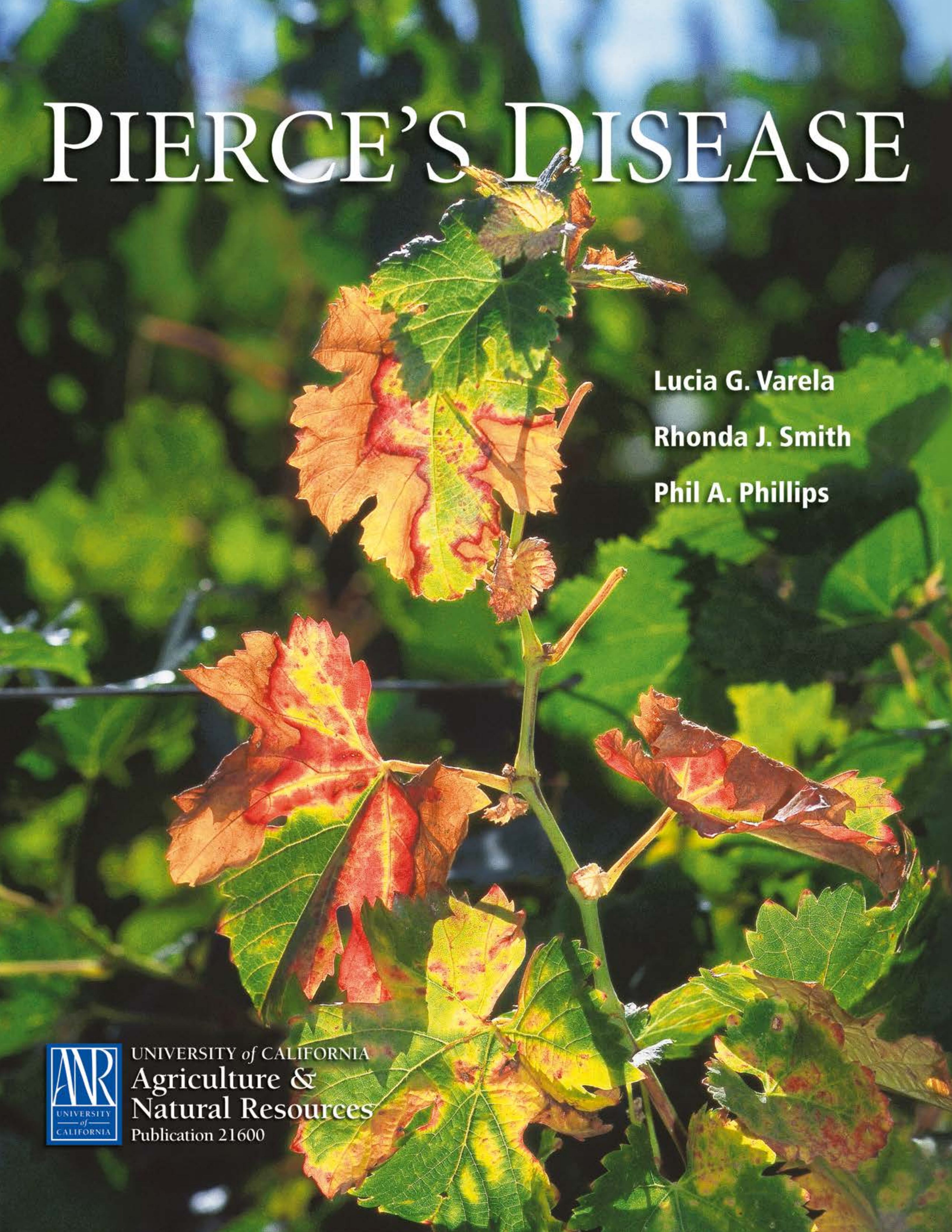
# PIERCE'S DISEASE



Lucia G. Varela
Rhonda J. Smith
Phil A. Phillips

UNIVERSITY of CALIFORNIA
Agriculture & Natural Resources
Publication 21600

# PIERCE'S DISEASE


**Lucia G. Varela**
Area Integrated Pest Management Advisor,
Cooperative Extension, Sonoma County

**Rhonda J. Smith**
Viticulture Advisor,
Cooperative Extension, Sonoma County

**Phil A. Phillips**
Area Integrated Pest Management Advisor,
Cooperative Extension, Ventura County

Contributor
**Alexander Purcell**
University of California, Berkeley



UNIVERSITY *of* CALIFORNIA
Agriculture & Natural Resources
Publication 21600

*The authors would like to thank Mary Bianchi, University of California Cooperative Extension Farm Advisor, San Luis Obispo and Santa Barbara Counties, for her review of the manuscript and suggested revisions.*

Credits: All photographs by Jack Kelly Clark
except for figure 7 by Phil A. Phillips.

For information about ordering this or other ANR Communication Services products, contact
University of California
Agriculture and Natural Resources
Communication Services
6701 San Pablo Avenue, 2nd Floor
Oakland, California 94608-1239
Telephone: 800-994-8849 or 510-642-2431
FAX: 510-643-5470
E-mail: danrcs@ucdavis.edu
Visit the ANR Communication Services website at http://anrcatalog.ucdavis.edu

Publication 21600



Printed in Canada on recycled paper.



7.5m-pr-1/01-GM/CO

# Contents

# INTRODUCTION

PIERCE'S DISEASE IS A SERIOUS BACTERIAL DISEASE THAT KILLS grapevines. It is caused by the bacterium *Xylella fastidiosa* that, once introduced, resides in the water-conductive system (xylem) of plants. The bacteria multiply in the xylem and block water movement in the plant. Diseased vines become nonproductive and may die just 1 or 2 years after infection. Currently, there is no known cure for the disease.

Pierce's disease has been present in California since at least the 1880s. In the past 100 years, it has periodically caused epidemic losses in coastal vineyards and in vineyards in the San Joaquin Valley. The bacteria are spread (vectored) from plant to plant by xylem-feeding insects such as sharpshooters. In the late 1990s, a new epidemic began in vineyards in the Temecula region of Southern California after the introduction of the glassy-winged sharpshooter, a new insect vector.

Pierce's disease is complex, and a number of factors are required for it to develop. In addition to the *X. fastidiosa* bacteria, factors include susceptible grapevines, alternative host plants and favorable environmental conditions for the bacteria, xylem-feeding insects, and insect host plants.

Most vineyards do not have all of these elements. Presently, Pierce's disease occurs most commonly near riparian areas and ornamental plantings in coastal California, near weedy crop fields or pastures in the San Joaquin Valley, and adjacent to citrus orchards or other habitats where the invading glassy-winged sharpshooter has established permanent populations.

# Symptoms of Pierce's Disease

Grapevines with Pierce's disease appear water-stressed. Symptoms of Pierce's disease first appear in mid to late summer and progress through the fall as evaporative demand increases. When a vine has mid- to late-season symptoms in one year followed by spring symptoms the following year, it is considered to be chronically infected. However, for positive identification of the disease, late summer or fall symptoms are more reliable than spring symptoms.

## Late Summer and Fall Symptoms during the First Year of Infection

Leaf scorching is the first symptom of Pierce's disease to appear midsummer. Leaf margins may become slightly yellow (chlorotic) and then die (see fig. 1), or they may suddenly become necrotic (see fig. 2). In either case the remaining part of the blade stays green. Red fruit varieties usually have some red discoloration (see fig. 3). Over a period of days or weeks, leaf margins progressively dry and then die. There is a wide variation in the expression of leaf symptoms, ranging from highly regular concentric zones of progressive marginal discoloration followed by necrosis (see fig. 1) to discoloration and necrosis occurring only in sectors of the leaf (see fig. 4). Scorched leaf blades abscise and fall, leaving the petioles attached to the cane (see fig. 5). Canes lignify irregularly, producing patches of green, surrounded by mature, brown tissue (see fig. 6). By late summer, berries in some or all fruit clusters may shrivel (see fig. 6), and shoot tips may die.

**Pierce's disease is probably present in your vineyard if you have the following four symptoms late in the season:**

- **Leaves scald in concentric rings or in sections.**
- **Leaf blades abscise, leaving petioles attached to the cane.**
- **Bark matures irregularly.**
- **Fruit clusters shrivel or raisin.**

It takes about 5 months for disease symptoms to appear (4 months in warm areas). Usually, only one or two canes show symptoms of Pierce's disease in the first season that a vine is infected, and this may not occur until late summer. However, in young vines, particularly in sensitive varieties, leaf symptoms may appear over the entire vine in a single season. In less susceptible varieties, late-season symptoms are less obvious or not present.

Normally, symptoms gradually spread along the cane from the point of infection out toward the end and more slowly toward the base. This has been the case for infections introduced by native sharpshooters that feed at the tip of the shoot. However, vines infected by the glassy-winged sharpshooter in Temecula frequently have leaf symptoms only at the base of several or all canes during

**Figure 1.** Late summer and fall foliar symptoms for a white variety show that leaf margins become slightly yellow and then die, leaving concentric zones of progressive marginal discoloration.

**Figure 2.** In some cases the leaf may suddenly become necrotic without significant chlorosis while part of the blade remains green.

the first season of infection (see fig. 7). This may represent infections caused by glassy-winged sharpshooter feeding near the base of new canes.

Climatic differences among growing regions can affect the timing and severity of Pierce's disease symptoms. Hot climates accelerate symptoms due to moisture stress even when there is more than adequate soil moisture. In cool regions such as the southern coastal areas of Ventura, San Luis Obispo, and Santa Barbara Counties, mid- to late-season symptoms in the first season of infection have not been observed. In these areas the first symptoms are delayed until the following spring and manifest themselves as reduced shoot growth.

**Figure 4.** In some cases the chlorosis and necrosis occur only in sections of the leaf.

## Symptoms of Chronically Infected Vines

Delayed and stunted shoot growth occurs in the spring following infection. On cordons or arms that had symptomatic canes the preceding fall, new growth is delayed up to 2 weeks (see fig. 8). Delayed bud break may appear in vines that did not have obvious symptoms the preceding year. Some spurs or canes may fail to bud out or may have stunted shoots, often with shortened, zig-zag internodes. The first four to eight leaves on a shoot may have interveinal chlorosis (see fig. 9) and may be small and distorted or asymmetrical.

**Figure 3.** Late-summer and fall foliar symptoms for a red variety show that leaf margins become slightly red and then die, leaving concentric zones of progressive marginal discoloration.

**Figure 5.** The petioles of leaves remain attached to the cane after the leaf blades fall.

**Figure 7.** Young vines infected by the glassy-winged sharpshooter in Temecula show symptoms at the base of several canes.

**Figure 6.** Canes lignify irregularly, producing patches of green surrounded by mature, brown tissue. Clusters may shrivel and dry up.

**Figure 8.** The chronically infected vine, right, shows early spring symptoms of delayed and stunted shoot growth.

Later in the spring, vines infected with Pierce's disease have smaller canopies than healthy vines. By midsummer, leaf scorch symptoms reappear in basal leaves and progress toward the ends of the shoots (see fig. 10). As the infection progresses, the top of the vine dies, and scion or rootstock suckers may sprout from near the soil level (see fig. 11). These shoots initially have no symptoms of Pierce's disease, yet experience has shown that they are nevertheless infected.

Certain foliar symptoms of Pierce's disease can be confused with other diseases or phenomena that affect vine growth (see table 1). In cooler coastal regions, Pierce's disease has been identified only after eliminating these other possible causes for observed symptoms.

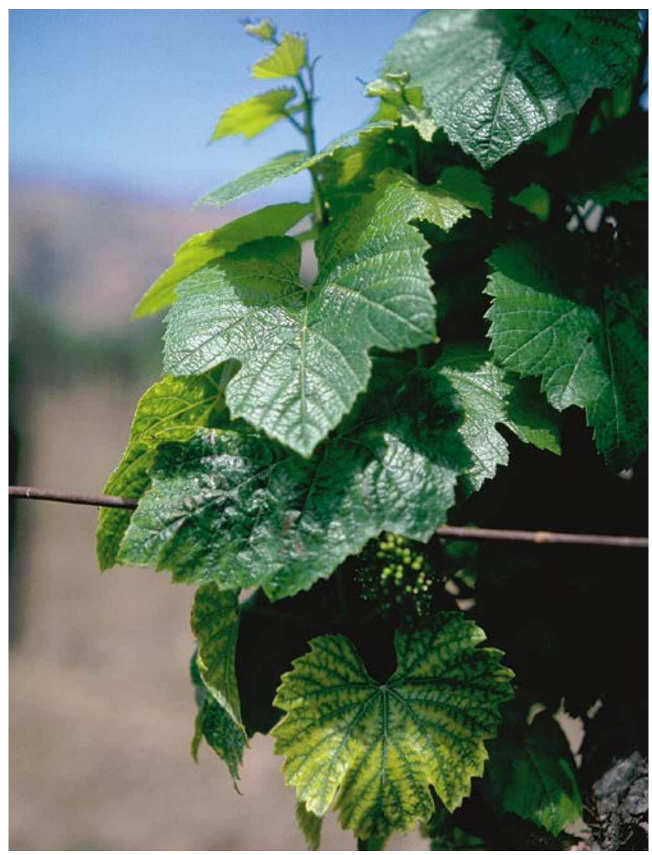


**Figure 9.** The first several leaves on a shoot with early-spring symptoms may be small and distorted with interveinal chlorosis.

**Figure 10.** The chronically infected vine, right, has a smaller canopy than the adjacent healthy vine, left.

**Figure 11.** As the infection progresses, the top of the vine dies while scion or rootstock suckers sprout from near the soil level.

**Table 1.** Grapevine diseases, pests, and nutrient imbalances that may produce symptoms similar to those caused by Pierce's disease

| Agent | Similar Symptoms | Distinguishing Features |
|---|---|---|
| Eutypa dieback | stunted shoots; small, chlorotic, and distorted leaves | associated with pruning-wound cankers (wedge-shaped discoloration in cross section) |
| Armillaria root disease (oak root fungus) | leaves turn red or yellow; uniformly weak and shorter shoots | examine trunk below soil line and roots for white plaque and shoestring-like fungal structures |
| Black measles | interveinal chlorosis that becomes necrotic | no irregular maturing of canes; berries may have dark spots |
| *Phylloxera* | stunted shoots | examine root tips for galls; bark sloughs off easily on older roots; no persistent petioles |
| Drought-induced early spring boron deficiency | delayed bud break; slow shoot growth; distorted shoots with short internodes; lower leaves may be fan shaped | shoot growth normal by late spring; no leaf scorching in the fall; uniform symptoms in a large area |
| Late spring boron deficiency | yellow mottling between leaf veins that may turn necrotic | shoot growth normal by midsummer without symptomatic leaves |
| Excess sodium or chloride in soil | marginal leaf burn | no irregular maturing of canes |
| Zinc deficiency | small, distorted leaves with interveinal chlorosis | leaf veins remain green; wide range of berry sizes; reduced berry set |

## Grapevine Susceptibility

All vinifera varieties are susceptible to Pierce's disease, but they vary markedly in levels of tolerance (see table 2). The bacteria spread more slowly in more tolerant varieties than in more susceptible varieties. In vineyards with a history of high incidence of Pierce's disease, even the most tolerant varieties have significant vine loss.

Young vines are more susceptible than mature ones, probably because very little wood is pruned from young vines. This causes more infected wood to be retained. It is also possible that the bacteria can move faster through younger vines than through older vines.

Both variety and age determine how long a vine with Pierce's disease can survive. One-year-old Chardonnay or Pinot Noir can die the year it becomes infected. Ten-year-old Chenin Blanc or Ruby Cabernet can live with chronic infections for several years, although it will not bear a full crop.

Rootstocks vary widely in susceptibility. For example, *V. rupestris* (St. George) is highly tolerant. However, rootstocks do not impart resistance to vinifera varieties grafted onto them.

**Table 2.** Tolerance levels of *Vitis vinifera* to Pierce's disease

| Most Susceptible | Less Susceptible | Most Tolerant |
|---|---|---|
| Barbera | Cabernet Sauvignon | Chenin Blanc |
| Calmeria | Crimson Seedless | Ruby Cabernet |
| Chardonnay | Flame Seedless | Sylvaner |
| Emperor | French Columbard | Thompson Seedless |
| Fiesta | Grey Riesling | White Riesling |
| Mission | Merlot | Zinfandel |
| Pinot Noir | Napa Gamay | |
| Red Globe | Petite Sirah | |
| | Ruby Seedless | |
| | Sauvignon Blanc | |

All *V. vinifera* varieties are susceptible to Pierce's disease, yet they vary markedly in levels of tolerance. Also, young vines of all varieties are extremely, and perhaps equally, susceptible to Pierce's disease.

# XYLELLA FASTIDIOSA

ONCE INTRODUCED, THE BACTERIUM THAT causes Pierce's disease, *Xylella fastidiosa,* lives in the xylem of plants and is spread from plant to plant by xylem-feeding insects. The chief function of xylem tissue is to transport water and minerals from the soil to aboveground plant organs. In infected grapevines, the bacteria multiply for several months and spread throughout the xylem, eventually blocking the movement of water. Thus, many symptoms of Pierce's disease resemble water stress.

There are different strains of *X. fastidiosa.* In addition to causing disease in grapevines, the Pierce's disease strain of the bacterium causes alfalfa dwarf disease and almond leaf scorch in California. It has also been found to multiply in many other plants without causing symptoms. A strain of *X. fastidiosa* that causes oleander leaf scorch, a disease first found in California in 1994, does not cause disease in grapes. In the eastern United States, various strains of *X. fastidiosa* cause phony peach disease and leaf scorch diseases in oak, elm, maple, mulberry, plum, and sycamore. In South America, strains of *X. fastidiosa* cause diseases in citrus, coffee, and plum. The relationship among the different strains is presently under investigation.

## Host Plants of *Xylella fastidiosa*

Many plants harbor *X. fastidiosa* without having symptoms of disease. The role that each plant species plays as a reservoir of the bacteria depends on how *X. fastidiosa*

## Diagnostic Tests for *Xylella fastidiosa*

Positive identification of *X. fastidiosa* can be accomplished by three methods: enzyme-linked immunosorbent assay (ELISA), a serological test; polymerase chain reaction (PCR) analysis, a molecular method; and culturing the bacterium on selective media. All these tests may be performed by some commercial laboratories. However, none of these methods distinguishes Pierce's disease strains of the bacteria from other strains of *X. fastidiosa,* such as the strain that causes oleander leaf scorch. The only way to determine if the bacteria are the Pierce's disease strain is to find disease symptoms expressed in grapevines.

The different diagnostic tests have certain advantages and disadvantages (see table 3). Positive test results from symptomatic vines are a good confirmation of Pierce's disease. Negative test results, however, do not mean that Pierce's disease is absent. In chronically infected vines, bacteria do not move into the new season's growth until midsummer. Testing of diseased vines before this time may yield false negative results. Also, the bacteria are not evenly distributed throughout the vine; therefore, even summer and fall sampling can result in false negative results if samples are not taken from symptomatic plant parts.

ELISA is based on using an antiserum to detect the presence of the bacterium and is the most common test available at commercial laboratories. This technique is used to confirm the presence of *X. fastidiosa* in symptomatic plants after June. It does not provide as sensitive a detection of the bacterium as PCR.

Specific parts of the bacterium's DNA are enzymatically amplified with PCR. This is the most sensitive technique for detecting small numbers of bacteria in plants and is primarily used in research. However, commercial laboratories may also provide PCR testing. The test is specific for *X. fastidiosa,* but it cannot determine if the bacteria are dead or alive or how many bacteria are present in the sample. For cultural diagnosis, a selective medium has been developed for isolating and growing the Pierce's disease bacterium from leaf petioles.

Make arrangements with the diagnostic laboratory for taking samples and shipping. Samples taken from August through October of symptomatic leaves that still contain some green tissue and are attached to the canes generally give the most reliable test results. Tag the samples and the plants from which they were taken in order to identify infected and uninfected plants.

**Table 3.** Advantages and disadvantages of diagnostic techniques used to detect *X. fastidiosa*

| Diagnostic Test | Advantages | Disadvantages |
|---|---|---|
| ELISA | fast, inexpensive | false positive possible, false negative possible |
| PCR | most sensitive | does not distinguish dead from live bacteria, expensive |
| Culture | false positive not possible | takes several weeks |

functions within the plant. *X. fastidiosa* acts differently in each plant species, depending on how rapidly the Pierce's disease bacterium can multiply, how the bacteria move within the xylem, and its maximum population density.

In most plant species, the bacteria multiply but remain localized as a "micro-site infection." These plants are referred to as propagative hosts. In other plants, the bacteria multiply and spread systemically, and they are known as systemic bacterial hosts. If the bacteria do not multiply in a plant, it is considered a nonhost because insect vectors cannot acquire the bacteria when feeding.

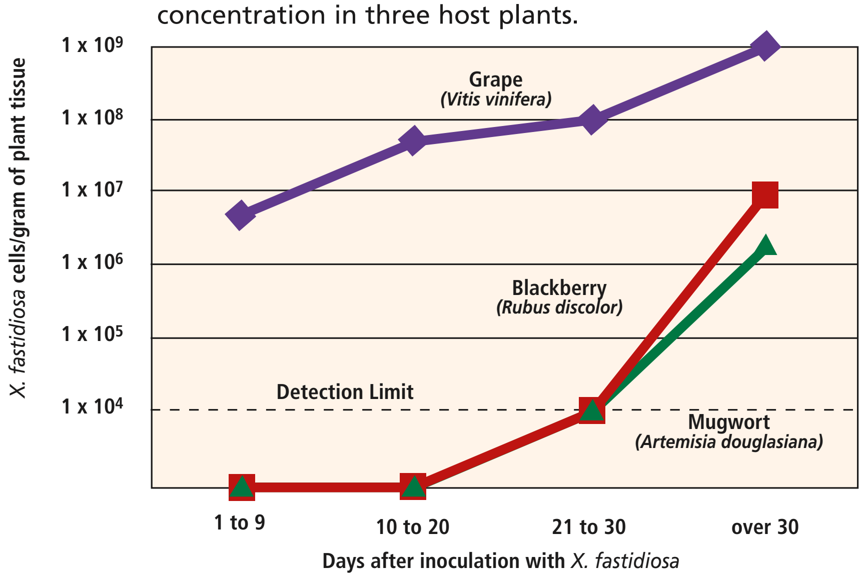
The more the bacteria multiply and move within the plant, the greater the probability that a vector can acquire it when feeding. For example, in the systemic bacterial host *Vitis vinifera*, the grape grown commercially in California, and in wild grape, the bacteria multiply quickly, spread systemically, and can reach concentrations of billions of live bacterial cells per gram of plant tissue (see fig. 12). In contrast, Himalayan blackberry *(Rubus discolor)*, which is also a systemic bacterial host, supports 10- to 1,000-fold fewer bacteria that move more slowly through the blackberry plant than through grape (see fig. 12).

In propagative hosts, sharpshooters can only acquire the bacteria by feeding on those parts of the plant where the bacteria were introduced. California mugwort *(Artemisia douglasiana)* is an example of a propagative host, and although it is not a significant bacterial reservoir, it is a common breeding host of the major vector (the blue-green sharpshooter) in coastal vineyards.

The role that a host plant plays as a reservoir and in the spread of the bacteria depends on whether it harbors the bacteria systemically and whether the insect vector feeds and breeds on it.

How *X. fastidiosa* functions within a plant has been determined only for relatively few plant species. Many ornamental plants are alternative hosts of *X. fastidiosa,* but, for most, it is unknown whether they are systemic or propagative hosts.

**Figure 12.** Variation and rate of increase in *Xylella fastidiosa* concentration in three host plants.



# Insect Vectors of *Xylella fastidiosa*

Xylem-feeding insects acquire bacterial cells while feeding on infected plants. Bacteria attach to the mouthparts and multiply, forming a bacterial plaque. During subsequent feeding, bacteria dislodge from the insect's mouth and enter the plant's xylem cells. Insect vectors capable of spreading X. fastidiosa belong to the sharpshooter subfamily in the leafhopper family (Cicadellidae) and the spittlebug (Cercopidae) family. The blue-green sharpshooter (*Graphocephala atropunctata*) (see fig. 13) is native to California and is the most important vector in coastal vineyards. The glassy-winged sharpshooter (*Homalodisca coagulata*) (see fig. 14) was introduced into southern California around 1989 and became the most significant vector in that region. Since then it has spread to several counties of the Central Valley. Major vectors in the San Joaquin Valley are the green sharpshooter (*Draeculacephala minerva*) (see fig. 15) and the red-headed sharpshooter (*Carneocephala fulgida*) (see fig. 16). They can also impact disease spread in coastal regions under some circumstances. Grape and variegated leafhoppers, common pests of grapevines, do not feed on xylem fluid and therefore do not spread the bacterium that causes Pierce's disease.

Since the xylem fluid is under negative pressure, insects tapping into it must have strong muscles to operate the sucking pump in their mouthparts. These bulky muscles give the face a swollen appearance (see fig. 17 and fig. 18), which differentiates them from other sucking insects.

Bacterial transmission to grape is extremely efficient for some vectors (see table 4). Sharpshooters and spittlebugs are able to transmit the bacteria almost immediately after acquiring them from an infected plant. Less than 100 bacteria per insect are required for efficient transmission. An infectious blue-green sharpshooter has more than a


**Figure 13.** Adult blue-green sharpshooter *(Graphocephala atropunctata).*


**Figure 14.** Adult glassy-winged sharpshooter *(Homalodisca coagulata).*


**Figure 15.** Adult green sharpshooter *(Draeculacephala minerva).*

90-percent chance of transmitting the bacteria during a day's feeding. An infectious glassy-winged sharpshooter has a 20-percent chance of transmitting the bacteria in the same amount of time.

Once the adult acquires the bacterium, the insect remains capable of transmitting it throughout its life. Immature insects are able to transmit until they molt, at which time the bacteria are shed with the lining of the mouth along with the outer skin. Newly molted insects have to reacquire the bacteria by feeding on an infected plant. The bacterium is not transferred from infected females to their eggs.

## Vector Descriptions and Life Cycles

### Blue-Green Sharpshooter

The blue-green sharpshooter adult is approximately ¼ inch (7 mm) long, dark-green to bluish-green, and has very characteristic black lines and spots on the back of the head and thorax and a yellow triangle between the wings. The legs and underside are light yellow (see fig. 13).

This vector has only one generation per year in most areas. Adults overwinter in riparian habitats but may also be distributed in low numbers in residential or commercial areas with trees and shrubs. Preferred breeding hosts in riparian habitats are Himalayan blackberry, California blackberry (*Rubus ursinus*), wild grape (*Vitis* sp.), periwinkle (*Vinca major*), California mugwort, stinging nettle (*Urtica dioica*), mulefat (*Baccharis salicifolia*), and blue elderberry (*Sambucus mexiana*).

Eggs are laid singly on green leaves and stems beginning in April, depending on temperature. Most adults (80 to 90 percent) breed in riparian areas. During the spring when temperatures exceed 60°F (15°C), a small proportion of adults migrate to vineyards that are immediately adjacent to riparian habitats. Their dispersal into a vineyard increases as natural vegetation dries up. These adults lay their eggs on vines that are within 300 feet (90 m) of the edge of the riparian vegetation. Most overwintering adults die by the end of June.

The flightless immatures (nymphs) (see fig. 19) emerge from late April or early May through July and remain on the same plant where they emerged from the eggs. Nymphs become adults between late June and the end of August. In summer, new adults move deeper into the vineyard than the original spring migration. At the beginning of September when grape foliage is less succulent, sharpshooters begin to move back into nearby natural habitats where they overwinter. Adults acquiring *X. fastidiosa* in the fall remain infective through the winter and spread the bacteria to new plants during the following spring.

### Glassy-Winged Sharpshooter

The glassy-winged sharpshooter adult is a large insect, almost ½ inch (13 mm) long (see fig. 14). It is dark brown


**Figure 16.** Adult red-headed sharpshooter *(Carneocephala fulgida).*

**Figure 17.** The side view of a glassy-winged sharpshooter shows the swollen face that is a distinguishing characteristic of the sharpshooter family.

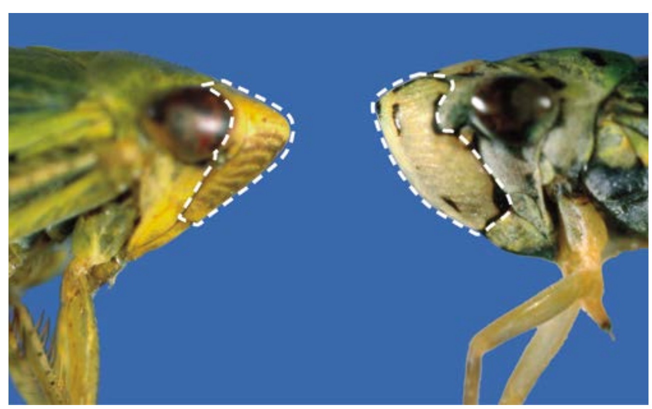


**Figure 18.** Sharpshooters belong to the leafhopper family but can be distinguished from other leafhoppers by the swollen shape of the face plate (highlighted by the dotted line). Side view of a grass-feeding leafhopper (left), *Thamnotettix zeleri,* and the blue-green sharpshooter (right).

**Figure 19.** Blue-green sharpshooter nymph.

**Figure 20.** The smoke tree sharpshooter ***(Homalodisca lacerata),*** left, is native to Southern California and is distributed from Riverside County to the Coachella Valley. This sharpshooter has wavy white lines on its head. The glassy-winged sharpshooter (right) is distinguishable by the numerous, small, ivory-to-yellowish spots on its head.

**Figure 21.** Glassy-winged sharpshooter nymph.

to black with a lighter underside. The upper parts of the head and back are stippled with ivory-to-yellowish spots (see fig. 20); the wings are partly transparent with reddish veins. The female secretes a white substance that she stores at either side of the wings, appearing as two large white spots. However, these spots eventually rub off as the female comes in contact with foliage.

The glassy-winged sharpshooter has two generations per year in Southern California. It reproduces on a large number of native plants, agricultural crops, ornamentals, and weeds. Oviposition (egg-laying) occurs in late February through May and again in mid to late summer. Eggs are laid in a mass on the underside of leaves, usually in groups of 10 to 12 eggs but ranging from 1 to as many as 30 eggs. The green, sausage-shaped eggs are laid beneath the epidermis. The upper leaf surface above an egg mass may be marked over time by a yellowish elongated blotch. After hatching, the old egg mass appears as a tan to brown scar. Nymphs (see fig. 21) go through five immature stages, and the first-generation adults begin to appear in May through late August. Second-generation egg masses are laid June through late September and develop into overwintering adults.

**Green and Red-Headed Sharpshooters**

The green sharpshooter is approximately 5⁄16 inch (8 mm) long, green on the top side with tan to dark brown legs and underside (see fig. 15). The smaller males have black undersides. In some parts of Central California, adult green sharpshooters are brown during the fall. The red-headed sharpshooter is approximately 1⁄5 inch (5 mm) long, with green wings and thorax (see fig. 16). The sharply pointed head is a reddish color at its apex. Both species feed primarily on grasses. The green sharpshooter breeds and feeds on watergrass *(Echinochloa crusgalli),* bermudagrass *(Cynodon dactylon),* perennial rye *(Lolium perennae),* and fescue grass (*Festuca* sp.). The red-headed sharpshooter breeds and feeds primarily on bermudagrass and is not as common as the green sharpshooter.

The green sharpshooter has three generations per year while the red-headed sharpshooter has four. Both overwinter as adults and lay eggs from late February to early March. The overwintering adults do not live long (no later than March or April); thus, it is probably the first generation of the season that migrates to neighboring vineyards in largest numbers.

## Vector Habitat

Most xylem-feeding insects require succulent plant tissue or rapidly growing plants as food sources. These plants are found primarily in habitats where soil moisture promotes vigorous plant growth. Grapevines are a good feeding host for the vectors because they are pruned every year, thus producing succulent new growth annually.

In coastal regions, riparian vegetation is the principal breeding habitat for blue-green sharpshooters (see table 4), which have been collected from over 150 species of plants. These insects shift their feeding preferences during the year, always preferring succulent plant growth. Blue-green sharpshooters can also be found in ornamental landscaping in parks and near residences or commercial buildings. When pruned in the winter, woody ornamentals produce spring growth that is very vigorous and succulent. Insects are attracted to this growth even when the same plants would otherwise be minor feeding hosts. For example, live oaks are normally an occasional feeding host for the blue-green sharpshooter in the spring; however, if they are heavily pruned, this insect finds the suckers highly

**Table 4.** Pierce's disease vectors: Bacterial transmission efficiency, habitats, and monitoring methods

| Vector | Blue-green sharpshooter | Glassy-winged sharpshooter | Green sharpshooter | Red-headed sharpshooter | Spittlebugs |
|---|---|---|---|---|---|
| **Bacteria transmission efficiency** | high | low | low | high | high |
| **Breeding habitat** | riparian areas, some ornamental landscapes | crops, riparian areas, ornamental landscapes, native woodlands, weeds | grasses in wet areas | grasses in wet areas, but tolerates drier conditions | riparian areas, ornamental landscapes, weeds |
| **Breeding hosts** | woody perennials | woody perennials, herbaceous plants | sedges, nutgrass, water grass, ryegrass, fescue grass | bermudagrass, semi-aquatic grasses | grasses, herbaceous plants |
| **Occurrence in breeding habitat** | frequent | very frequent | frequent | sporadic | frequent |
| **Movement into vineyard** | along riparian edge | widespread | along irrigated pastures and ditches | along irrigated pastures and ditches; may breed on bermudagrass in vineyards | only adults along riparian edge; carried by wind beginning in May |
| **Most common monitoring methods used** | yellow sticky traps; visual inspection | yellow sticky traps; beating trays; visual inspection | sweep net (not attracted to yellow sticky traps) | sweep net (not attracted to yellow sticky traps) | yellow sticky traps; visual inspection |

attractive for laying eggs.

The glassy-winged sharpshooter resides in a wide range of habitats that include agricultural crops, ornamentals, native woodlands, and riparian vegetation and is reported to feed on over 130 plant species. It feeds on growth that is less succulent than that preferred by other sharpshooters, including shoots and woody stems, but still prefers succulent growth. It occurs in unusually high numbers in citrus and macadamia. Crepe myrtle, pittosporum, and sumac are especially preferred in Southern California. The full range of plants that this insect can utilize as feeding and breeding hosts is not known. Host plant preference changes according to availability and the nutritional value of the host plant at any given time.

In the Central Valley, irrigated pastures, hay fields, or grasses on ditchbanks are the principal breeding habitats for the green sharpshooter and red-headed sharpshooter (see table 4), which prefer grasses and certain annual weeds for breeding and feeding. Grapes are only accidental hosts of grass-feeding sharpshooters. In coastal vineyards adjacent to their breeding habitat, these sharpshooters can be a source of Pierce's disease.

# Disease Incidence and Spread in Vineyards

Pierce's disease occurs in vineyards across the southern United States, from Florida through Texas and into California. In the East, it extends up to Virginia. In the West, it has not been found north of California. In general, the disease is rare and less severe in areas that are farther north or at higher elevations. The geographical distribution of Pierce's disease appears to be related to the ability of the bacteria to survive winter temperatures; however, the effect of low winter temperatures on bacterial survival is not well understood.

The pattern and incidence of Pierce's disease in a vineyard is related to which vector is infecting vines in that region. The location on the vine where the bacteria are introduced and the time of year that infection occurs determine whether or not the bacteria will remain in the vine over the winter and cause disease symptoms in the spring. Also, in chronically infected vines, the time of year at which the bacteria move into the current season's growth affects when an uninfected vector can acquire it.

Winter pruning removes first-year infections from current season's growth, especially infections that occur late in the season. However, if there is sufficient time for the bacteria to move from the area of infection to permanent parts of the vine before dormancy, then *X. fastidiosa* remains in the vine after winter pruning.

In a chronically infected vine, although spring symptoms of Pierce's disease may be present, the bacteria do not move up into the new season's growth until May or June. As a result, an uninfected sharpshooter feeding on succulent vine growth does not acquire bacteria from these vines until the summer months.

## Spread by the Blue-Green Sharpshooter

In coastal regions, vines adjacent to riparian vegetation are most likely to be infected when infective, overwintering blue-green sharpshooter adults enter vineyards in the spring. Most diseased vines are found in the first 200 to 300 feet (60–90 m) from the vector source, which matches the distribution pattern of blue-green sharpshooters within vineyards from March through May.

Early in the growing season, vine shoots are short; thus the bacteria can readily multiply and spread into the permanent structure of the vine. The bacteria also have several months to multiply. This allows for a high bacterial population to be present in the vine by fall, increasing the chance that infection will persist through the following winter and become chronic.

In late summer and fall, the new generation of blue-green sharpshooter adults is widely distributed in vineyard blocks, and vines can be infected at this time. However, these late infections rarely result in Pierce's disease. Blue-green sharpshooters generally feed on young tissue, and there is insufficient time for bacterial multiplication and movement from these leaves to the parts of the vine that are not pruned off. Most late-season infections are likely eliminated during winter pruning, or the bacteria fail to survive the cold winter months.

Vine-to-vine transmission is not common with the blue-green sharpshooter vector. In the spring, the blue-green sharpshooter cannot acquire the bacteria from chronically infected vines since the bacteria do not move up into the new season's growth until May or June. Although the new generation of blue-green sharpshooters moves the bacteria from vine to vine in the summer and fall, these late-season infections are likely to be pruned off. Thus, Pierce's disease does not usually occur when *X. fastidiosa* is transported by the blue-green sharpshooter from one vine to another vine in the same growing season.

While vine-to-vine movement of the bacteria by this vector is not significant, movement from vine to alternative host plant may be a significant factor in reinfection from one year to the next. In summer, adults of the new generation feed on spring-infected or chronically infected vines, and this increases the number of infective insects migrating to the riparian habitat to overwinter. Since infective adults remain capable of spreading the bacteria throughout their lives, these overwintering insects are a source of infection the following spring when they migrate back into the vineyard.

## Spread by the Glassy-Winged Sharpshooter

Several characteristics of the glassy-winged sharpshooter make it potentially the most important vector of Pierce's disease and may dramatically change where this disease occurs in California. This insect feeds and reproduces on a wide range of plant types in diverse habitats, where it can reach very high populations. It is a strong flier, so it can move deeply into vineyards adjacent to these habitats. It often feeds on the base rather than on the tips of canes, as well as on 2-year-old wood.

Until now, because of the limited dispersal ability of the blue-green, green, and red-headed sharpshooters, Pierce's disease has been primarily a localized problem next to these vectors' habitats: riparian corridors, certain ornamental landscapes, and lush growing grasses. However, the glassy-winged sharpshooter breeds in citrus, avocado, macadamia, eucalyptus, and sumac groves and can attain large numbers in these and other plants. Previously, these plants were not hosts for Pierce's disease vectors, and the distribution characteristics of the disease are likely to change.

By feeding low on the cane, glassy-winged sharpshooters increase the number of late-season infections that are not removed by winter pruning, thus increasing the number of chronically infected vines. This enables vine-to-vine spread of *X. fastidiosa,* which has previously not occurred in California. Vine-to-vine spread can be expected to increase the incidence of Pierce's disease exponentially rather than linearly.

The glassy-winged sharpshooter also feeds on dormant grapevines during winter. It is not known whether glassy-winged sharpshooters are capable of inoculating or acquiring the bacteria while the vine is dormant.

## Spread by the Green and Red-Headed Sharpshooters

In the San Joaquin Valley and, to a lesser extent, in coastal regions, lush-growing perennial grasses or sedges adjacent to vineyards may harbor green and red-headed sharpshooter populations. Grapes are not a preferred host for these sharpshooters. The green sharpshooter is not associated with significant incidence of Pierce's disease until populations are very high, and it may require more than a year to reach a critical population. Most Pierce's disease associated with the green sharpshooter occurs in the spring, downwind from the source from which the vector moves into the vineyard after reaching high populations. Red-headed sharpshooters may disperse into vineyards when grasses they feed upon dry.

As with blue-green sharpshooters, the green sharpshooter and red-headed sharpshooter feed on succulent vine growth, and springtime infections result in diseased vines. Most late-season infections are probably eliminated during winter pruning, or the bacteria fail to survive the cold winter months.

Annual cover crops are not important vector sources unless the cover is attractive to vectors (for example, bermudagrass) and is allowed to grow throughout the year. Cover crops managed with repeated mowing and irrigation do not generally provide the kind of weeds or the permanent habitats needed for a buildup in sharpshooter populations.

## Spread by Other Sources

Pierce's disease does not appear to be spread in a vineyard via contaminated pruning shears. Hot water treatment of dormant grape cuttings (immersion at 113°F [45°C] for 3 hours or at 122°F [50°C] for 20 minutes) destroys *X. fastidiosa* without damaging the wood. If fall budding is done with fresh budwood, care must be taken that the buds come from uninfected vines. Since fresh budwood may be collected prior to the onset of symptoms of either chronic or current-season infections, this may be difficult. Due to the uneven distribution of the bacteria within the vine, a diagnostic test from one section of the vine could give a false negative. Therefore, it is best to avoid collecting budwood in vineyards with a history of Pierce's disease.

# Vector Monitoring

It is important to monitor blue-green sharpshooters in riparian vegetation and ornamental landscapes to determine which plants are the sources of insects and to time chemical control measures. Early detection of the glassy-winged sharpshooter in areas where it is not known to be established is critical for developing control strategies. Blue-green and glassy-winged sharpshooter adults can be monitored with yellow sticky traps or tape (see table 4). Beating trays and sweep nets are useful for finding adults in cool weather and nymphs. Visual inspection of plants is used to detect egg masses of the glassy-winged sharpshooter, as well as nymphs and adults of both vectors.

If diseased vines are observed next to lush grasses, monitor the grasses for green and red-headed sharpshooters with a sweep net. These two vectors are not attracted to yellow sticky traps.

## Yellow Sticky Traps and Tape

To monitor blue-green sharpshooter movement, place sticky traps on the edge of this vector's habitat, such as riparian areas and ornamental landscapes, as well as 50 feet (15 m) into an adjacent vineyard. For early detection of glassy-winged sharpshooters, place traps at the interface of the vineyard and all adjacent vegetation (for example, other crops, native woodlands, ornamental landscape, and riparian vegetation). Glassy-winged sharpshooter adults tend to move among plants throughout the day, as well as seasonally. Thus, monitoring between different plant types and habitats increases the probability of detecting this vector.

When vector populations are low, it is important to have many traps. Place a minimum of six traps per vineyard block 100 to 200 feet (30–60 m) apart at vine canopy height. Start trapping in early March. Check traps once per week initially and more frequently after 2 or 3 days of warm weather. Remove insects from traps after counting them. Replace traps when they become excessively dirty or discolored by moisture. For the glassy-winged sharpshooter, continue monitoring throughout the season until day-time high temperatures remain below 65°F (18°C). Use yellow sticky traps no smaller than 4 by 7 inches (10 by 18 cm). For glassy-winged sharpshooters, it is better to use larger sticky cards that contain more sticky material.

As you begin to detect blue-green sharpshooters in the traps, you may want to place a continuous yellow sticky plastic tape to detect "hot spots." The tape allows you to determine where the greatest concentrations of blue-green sharpshooters are entering a vineyard from surrounding vegetation. Tapes are not effective for mass-trapping of sharpshooters for control purposes.

Tapes are useful in early detection of glassy-winged sharpshooters when their numbers are very low. The larger the trapping surface area, the higher the probability is of catching the insect, provided the tape is changed frequently to maintain stickiness. Tapes may need to be replaced every 2 to 4 weeks, depending on how frequently they get wet or soiled. Support tape every 10 to 15 feet (3–5 m) at waist height with a grape stake, fence post, or sturdy tree trunk.

## Beating Tray Samples

Beating tray samples can be useful to locate nymphs on plants where insects breed. They can also be used to find adults as long as the temperature is lower than that required for them to fly. Monitor for glassy-winged sharpshooters early in the morning when the ambient temperature is below 60°F (15°C). Place a large white sheet of fabric under the host plant to be sampled. Beat or shake the plant with moderate force. Insect adults and immatures will drop to the white sheet and remain nearly stationary. This sampling method is for detecting, as well as for population monitoring and collecting. At warmer temperatures, insects either jump or fly away before dropping to the sheet.

## Visual Inspection

To determine where the vectors are coming from or for early detection of the glassy-winged sharpshooter, make direct observations on vegetation. Look for sharpshooter adults and immatures on host plants and on grapevines. For blue-green sharpshooters, search the leaves. To be able to see the vector on both sides of the leaf, squat down so that the leaves are backlit. For glassy-winged sharpshooters, search leaf petioles, twigs, and small branches for the presence of immatures and adults. Try not to disturb the plants since sharpshooters tend to hide when disturbed. Egg masses of this vector can be found on the underside of the leaf and may appear as a chlorotic spot on the upper leaf surface.

## Sweep Net

A sweep net is the best sampling method to monitor adult green and red-headed sharpshooters along pastures and ditches, but sweeping is a poor method for detecting nymphs of these vectors. Blue-green and glassy-winged sharpshooter adults and nymphs can be sampled on their preferred host plants with the use of sweep nets. A good guideline is to make fifty sweeps per sample and take at least four samples. To look at the net's contents, turn the sweep net inside out into a clear plastic bag. Specimens are easier to observe in the plastic bag.

# MANAGEMENT

BEFORE UNDERTAKING A MANAGEMENT program, it is important to assess the risk of Pierce's disease in your vineyard. The following elements must be present for disease to occur: susceptible vines, an insect vector, and alternative host plants with a reservoir of the bacteria. It is important to determine if all of these are present at your site. Make sure you can recognize the disease symptoms. Survey your vineyard to determine if Pierce's disease is present and monitor for vectors to assess your situation.

Given the complexity of this disease, several practices must be used simultaneously to manage it. Once the vector has become established, it cannot be eradicated. Management strategies are then focused on reducing vector populations and delaying the spread of vectors to new regions. Another management strategy is to reduce the reservoir of *X. fastidiosa*. Each vector acquires bacteria from different alternative hosts, depending on the vector's habitat. Therefore, this strategy must be tailored for the principal vector in a region.

When establishing or replanting vineyards near an area with a history of Pierce's disease, consider planting varieties that are less susceptible to the disease.

## Biological Control

Blue-green sharpshooter populations are under good natural biological control from generalist predators and egg parasites and rarely appear in high numbers in vineyards. Unfortunately, it is such an efficient vector that only a small number are needed to cause a high incidence of vines with Pierce's disease. Biological control alone cannot reduce vector populations well enough to prevent the spread of *X. fastidiosa.*

Egg parasites frequently attack glassy-winged sharpshooter egg masses. The predominant parasitoid, *Gonatocerus ashmeadi* (see fig. 22), is a tiny wasp (1.5 mm long) that achieves up to 50 percent parasitism early in the spring and as high as 80 to 95 percent in the summer months. Parasitized eggs are identified by the small circular hole left by the emerged parasite at one end of the egg. Related species have also been found parasitizing glassy-winged sharpshooter eggs in low numbers. In addition, the larvae of green lacewings feed on the eggs of glassy-winged sharpshooters.

## Vine Removal and Cutting Back Permanent Wood

Vines with Pierce's disease are a source of bacteria for sharpshooters, especially the glassy-winged sharpshooter. Chronically infected vines are also less productive and incur farming costs without significant crop return. Therefore, chronically infected vines should be removed as soon as they are detected. In own-rooted vineyards, layering may be used to replace vines that have been removed due to Pierce's disease although this practice cannot be used if the incidence of diseased vines is high.

Field research trials indicate that, under some conditions, cutting the trunk off just above the graft union may generate symptom-free vines. In theory, with this practice, new trunk and fruiting wood could be trained and a crop established much faster than replacing an entire vine. When symptoms are only found at the terminal end of canes, normal dormant pruning practices remove infected wood with nearly the same result as severely cutting back permanent wood. It is not certain at this time whether the regrowth subsequent to cutting a vine back will remain disease-free, even if reinfection does not occur.

## Riparian Vegetation Management

In vineyards adjacent to riparian vegetation where the blue-green sharpshooter is the major vector and the glassy-winged sharpshooter has not been established, one approach to reducing the severity of Pierce's disease is to alter the composition of the riparian plant community. Research has shown that by removing the blue-green sharpshooter's principal breeding hosts and systemic hosts of *X. fastidiosa* and replacing them with native, nonhost plants, fewer infective blue-green sharpshooters will be present each year.

Because the riparian corridor is ecologically sensitive and regulated by federal, state, and local authorities, the


**Figure 22.** This tiny wasp *(Gonatocerus ashmeadi)* parasitizes the egg of the glassy-winged sharpshooter.

unauthorized removal of vegetation is prohibited or restricted. In addition to addressing concerns related to Pierce's disease, any vegetation management plan must enhance and protect important natural resource values provided by the riparian habitat. Vegetation provides habitat for wildlife and fish, promotes streambank stability, and protects water quality. A well-designed vegetation management plan will protect these resources, enhance plant diversity and structure, as well as reduce the population of the blue-green sharpshooter. Contact the nearest office of the California Department of Fish and Game for current regulations and guidelines concerning any proposed modification within the riparian corridor.

Vegetation management and removal of ornamental plants are not strategies recommended for the control of the glassy-winged sharpshooter. This insect feeds and breeds on an extremely wide range of host plants. If the preferred plants are not available, it exploits other plants. The removal of all host plants is not feasible. Furthermore, the primary source of bacterial innoculum for this insect is infected grapevines.

## Weed Management

Pierce's disease will continue to occur in vineyards adjacent to hay fields, pastures, ditches, and other vector-breeding areas as long as grasses that support breeding of green or red-headed sharpshooters are present. Monitor for the presence of vectors and prevent them from breeding by controlling lush grasses rather than attempting to control the insects with insecticide applications. Insecticides are not effective against the green and red-headed sharpshooters because eggs, which are not killed by insecticides, are present from early spring through fall due to the overlap in generations. Alfalfa fields free of grass weeds do not support significant populations of these sharpshooters. Clean up grasses and sedges growing along ditches and roads prior to bud break in grapes. Irrigated pastures that cause Pierce's disease hot spots in nearby vineyards cannot be managed to prevent sharpshooter breeding. If possible, avoid planting vineyards adjacent to pastures in regions with a history of Pierce's disease problems. Growers with a high incidence of Pierce's disease near permanent pastures may consider planting a buffer crop between the pasture and the vineyard to increase the distance from the vector source.

## Insecticides

Insecticide treatments aimed at controlling blue-green sharpshooters in native or ornamental landscapes adjacent to vineyards can reduce Pierce's disease incidence by reducing the number of sharpshooters migrating into the vineyards in early spring. The degree of control has not been sufficient for extremely susceptible varieties such as Chardonnay and Pinot Noir or for vines less than 3 years old. Regulations prohibit the use of most insecticides in riparian habitats.

Ideally, blue-green sharpshooter chemical control should be done when warm weather increases vector foraging activity but before bud break. Cool weather immediately following treatments may decrease the effectiveness of insecticides in controlling this vector. Consider treatment if there is a sharp increase in trap counts after several successive warm days (above 70°F [21°C]), or if you see more than one sharpshooter per vine. Treat those plants where you observe the vectors and treat the edges of the vineyard if new vine shoot growth is greater than a few inches. Replace traps after treatment if they are no longer sticky. Continue monitoring traps and vegetation until late April or for a month after treatment to make sure the vector population is reduced. Respray if trap catches indicate another population increase. Monitor vector habitat from May through July with a sweep net and visually search for nymphs to learn where sharpshooters are reproducing.

Reducing populations of glassy-winged sharpshooters in breeding habitats near vineyards may be the most effective control strategy for this vector. Growers should try to reduce numbers of this vector present in the vineyard at any time using approved insecticides. Glassy-winged sharpshooters can detect a systemic insecticide in the xylem and are deterred from feeding. Whether or not this first feeding is sufficient to transmit *X. fastidiosa* is not yet known. Systemic insecticides are effective against immatures.

For the latest information on insecticides to control these pests, obtain a current copy of the *University of California Integrated Pest Management Guidelines for Grapes.* They are available at the University of California Cooperative Extension office in your county or on the Internet at www.ipm.ucdavis.edu.

# More Information

More information on Pierce's disease and its insect vectors can be found at the following websites:
http://www.cnr.berkeley.edu/xylella
http://ucceventura.xlrn.ucsb.edu/IPM/IPMHome.htm
http://danr.ucop.edu
http://www.ucr.edu/news/gwss