distances. Females mate, then locate and bore through the bark of

unhealthy trees. They excavate egg-laying tunnels beneath the bark that parallel the grain. Eggs are deposited along the sides of the parent gallery. Larvae hatch and burrow across the grain, away from the parent gallery. Larvae burrow and feed on sapwood for about a month. Larval galleries are usually packed with frass and sawdust. Parent galleries are clean. Pupation occurs at the end of the larval gallery and adults exit directly through the bark. Soon after emergence, beetles reinfest trees to deposit eggs for the next generation. There are two to four generations per year in the Southeast. Two generations or more may develop in a tree after it dies.

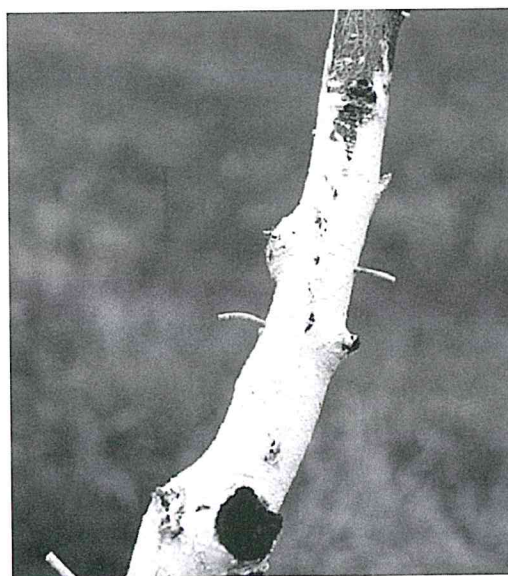
Ambrosia beetles may have one or more generations per year depending on the species. There usually is a significant emergence in the spring following several days of 70°F (21.1°C) temperatures. This usually is in early March. While *X. saxeseni* may have at least four major flights a season, *X. crassiusculus* has a major flight in early spring and very little activity during the season.

## CONTROL

Good cultural practices are the key in preventing shothole borer infestations. Keep trees healthy and vigorous. Eliminate breeding sites by removing



**FIGURE 7.7.14.6.** Ambrosia beetles tunnel through the bark and vascular tissues into the wood, ambrosia fungus may establish in the galleries. Image by Clyde S. Gorsuch.



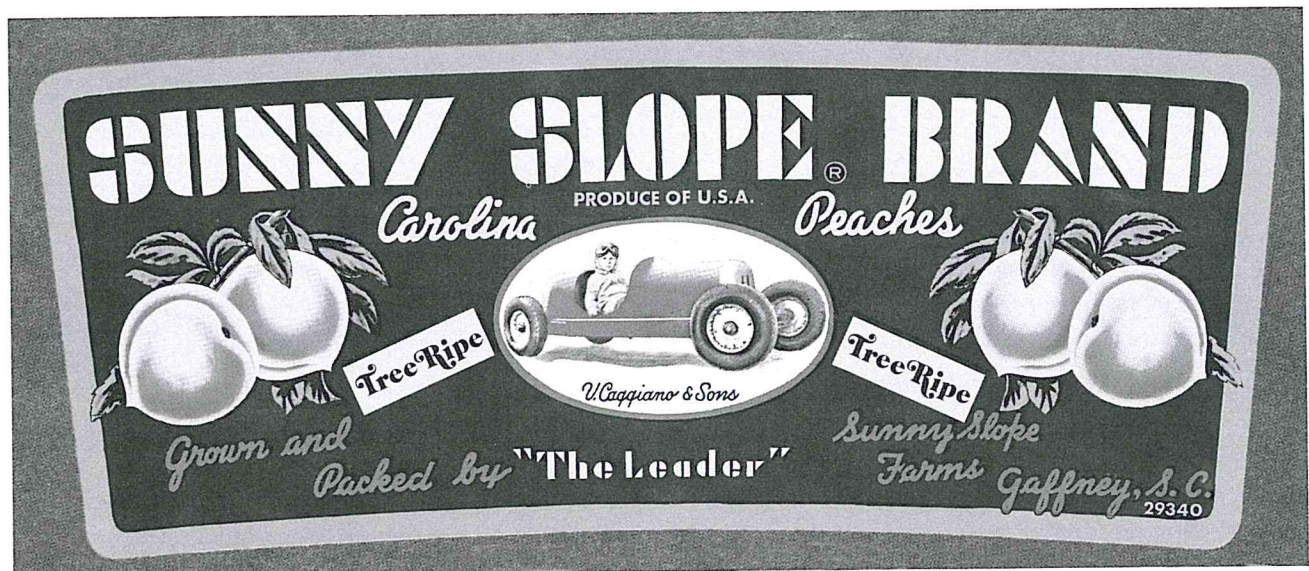
**FIGURE 7.7.14.7.** Sawdust "toothpicks" protruding from peach tree. Image by Clyde S. Gorsuch.



and destroying infested trees or limbs as soon as they are found. Prunings should be disposed of promptly. Pruning debris that is small enough should be flailed. Larger wood should be ground-up on-site, or removed and burned. Always destroy limb piles before adults emerge in March and April. Wild fruit trees and other potential breeding sites near the orchard should also be removed.

Painting tree trunks and scaffold limbs with whitewash or white water-based latex paint may help repel adult beetles, especially on young trees. Painting with latex paint may also prevent sun scald and winter injury that would attract beetles

the next season. Infested trees can be sprayed with a residual insecticide to prevent reinfestation by shothole borers. Insecticides have little impact on ambrosia beetles. There are no effective controls for shothole borers or ambrosia beetles already in the trees.



7







## 7.7.15 Peachtree Borer

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The peachtree borer, *Synanthedon exitiosa* (Say), is a serious tree-infesting pest of *Prunus* species that is native to much of North America. It is a pest of peach, plums, nectarines, cherries, and related plant species.

### DESCRIPTION

The adult of the peachtree borer is a clear-winged moth. The female moth is a rich dark blue, with a broad orange band around the abdomen (Figure 7.7.15.1). Forewings of the female are blue and opaque and the hindwings are clear except for their opaque blue margins. Female moths are slightly larger than males, having a wingspread of

about 1-1/4 to 1-1/2 inches (30 to 38 mm). Males have a wingspread of about 1 to 1-1/4 inches (25 to 30 mm). The male moth (Figure 7.7.15.2) is dark blue, with several yellow-white stripes around the abdomen. Its wings are clear with dark borders. The males of peachtree borer and either sex of lesser peachtree borer are quite similar in appearance. Characters for distinguishing the two species follow. Peachtree borer males: the tip of the abdomen has a triangular tuft of scales; when viewed from the front, mouthparts and front legs next to the thorax are white. Lesser peachtree borer males: the abdomen is pointed, the mouthparts are black, and the legs have white tufts of hair at joints.

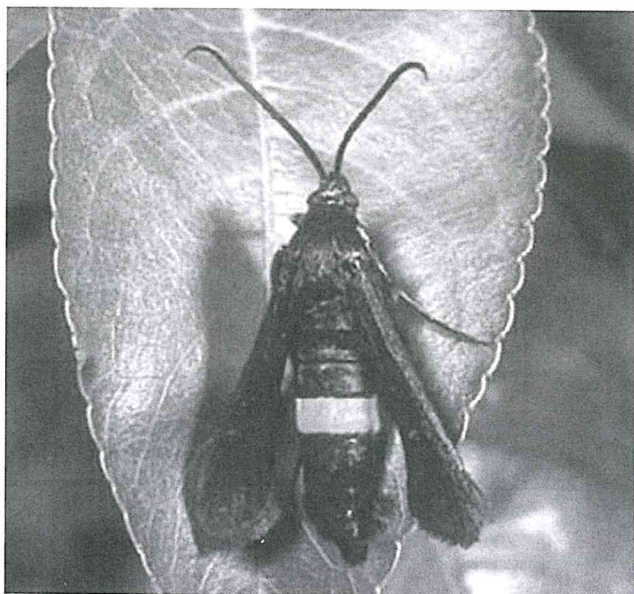


FIGURE 7.7.15.1. Adult female peachtree borer. (color plate, page 278, Figure 7.7.15.1)

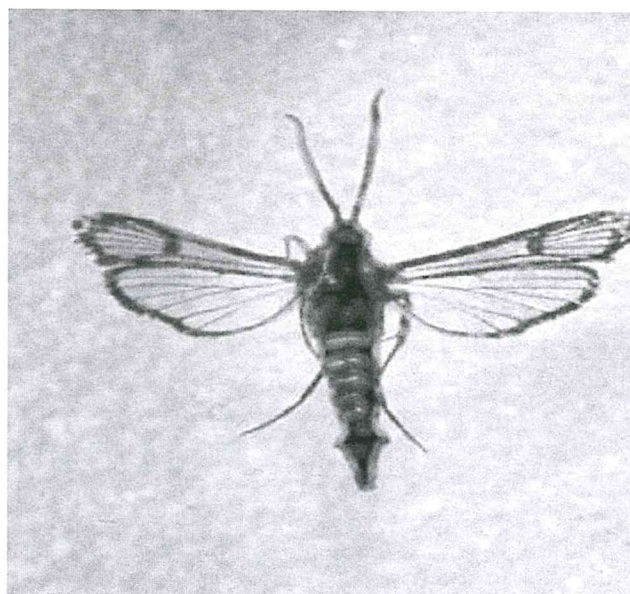


FIGURE 7.7.15.2. Adult male peachtree borer. (color plate, page 278, Figure 7.7.15.2)





**FIGURE 7.7.15.3. Larvae of peachtree borer. (color plate, page 278, Figure 7.7.15.3)**

Larvae are yellowish-white to cream-colored caterpillars with brown heads and are 1 to 1-1/4 inches (25 to 30 mm) long when fully grown (Figure 7.7.15.3). When larvae are about half grown, the plate just behind the head also becomes yellowish-brown. Like most caterpillars, peachtree borers have three distinct pairs of legs just behind the head, and short, fleshy prolegs on the third, fourth, fifth, and sixth abdominal segments.

### PLANT INJURY

Only the larval stage of the peachtree borer causes injury. Larvae burrow in and feed on the cambium and inner bark of trees, usually at the base of the trunk from three inches below to 10 inches above the ground line. They also feed on large roots that are near the soil surface. Larvae construct and feed in galleries. Accumulating gum, frass, and bark chips are pushed out of galleries to the outside (Figure 7.7.15.4). These masses are often the first evidence of infestation. Several larvae may develop in one tree. Young trees are particularly susceptible to borers; when infested they are unthrifty and grow poorly. Borers easily damage large portions of the vascular tissue in small trees; mortality is common in these instances. Older trees infested by borers may exhibit partial die-back, yellowing of foliage, stunted growth, and loss of vigor and productivity.



**FIGURE 7.7.15.4. Damage from peachtree borer. (color plate, page 278, Figure 7.7.15.4)**

### SEASONAL HISTORY AND HABITS

The peachtree borer usually passes the winter as a larva inside its burrow beneath the bark. Some larvae may overwinter in silken coverings or hibernaculae constructed on the bark outside their burrows. Larvae overwintering in their burrows may feed during warm periods. Overwintering larvae vary in size, depending on when they hatched during the previous season.

As larvae mature, they leave their burrows in the trees, move to just beneath the soil line, at or within four inches of the tree trunk, and construct silken cocoons in which to pupate. The cocoons are elongate, brownish, and about 3/4 inch (20 mm) long. The pupal stage lasts three to four weeks, averaging about 28 days. Just before adult emergence, the dark-brown pupa forces its way out of the cocoon. The empty pupal case generally remains, protruding partially above the soil surface after the moth emerges.

Adult peachtree borers begin to emerge as early as April or May and may be present in orchards through November. In Georgia's Fort Valley plateau, most peachtree borer moths emerge in July, August, and September, with peak emergence typically occurring in late August. In Georgia's primary coastal plain growing region, Brooks County, there is a period of heavy peachtree borer emergence in May and June, with the seasonal low of both peachtree borer and lesser peachtree borer moths in July and August. In the Georgia



coastal plain, a second major adult emergence begins in early September; it may last through early October. In Oklahoma and Arkansas, the borer flight begins in early May, with over 80 percent of the moths emerging from June through August.

Moths are active during the day, and mating pairs are not an uncommon sight in infested orchards. Females normally mate and begin to lay eggs within a few hours after emerging. Each female lays 200 to 800 reddish-brown eggs, averaging about 400. They are usually laid singly in cracks, under loose bark, near wounds, or other rough areas on tree trunks. Occasionally, eggs are laid on leaves, weeds, or soil near the base of the tree.

Eggs hatch in eight to ten days and the tiny 1/25 inch (1 mm) long larvae immediately burrow into the bark in the lower part of the tree. Under favorable conditions, the larvae attain considerable size in a few weeks. Larvae overwinter in the tree.

## CONTROL

Peachtree borers should be controlled with timely insecticide application(s) or by use of pheromone mating disruption. Young peach trees are particularly susceptible to borer injury. Trees are normally planted in the fall or winter, after the risk of borer infestation has passed in all but the warmest southeastern production areas. Newly planted trees should be protected from borers and other tree pests by handgun application of insecticide to the trunks. This application should be made before borers and scale become active in the spring. Young trees should receive an additional treatment late that first season by re-treating with an appropriate residual insecticide or use of pheromone mating disruption.

Pheromone traps do not provide control, but they are useful monitoring tools to follow the progress of adult borer emergence and to assess the relative abundance of borers. Monitoring helps improve the timing of control treatments.

A drenching trunk spray of long-residual insecticides applied using a handgun is the standard treatment for borer control. This spray establishes a residual insecticide barrier that is lethal to borer larvae for several months. Borer sprays in the Ft. Valley, Georgia, area should be applied in August. In Georgia's coastal plain growing areas, borer treatments should be made to control the first emergence peak in May and June. Most peach varieties grown in the coastal plain should be treated for borers immediately after they are harvested. Sprays made for white peach scale from mid-September to late October or a delayed dormant oil spray plus a residual insecticide will also provide helpful control of peachtree borers. In many southeastern production areas, early- and mid-season varieties could also be treated with trunk sprays after harvest, as emergence runs from June through August. In Arkansas, successful control was achieved with a trunk drench spray of a residual insecticide applied at bud swell.

Peachtree borers can also be controlled without use of an insecticide. Commercially available, artificial sex pheromone of the peachtree borer, 96:04 Z,Z:E,Z, normally released into the orchard atmosphere from 100 or more slow-release dispensers equally placed throughout the orchard canopy, saturates the site's atmosphere with the pheromone. Male and female borers use this pheromone, a volatile chemical emitted by receptive females, to locate one another for mating. The pheromone-saturated air confuses and repels the males. They respond by moving out and away from the pheromone-laden orchard. This tactic effectively disrupts and prevents peachtree borer mating.

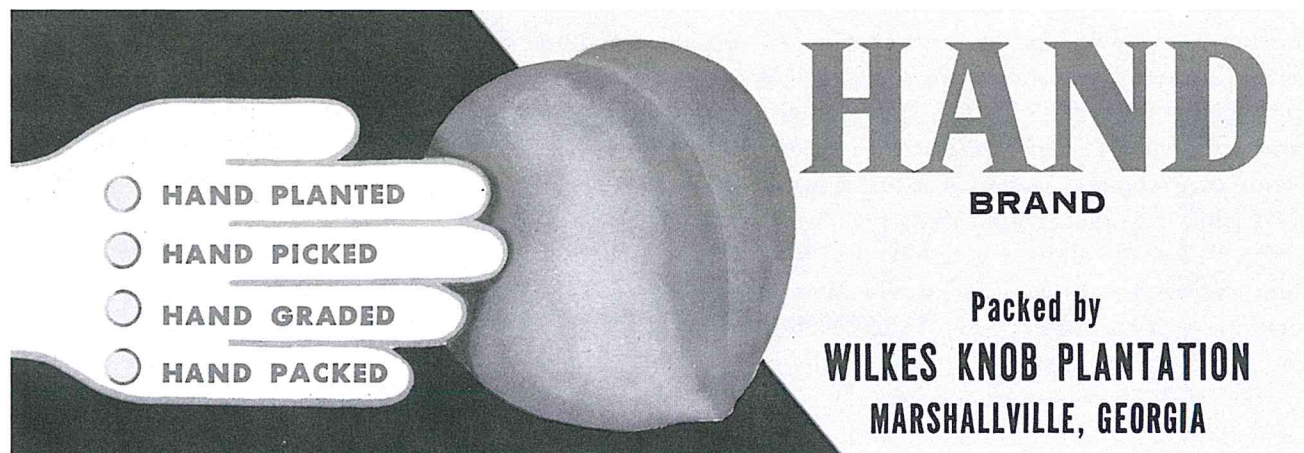


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7







## 7.7.16 Lesser Peachtree Borer

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The lesser peachtree borer, *Synanthedon pictipes* (Grote & Robinson), like its relative the peachtree borer, is a native insect that is an important pest of native and introduced *Prunus* species. Lesser peachtree borer is found in most peach-growing areas east of the Rocky Mountains.

### DESCRIPTION

Lesser peachtree borer adults (Figure 7.7.16.1) are metallic, blue-black, clear-winged moths that somewhat resemble dark wasps. They have a wingspread of about 3/4 to 1-1/4 inches (19 to 30 mm). Males and females are similar in appearance; both sexes resemble male peachtree borer moths (Figure 7.7.16.2). Yellow crosswise bands are usually present on the second and fourth abdominal segments, although the second band may be indistinct. The wings are clear except for dark borders. In male lesser peachtree borers, the tip of the abdomen is pointed; the abdomen of peachtree borer males ends in a triangular tuft of scales. Lesser peachtree borer larvae are creamy-white caterpillars with dark-brown heads, and are very similar to, but smaller than, peachtree borer larvae. They are about 1 inch (25 mm) long when fully grown. Larval feeding habits and appearance are almost identical to those of the peachtree borer larvae, but lesser borers are usually found higher in the tree. Lesser peachtree borer larvae will attack any above-ground structural wood.

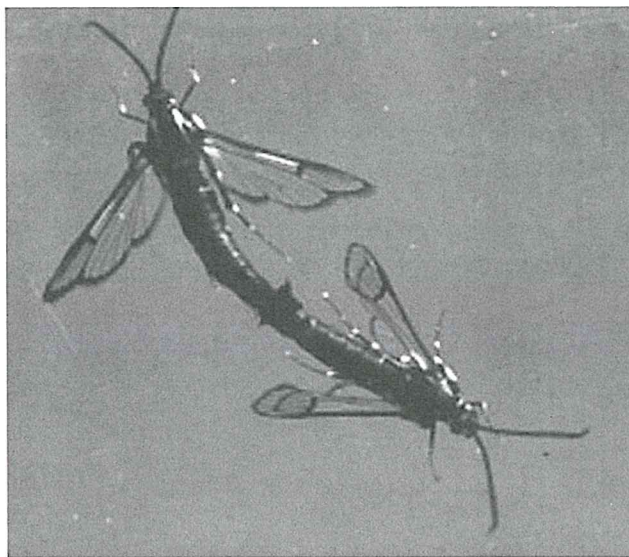


Figure 7.7.16.1. Adult lesser peachtree borer.

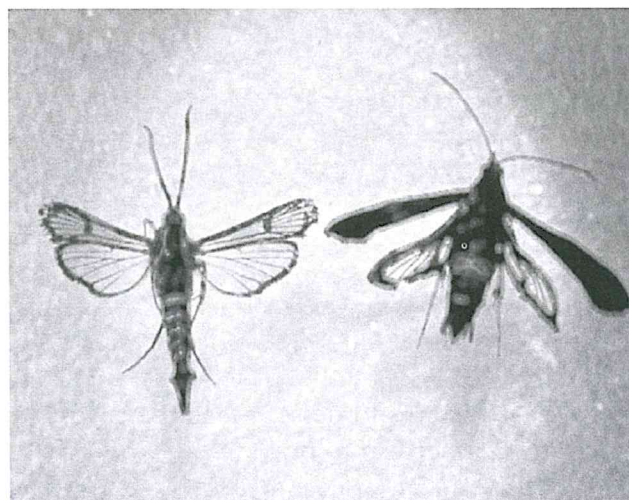


Figure 7.7.16.2. Adult peachtree borer.



## PLANT INJURY

Damage to trees is caused by the larval stage. Lesser peachtree borer larvae burrow, feed, and develop in the inner bark and cambium, primarily in the upper trunk and large branches. Masses of gum mixed with frass and wood borings normally exude from infested areas. Infestations are most common under loose bark in crotches and around wounds or cankers. "Bleeding" dark, dead, or swollen areas on the trunk or scaffold limbs may indicate infestations (Figure 7.7.16.3). Larval feeding can reduce tree vigor and weaken limbs, and damaged areas may provide entry sites for other pests, such as *Cytospora* canker or shothole borers. In heavily infested trees, large scaffold limbs may be completely girdled by borers and die. Lesser peachtree borer infestations frequently worsen as orchards age, because of the wounding inherent in heavy pruning and the overall weakening of trees as they age. Uncontrolled infestations are severely injurious and may render trees unsalvageable.

## SEASONAL HISTORY AND HABITS

Lesser peachtree borers overwinter as partially grown larvae in galleries beneath the bark. Overwintering larvae range in size from 1/4 to 1 inch (6 to 25 mm). They feed periodically during warm spells through the winter and complete development in the early spring. Older, more mature larvae may begin to pupate as early as January in the Southeast's warmer production areas. Prior to pupation, each larva constructs a hibernaculum, a silken, frass-covered protective structure, under the bark near the exit of its gallery. Pupation occurs in the hibernaculum. The mature pupa works its way out of its silken sac and partially through the bark. The empty light-brown pupal skin normally can be found protruding through the bark surface after moth emergence.

Emergence patterns for lesser peachtree borer adults differ according to region. In Georgia's lower coastal plain, adults may begin to emerge in January and February. The seasonal low of lesser peachtree borers and peachtree borer moths in the lower coastal plain may occur in August.



**Figure 7.7.16.3. Larval feeding damage, "bleeding limbs."**

Emergence of lesser peachtree borer normally peaks again in the coastal plain by late August or early September. It lasts until cold weather forces it to a halt, normally sometime in November.

In the fall-line production area of Georgia, South Carolina, and Alabama, lesser peachtree borer adults begin to emerge in March, but peak emergence of first brood lesser peachtree borer moths is typically in April and May. First brood emergence is normally over by mid-June. The second moth flight normally peaks between July and September.

Shortly after emerging, lesser peachtree borer females mate and begin to lay small, reddish-brown eggs along the trunk and limbs. Eggs are usually laid singly in cracks in the bark, frequently in the crotch. Females seem to prefer laying their eggs around wounds or injuries such as sunscald, winter injury, mechanical injury, broken or cracked limbs, *Cytospora* cankers, or existing borer infestations.

Eggs hatch in one to three weeks, depending upon temperature. Upon hatching, young larvae immediately bore into the bark. Larvae find it more difficult to establish in healthy undamaged bark. Most larvae feed and develop beneath the bark for about 40 to 60 days, then pupate to give rise to another brood of moths.

Larvae hatching from eggs laid by second brood moths normally overwinter. A few late first brood larvae may also overwinter.



## CONTROL

Lesser peachtree borer infestations are more common in poorly managed orchards of low vigor where limb breaks due to overloading with fruit or wind damage are left unattended. Proper canopy management and fruit thinning reduces an orchard's attractiveness to lesser peachtree borer. Presence of borers can be determined by inspecting scaffold wounds for the light brown pupal skins.

Adult populations should be suppressed either with well-timed, residual insecticide applications or by use of pheromone mating disruption. Adult activity can be monitored using pheromone traps. In southeastern production areas, in-season cover sprays, followed by handgun application of a residual insecticide after harvest, are the current standards for control of peachtree borer and, to some extent, scale and lesser peachtree borer. In the coastal plain, populations of both lesser and greater peachtree borer species and scale are often high. Additional control of these three pests can be gained by use of a residual insecticide with superior oil at delayed dormant. Delayed dormant

drench application of a residual material to trunks and scaffold wounds is an effective alternative against both borer species. In many instances, mating disruption may be a viable control option. Please refer to the peachtree borer chapter for discussion of mating disruption.

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# SOUTHEASTERN PEACH GROWERS' HANDBOOK

## 7 • INSECTS AND MITES

### Color Plates



**FIGURE 7.7.1.2.** Green peach aphids with lacewing larvae predator.



**FIGURE 7.7.2.1.** Western flower thrips.



**FIGURE 7.7.2.2.** Russetting from early-season thrips injury, primarily during bloom. Image by J. A. Payne.



**FIGURE 7.7.2.3.** Silvering caused by thrips feeding on maturing fruit. Image by J. A. Payne.





**FIGURE 7.7.4.1.** Armored scale insect (San Jose peach scale).



**FIGURE 7.7.4.2.** Armored scale insect without protective covering.



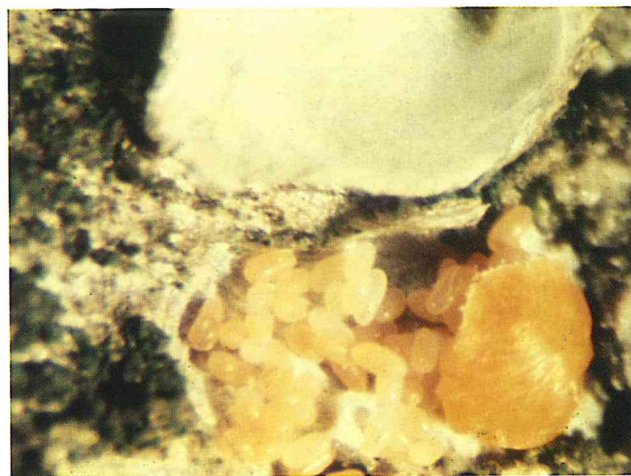
**FIGURE 7.7.4.3.** Soft scale insect (terrapi scale).



**FIGURE 7.7.4.4.** Various instars of Comstock mealybugs. Image by Juang-Horng Chong.



**FIGURE 7.7.4.5.** Recently settled white peach scale crawlers; females (translucent cream), males (pink).



**FIGURE 7.7.4.8.** Female white peach scale cover with eggs.





**FIGURE 7.7.4.9.** White peach scale crawlers (males pink, females translucent).



**FIGURE 7.7.5.2.** Adult leaffooted bug.



**FIGURE 7.7.5.3.** Stink bugs. Image by J. A. Payne.



**FIGURE 7.7.6.1.** Adult plum curculio.



**FIGURE 7.7.6.2.** Larval plum curculio.

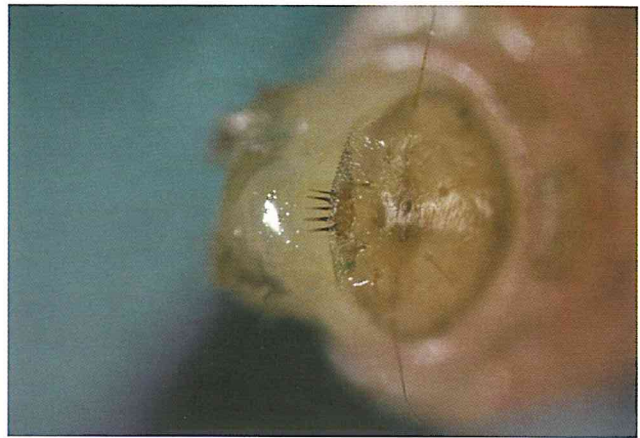


**FIGURE 7.7.6.3.** Egg deposition by plum curculio on peach. "Silvering" of the fruit surface is pre-harvest thrips injury. Image by J. A. Payne.





**FIGURE 7.7.1.** Adult oriental fruit moth. Image by Jack Kelly Clark.



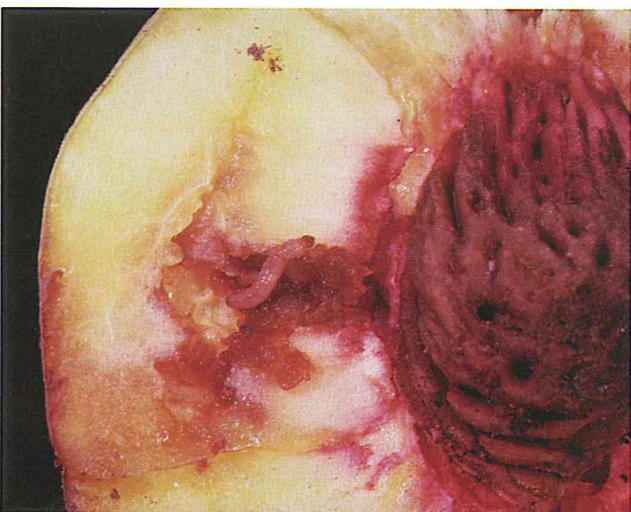
**FIGURE 7.7.2.** Anal comb of oriental fruit moth larva. Image by Jack Kelly Clark.



**FIGURE 7.7.3.** Flagging damage by oriental fruit moth larvae.



**Figure 7.7.4.** Oriental fruit moth larva in stem. Image by Jack Kelly Clark.



**FIGURE 7.7.5.** Fruit damage by oriental fruit moth larvae. Image by Jack Kelly Clark.



**FIGURE 7.7.8.1.** Peach twig borer larva. Image by Jack Kelly Clark.





**FIGURE 7.7.8.2.** Peach twig borer hibernaculum, a silk-lined cell in which larvae overwinter. Image by Jack Kelly Clark.



**FIGURE 7.7.9.1.** Glassy-winged sharpshooter, *Homalodisca coagulata*. Image by Jeff Brushwein.



**FIGURE 7.7.10.2.** European red mite female. Image by Jack Kelly Clark.



**FIGURE 7.7.10.3.** Twospotted spider mite summer coloration. Image by Jack Kelly Clark.

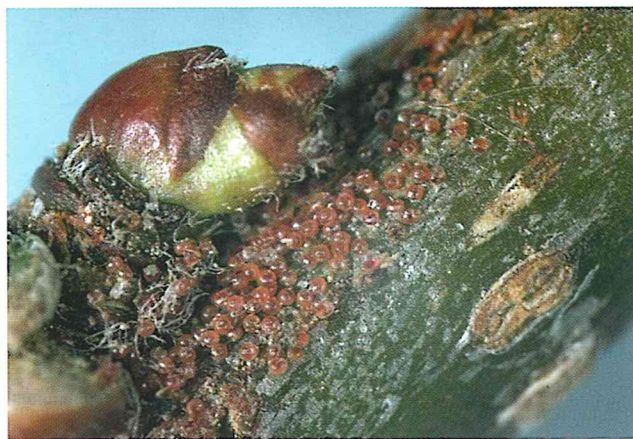


**FIGURE 7.7.10.4.** Leaf damage caused by mites. Bronzing on the top, light damage on the center, and a normal leaf on the bottom.



**FIGURE 7.7.10.5.** Webbing caused by twospotted spider mites.





**FIGURE 7.7.10.6.** European red mite eggs around a dormant bud. Image by Jack Kelly Clark.



**FIGURE 7.7.10.7.** Twospotted spider mite overwintering coloration. Image by Jack Kelly Clark.



**FIGURE 7.7.12.1.** Adult June beetle.



**FIGURE 7.7.15.1.** Adult female peachtree borer.



**FIGURE 7.7.15.2.** Adult male peachtree borer.



**FIGURE 7.7.15.3.** Larvae of peachtree borer.



**FIGURE 7.7.15.4.** Damage from peachtree borer.