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Pierce's disease of grapevine

Important concepts of disease ecology to inform management decisions

Pierce's disease (PD) is caused by the pathogen *Xylella fastidiosa* subsp. *fastidiosa,* a xylem-limited bacterium that affects water transport in the host. *Xylella fastidiosa* is transmitted by xylem-feeding insects: sharpshooters and spittlebugs. There are multiple subspecies of *X. fastidiosa* causing disease in crops, such as almond leaf scorch (*X. fastidiosa* subsp. *multiplex)*, olive quick decline and citrus variegated chlorosis (*X. fastidiosa* subsp. *pauca*). *Xylella fastidiosa* subsp. *fastidiosa* is the only known subspecies to infect grapevines.

Pierce's disease of grapevine		
Pathogen	*Xylella fastidiosa*	Xylem-limited bacterium with multiple subspecies
Vectors	Sharpshooters Spittlebugs	Xylem-feeding insects
Host (pathogen)	Grapevine	*Vitis* spp.
Host (vectors)	Various	Riparian areas Ornamental plantings Grasses Biennial or perennial tap-rooted species
Environment	Temperature Vine water status	ADect acquisition and transmission of the pathogen by the vector "Winter curing" phenomenon may be explained by temperature (cold)

The vectors of *X. fastidiosa* are xylem-feeding insects in the family Cicadellidae (sharpshooters) and Aphrophoridae (spittlebugs). Sharpshooters and spittlebugs utilize many plants in their environment as feeding and breeding hosts. They acquire *Xylella* from *Vitis* spp.; once they acquire the bacterium as adults, they retain the ability to transmit it throughout the remainder of their life cycle. But they do not pass that ability on to their o<spring (not transovarial).

Vector species		**Important *breeding* hosts (other than *Vitis* spp.)**
Sharpshooters	Blue-green	blackberry, mugwort, elderberry, nettle
	Green	Grasses
	Red-headed	Grasses
	Glassy-winged	Citrus, crepe myrtle, oleander, jasmine vine
	Willow	Willow
	Pagaronia spp.	*Vitis* spp. (others unknown)
	Neokolla sp.	Alfalfa, milkweed, poplar, willow
Spittlebugs	Meadow	Wide host range of weedy & ornamental species
	Aphrophora sp.	Perennials and biennials with tap root (bristly oxtongue, wild carrot, soap plant (*Chlorogalum*)); vetch; pine
	Clastoptera brunnei	Coyote brush, mugwort, gumweed, vetch

Xylem sap has very low nutrient content (95% water) and is energetically costly to pump because it is under negative tension (:: -1 MPa). Xylem-feeding insects have adaptations such as strong cibarial (anterior to the mouth cavity) muscles, an e<icient digestive system

with a filter chamber to process large volumes of liquid (up to 300 x body weight per day), and, as documented for glassy-winged sharpshooter, an excretion system that exploits droplet superpropulsion to void their waste as 'leafhopper rain' (Challita et al. 2023, 10.1038/s41467-023-36376-5).

Pierce's disease cycle on the North Coast for blue-green sharpshooter

In California, glassy-winged sharpshooter is the vector that gets the most attention statewide. Established regulatory programs have minimized dispersal of glassy-winged sharpshooter from the southern regions of California where it is established. It is not known to be established in North Coast wine grape production areas.

Blue-green sharpshooter is the most prevalent vector in the North Coast. Adult blue-green sharpshooter (BGSS) overwinter principally in riparian areas, but they have also been found in ornamental vegetation. After budbreak, BGSS enter the vineyard and feed on rapidly growing grapevine tissue. Transmission of *X. fastidiosa* to grapevine may occur at this time, if the vectors are infectious. Most transmission events that result in permanent, chronic infections of grapevines occur in the spring, and result from feeding events by the overwintering adult population. These overwintering adults lay eggs in grapevine or other breeding hosts, and the hatching nymphs and resulting adults are referred to as the summer generation. Feeding continues during the summer generation, in vineyards and surrounding vegetation. When the summer generation of adults feed on grapevines that are infected with *X. fastidiosa*, they acquire the bacterium. In the fall, adult BGSS from the summer generation migrate to overwintering hosts. These same adults will return to the vineyard in the spring, initiating the annual cycle. The Pierce's disease cycle is described as *interannual secondary spread*: BGSS adults acquire the pathogen from grapevines in late summer or fall, retain it through the winter, and transmit it to vines when they return to the vineyard in the spring.

Grapevine cycle	**Disease cycle (with blue-green sharpshooter)** ***Interannual secondary spread***
Dormancy	BGSS adults overwinter (mainly in riparian areas) "Winter curing" phenomenon
Budbreak Rapid shoot growth Bloom	BGSS adults feed on grapevines BGSS transmit *X. fastidiosa* to grapevine (chronic infections) BGSS adults lay eggs, nymphs develop
Veraison	BGSS summer generation of adults present BGSS transmit *X. fastidiosa* to grapevine (curable infections) BGSS adults acquire *X. fastidiosa* from grapevine
Pre-harvest	BGSS adults migrate to overwintering vegetation

Pierce's disease symptoms

Transmission events that result in chronic infections happen in the spring, when BGSS transmit *X. fastidiosa* to previously healthy vines. In newly infected vines, the first PD symptom is "berry shrivel", appearing as the berries ripen. Esca infections also result in berry shrivel, so care must be taken not to confuse symptoms of Esca infections with PD infections. Esca can be distinguished by the unique leaf symptoms, and the spots (measles) that are present on berries. In the first year of infection, there are few obvious symptoms of PD other than berry shrivel. Once the infected vines go through dormancy, the symptoms become more widespread and severe. In chronically infected vines, PD symptoms in spring include chlorosis and poor growth characterized by stunted shoots or buds that do not grow (dead positions). In the summer and fall, berry shrivel, leaf scorch, matchstick petioles and uneven shoot maturation are the typical symptoms.

<table>
<tr><td>Spring</td><td>Transmission event: Blue-green sharpshooter transmits Xylella fastidiosa to grapevine</td><td></td></tr>
<tr><td>Summer</td><td>Berry shrivel</td><td></td></tr>
<tr><td colspan="3">Dormancy</td></tr>
<tr><td rowspan="2">Spring</td><td>Leaf chlorosis</td><td></td></tr>
<tr><td>Stunted shoot growth and dead spur positions</td><td></td></tr>
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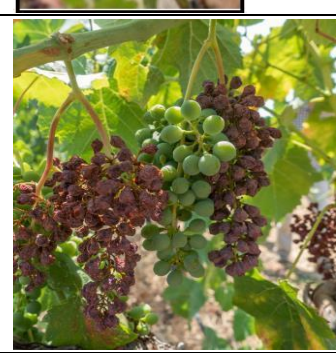
<tr><td rowspan="4">Summer through fall</td><td>Leaf scorch</td><td>
</td></tr>
<tr><td>Matchstick petiole: leaf blade abscises, petiole remains attached to shoot</td><td></td></tr>
<tr><td>Uneven shoot maturation</td><td></td></tr>
<tr><td>Berry shrivel</td><td></td></tr>
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Pierce's disease management

Monitor to determine vector species composition

Monitoring for BGSS is commonly conducted with yellow panel traps because they are a low-input method. Deploy traps prior to budbreak and monitor vector ingress from vineyard-adjacent landscapes (riparian, ornamental, grasslands, ditches, etc.), recording trap captures on a weekly or biweekly basis. Because the yellow panel traps are not baited with an attractant, they are less informative as a measure of vector abundance. Several of the vector species (green and red-headed sharpshooter, spittlebugs) are rarely captured in traps. If you suspect a vector other than BGSS, utilize monitoring methods other than traps. Sweep samples targeting host plants in vineyard-adjacent landscapes can be a more sensitive detection tool, particularly for red-headed and green sharpshooter. For spittlebugs, inspect weeds and other broadleaf plants for evidence of nymph feeding, which is characterized by the presence of spittle.

Reduce vector breeding habitat

The most e<ective strategy to reduce vector populations is to remove their breeding hosts from vineyard-adjacent landscapes. Riparian revegetation projects along rivers, streams and creeks that target BGSS breeding hosts have the added benefits of restoring native plants, reducing erosion, mitigating flooding, and removing human-mediated barriers to fish and other wildlife. Supported via local and federal funds, coordinated revegetation projects in Napa have reduced BGSS populations locally and regionally. Vineyard-specific e<orts to reduce spittlebug habitat through mowing or other physical measures have disrupted their life cycle and limited their populations.

Remove symptomatic vines

Once PD symptoms are present, the diseased vines should be marked and removed from the vineyard prior to the next growing season. Do not attempt to retrain or rejuvenate vines that have PD symptoms, even if the symptoms seem "mild" or limited to a specific region of the vine, such as only one shoot or one side of the cordon. By the time PD symptoms become obvious to field scouts and others, the pathogen is established in the vine and detectable throughout the woody and green tissue, including into the roots. Thus, the pathogen cannot be eradicated by removing and retraining the vine.

Train vineyard field crews on PD symptoms and vine removal

Vines may live for multiple years with PD infections, even as they are slowing declining and becoming less productive. During this time, attentive crew members may attempt to revive or retrain these declining vines. However, they should be discouraged from retraining vines that are failing due to PD, because this will not remove the pathogen from the vine, and the declining vines continue to serve as a source of pathogen inoculum, perpetuating disease in the block. Therefore, educational efforts aimed at vineyard teams should emphasize symptom recognition and improve knowledge of the disease cycle. Vineyard teams should mark vines with PD symptoms and notify supervisors or managers so that the vines can be removed prior to the following growing season.