A Preliminary Investigation of the New and Serious Malady of *Schinus molle* Canopy Thinning

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Although in California it goes by the common name California pepper tree, *Schinus molle* is not a native of our State. Nonetheless, this common name suggests the prominent, iconic role this tree has played in its namesake state's culture, history, and landscape horticulture. Much revered but sometimes reviled, *S. molle* is one of the more common landscape trees in the coastal plains and valleys of southern and central California, from San Diego to the Bay Area. It has been widely planted along public highways in rural and urban areas and is a common park, street, and home landscape tree (**Figs. 1–3**). Native to dry areas of South America and Mexico, *S. molle* is considered a Mediterranean-climate plant and well adapted to California's similar climate of cool, moist winters and warm to hot, rainless summers. Indeed, it is now promoted as an acceptable species for drought-tolerant plant palettes in ever-drying California.

Thus, considering the importance of this tree in the California landscape, it is disconcerting that the new and serious malady of *Schinus molle* canopy thinning has appeared in the last several years. Here, we discuss the host tree and provide the history and suspected causes, symptoms, and potential management strategies for canopy thinning.

Schinus molle

A typically much prized tree in California, *Schinus molle* is valued for is handsome weeping habit (**Figs. 4–5**) and tolerance of a wide array of adverse conditions, including heat, moderate cold (hardy to -12 C), drought, poor soil, smog, wind, and other adverse conditions that make it well adapted to California's ever-drying and increasingly arid climate (Baldwin 2024, Iponga et al. 2008, UFEI 2024). With older specimens especially, the stout, rough, gnarly trunks, often with numerous, rounded protuberances, and typically broad, canopies with gracefully pendulous branches and foliage, make this tree immediately recognizable (**Figs. 6–7**).

Carl Linnaeus (1707–1778), Swedish biologist and physician who formalized binomial nomenclature, the modern system for naming organisms (Britannica 2024, Calisher 2007), named

1. *Schinus molle* has been widely planted in urban areas in California, as here in San Diego. Not the handsome, weeping habit of this old specimen.

2. Schinus *molle* is frequently used as a home landscape tree, Lakewood, California.

3. Here *Schinus molle* is used in a common area of a homeowners' association, Seal Beach, California.

4. At El Dorado Park, Long Beach, California, *Schinus molle* is valued for its handsome weeping habit among several other attributes.

5. Also at El Dorado Park, Long Beach, California, *Schinus molle* makes an impressive group planting of trees with weeping habit.

6. Marianne Hodel complements an especially venerable, old specimen of *Schinus molle*, Balboa Park, San Diego, California with weeping habit and a stout, gnarly trunk.

7. The trunk of the *Schinus molle* in Figure 6 is stout, rough, and gnarly and has numerous, rounded protuberances, with Marianne Hodel.

8. Father Antonio Peyri planted this first specimen of *Schinus molle* in California in the early 1830s at the Mission San Luis Rey de Francia in Oceanside, where it still exists today, with Marianne Hodel.

9. The trunk of the *Schinus molle* in Figure 8 is exceedingly large, with rounded protuberances and several hollow portions, and its branches have artificial support.

and described *Schinus molle* in 1753 in his epic, two-volume *Species Plantarum*, a listing of all plants known at the time (Britannica 2024). He based this species on others' earlier, illustrated accounts.

Father Antonio Peyri first planted *Schinus molle* in California in the early 1830s at the Mission San Luis Rey de Francia in Oceanside, where the original tree still exists (**Figs. 8–9**). Well adapted to California and providing much-needed shade with little or no care, it quickly gained wide popularity and was planted abundantly in the middle and late 19th century, where it became closely associated with the Spanish missions and known as the California pepper tree (Masters 2013). Briefly in the early 20th century it fell out of favor because it was an alternate host of black scale, a serious threat to citrus crops (Masters 2013); however, as citrus production shifted to the San Joaquin Valley, black scale became less of a problem there, occurring only on grapefruit and then only near olive trees (Grafton-Cardwell 2017).

Schinus molle has numerous common names, including Peruvian pepper, Peruvian peppertree, American pepper, California peppertree, California pepper tree, false pepper, rosé pepper, *molle de Peru*, pepper tree, peppercorn tree, *pirul*, Peruvian mastic, Peruvian mastic tree, *anacahuita*, *aguaribag*, *escobilla*, pepperina (Baldwin 2024, Hanrow 2024, PP USDA 2024, UACM, QPIC 2024).

The botanical genus name *Schinus* is from the Greek word for the related mastic tree, *shinos*, while the specific epithet is derived from *mulli*, the Quechua word for tree (AMLQ 2005), or the Latin word *molle*, meaning soft (Ritter 2011), the latter likely alluding to the pendulous, relatively fine-textured foliage.

Our description of *Schinus molle* is taken from Baldwin (2024), Barkley (1944), Blood (2001), Goldstein and Coleman (2004), Macbride (1951), Miller and Wilken (2012), TSO (2024), and our observations of living plants.

The species is a fast-growing, polygamodioecious (staminate and pistillate flowers are on separate plants but each plant also has bisexual flowers), aromatic, large, multibranched shrub to more typically medium to large evergreen tree, eventually to about 20 m tall and wide. Branch ends tend to droop, lending a weeping or pendulous appearance to the tree (**Figs. 1–6, 8**). Root suckering or sprouting is common.

Trunks of *Schinus molle* are often short and stout, mostly solitary, sometimes multi-trunked or with two or more main branches rising near or at ground level, typically less than 1 m in diameter at standard height. Old trees can have much larger trunks, to 2 m in diameter or even larger. In many of these situations, interior portions of these trunks become hollow. Bark is rough, fissured, scaly, and gray to tan or grayish brown (**Fig. 10**). Older trees sometimes develop burl-like protuberances, the cause of which is not well documented (**Figs. 7, 9, 11**).

10. Bark of *Schinus molle* is rough, fissured, scaly, and gray to tan or grayish brown, Seal Beach, California.

11. Trunks of old specimens of *Schinus molle* frequently develop burl-like protuberances, as on this specimen at the Los Angeles County Arboretum and Botanic Garden, Arcadia, with Marianne Hodel.

12. Leaves of *Schinus molle* are pinnately compound and drooping.

13. Pinnae margins of *Schinus molle* are entire to coarsely toothed.

14. Inflorescences of *Schinus molle* are a lateral panicle or terminal thyrse, and shorter to but typically longer than the leaf.

15. Flowers of *Schinus molle* are small, white to cream-colored, fragrant, and mostly in the spring and summer.

16. Clusters of mature fruits of *Schinus molle* are quite showy.

17. The small, spherical, red, pink, or purplish fruits of *Schinus molle* are a drupe, and mostly appear in the fall or winter but can persist year-round.

Leaves are pinnately compound, 8–30 × 4–9 cm, mostly drooping or pendulous, imparipinnate, and bright green (**Fig. 12**). Petioles are 2–3 cm long while the rachis is slightly winged. Pinnae number 19–41 and are 0.8–6 × 0.4–0.8 cm, lanceolate to linear-lanceolate, sessile, and with an acute, slightly curved apex. Margins are entire to coarsely toothed (**Fig. 13**).

Inflorescences of *Schinus molle* are a lateral panicle or terminal thyrse, 8–40 cm long, and shorter to but typically longer than leaf (**Fig. 14**).

Flowers are small, 3–4 mm diam., white to cream-colored, fragrant, and mostly in the spring and summer (**Fig. 15**).

Fruits of *Schinus molle* are in showy clusters, a drupe, 5–7 mm in diameter, spherical, red, pink, or purplish when mature, with a shiny, brittle epicarp, and held on a short pedicel 2–5 mm long (**Figs. 16–17**). Fruits are mostly present in fall and winter but can be found year-round.

Bark, leaves, and fruits are aromatic (Blood 2001) while branches and twigs can secrete a white or clear sap when cut (TSO 2024).

As broadly interpreted, *Schinus molle* is widespread in arid zones of South America, including Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, and Venezuela, and Mexico (TSO 2024), to 3,650 m elevation (Baldwin 2024) although in California it occurs only up to 700 m elevation (Miller and Wilken 2012). Its natural range is difficult to discern, though, because it has become so widely planted and has escaped cultivation to become naturalized and invasive (TSO 2024). Also, the extent of its distribution depends on whether one accepts its variety, *S. molle* var. *areira*, which occurs from Mexico to Chile, as a separate species. If so, then as more narrowly interpreted, *S. molle* is restricted mostly to south central South America (TSO 2024), from Peru and Chile's intermountain Andean deserts to central Argentina (Baldwin 2024, Blood 2001).

Schinus molle occurs in mixed savannas and scrub, typically near water courses but not always (TSO 2024). It is common to see escaped specimens on dry hillsides in California where they rely only on the unreliable rain for sustenance and survival.

Because *Schinus molle* is tolerant of a wide array of adverse conditions and grows with little or no care, it has become widely naturalized around the world and a serious, invasive weed, especially in South Africa (Iponga et al. 2008) and Australia (Blood 2001). It is listed as mildly invasive in Californian because its impacts are minor at the state-wide level and/or information is insufficient to justify a higher or more severe score (Cal-IPC 2024).

Schinus molle has a reputation for damaging hardscape with roots and root suckers, and also interfering with buried utility lines and water and sewer pipes (Master 2013, Masters and Farmer

2014). It is said that this species litters the ground under the tree's canopy with an excessive quantity of leaves, fruits, and twigs (Hoang 2019, UFEI 2024). Indeed, when walking under a tree with such an accumulation of litter, especially leaves, one can hear the unforgettable, distinctive, tell-tale sound of crunching dried leaves and smell the characteristic aromatic foliage. It is also stated that oils in the leaves make it difficult to grow other plants under *S.* molle, but this statement is untrue. Plants will grow under *S. molle,* and it is more likely simply the depth of the leaf litter, shade, and lack of water that tend to inhibit plant growth.

Where it grows, *Schinus molle* is recognized for its hard, durable wood much prized for saddlery and fruits for spice production. Its fruits are often sold as "pink peppercorns" although *S. molle* is not closely related to black pepper. Still, its fruits are used in the culinary arts and typically blended with commercial black peppers (UFEI 2024). Once thought to be mildly to highly toxic (Taylor 2005), its fruits are now considered not toxic but can be mildly irritating, especially to children (Hoang 2019). Parts of the tree are used as antiseptic/antibacterial agents in traditional medicines and as a textile dye (UFEI 224).

Schinus molle has been mostly pest- and disease-free in California although pests, such as psyllids, aphids, thrips, and scales, and diseases, including Armillaria, Phytophthora, and Texas root rot have been documented (UFEI 2024). Until the advent of canopy thinning, the most damaging malady of *S. molle* here was the pepper tree psyllid (*Calophya schini*), which appeared in July 1984 in Long Beach, and caused extensive and severe damage on trees, including distorted new growth and especially unsightly, deep prominent leaf pitting (Downer et al. 1988). Fortunately, an introduced parasitic wasp (*Tamarixia schina*) has largely controlled this pest (Kabashima et al. 2014).

In California, *Schinus molle* is primarily an ornamental tree for roads and highways, parks and other public areas, urban streets, and home landscapes. Extremely well adapted to California's climate and tolerant of a wide array of adverse conditions, this prominent, iconic tree is steeped the State's culture, history, and landscape horticulture; thus, canopy thinning is a disconcerting development.

History of *Schinus molle* Canopy Thinning

Co-author Hodel noticed this malady in early 2020 during one of his early morning walks around his Seal Beach neighborhood in Orange County. What caught Hodel's attention were the canopy thinning and stunted, deformed, "bunchy" new growth on several but not all trees of *Schinus molle* (**Figs. 18–20**). The malady was localized, and Hodel did not observe it in other areas. Nonetheless, Hodel was reminded of this malady every time he took his early-morning walk.

18. The canopy thinning and stunted, deformed, "bunchy" new growth of this *Schinus molle*, Seal Beach, California, were what caught Hodel's attention; here it is in October 2020.

19. Co-author Paul Santos checks the roots on the *Schinus molle* specimen in Figure 18 six months later in April 2021. Note the further decline.

20. The same *Schinus molle* specimen in Figures 18 and 19 but in December 2022 and now much defoliated. It would die and be removed in 2023.

21. A potentially big break in our study of *Schinus molle* canopy thinning came in October, 2023 when co-author Santos found small, green leafhoppers on these much affected parkway trees, Tustin, California.

About six months later, Hodel shared his concern with co-author Santos, who had also noticed this malady but earlier in 2019. Together and independently, we collected leaf and twig material and soil from root zones of symptomatic trees, compiled horticultural histories, and screened the material for pests (insects and mites), culturable diseases (powdery mildew and other foliar diseases, collar and root rots, cankerous lesions), and abiotic disorders. We observed no internal staining or necrosis, and symptoms were inconsistent with root rots. We detected no pathogens after plating out symptomatic material. Despite this work, a definitive answer to the cause of this malady was elusive.

In middle 2023, we sent affected material of *Schinus molle* to the Plant Diagnostic Center at the California Department of Food and Agriculture (CDFA) where two bacterial pathogens, *Pantoa agglomerans* (C-rated) and *Erwinia billingiae* (Z-rated), were detected on affected samples. These were detected in culture and confirmed by PCR and DNA sequencing. Both have been reported as somewhat weak pathogens on certain plant hosts but neither has been reported to infect *Schinus molle*. We doubt these are the cause of this malady, but, nonetheless, pathogenicity tests should be conducted to determine susceptibility of *S. molle*.

A potentially big break came in October 2023 when Santos collected small, green leafhoppers from much affected, symptomatic *Schinus molle* in Tustin, in Orange County, California (**Fig. 21**). He tipped Hodel off and immediately Hodel and co-author Ohara found the same leaf hopper on symptomatic trees in Long Beach, Lakewood, and Azusa, all in Los Angeles County and at the same site in Orange County where Santos had first found them. These leafhoppers have now been collected from symptomatic *S. molle* in adjacent Riverside and San Bernardino counties.

In November and December 2023, we sent leafhoppers and symptomatic leaves and twigs collected from the affected *Schinus molle* in Long Beach to entomologist Alessandra Rung and plant pathologist Cheryl Blomquist at CDFA. Rung performed molecular work on the leafhopper to determine its identity while Blomquist performed molecular work on the plant samples and leafhopper to check for phytoplasmas that the leafhoppers might be vectoring. Also, at Rung's suggestion, we sent leafhoppers to co-author Christopher Dietrich at the University of Illinois for identification based on morphological characters.

Dietrich found two leafhoppers in the samples we sent him, which he tentatively identified as *Empoasca sativae*, the smaller but more common of the two and comprising most of the leafhoppers in the sample, and *Kybos carsosna*, the larger but less common of the two and closely related to and formerly included in *Empoasca*. Dietrich suspected that *E. sativae* was likely the primary suspect because of its polyphagous nature, much higher numbers in the sample, and that it appeared to be feeding on petioles and leaf rachises in photographs that Hodel shared with him. On the other hand, *K. carsosna* is known nearly exclusively to occur on plants in the

22. The primary suspect in *Schinus molle* canopy thinning is a small, green leafhopper tentatively identified as *Empoasca sativae*, here in Long Beach, California.

23. Two *Empoasca sativae* are perched on this young, fresh, green twig of *Schinus molle*, Long Beach, California. Note the dark, minute, pint-point spots, likely wounds where the leafhoppers' stylets were inserted to feed.

24. An *Empoasca sativae* has its stylet inserted into a fresh, green leaf rachis on *Schinus molle*, Lang Beach, California.

25. A feeding *Empoasca sativae* likely has its stylet inserted into the pinnae midrib on *Schinus molle*, Long Beach, California.

genera *Populus* (cottonwood) and *Salix* (willow). Dietrich suspected that the *Kybos* leafhoppers had shifted to *Schinus molle* as its primary hosts became deciduous and, if we had made our collections earlier in the year during the summer, we would have likely collected only *E. sativae*, not *K. carsosna*.

Rung's molecular analyses were inconclusive and did not match any known leafhopper in the genetic databases. This troubling and frustrating result could simply be because sequence data matching our leafhoppers had yet to be entered in the databases and/or unknowingly the leafhopper samples actually comprised the two species, *Empoasca sativae* and *Kybos carsosna*. Blomquist found no phytoplasmas in the affected *Schinus molle* samples.

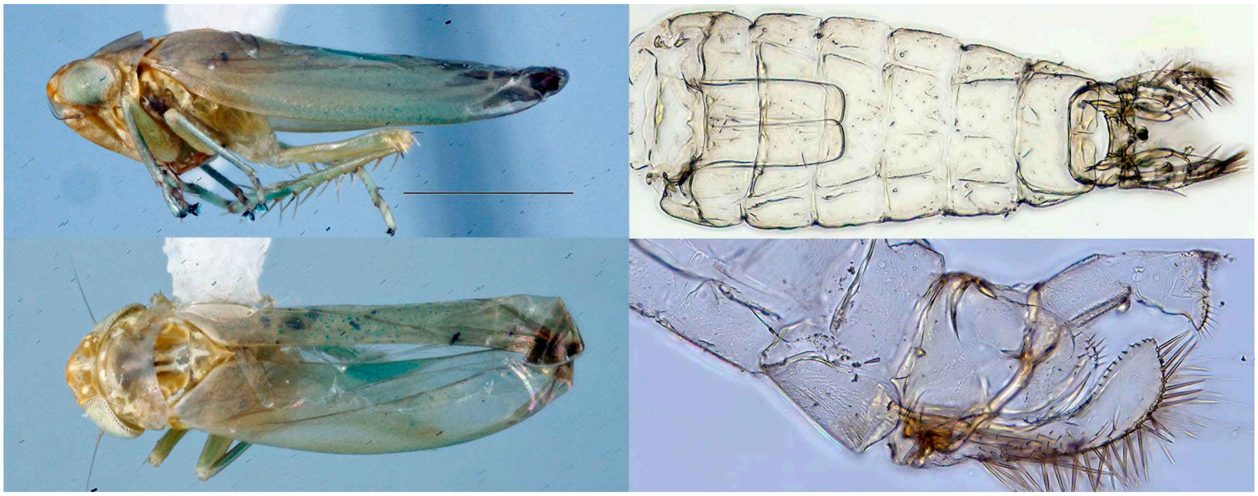
Thus, considering that we found no culturable pathogens, abiotic disorders, other insect or mite pests, and that the leafhopper *Empoasca sativae* was always associated with symptomatic trees, we conclude that it is the primary suspect in *Schinus molle* canopy thinning.

Empoasca sativae

Frederick W. Poos, an entomologist for the United States Department of Agriculture, named and described *Empoasca sativae* in 1933, basing it strictly on a large series of male leafhoppers that he had collected on alfalfa at Leavenworth, Kansas in August 1930. Other important taxonomic accounts of this leafhopper include DeLong and Knull (1946), who placed it in subgenus *Empoasca*, which comprised the American species, and Xu et al. (2021), who moved *E. sativae*, along with other species, to the genus *Hebata*, making *Hebata sativae*. Nonetheless, the male subgenital plate of *E. sativae* has a basolateral extension which, in addition to the preapically excavated pygofer appendage, supports retaining it in *Empoasca sensu stricto*. Additional, mostly general information about *E. sativae* can be found in BugGuide (2024), Dmitriev et al. (2022), GBIF (2024), and Oman (1949). Strangely, iNaturalist (2024) has no observations yet posted for *E. sativae*.

The following description of *Empoasca sativae* is mostly from Poos (1933), who primarily was providing information to distinguish the species from *E. fabae* and *E. abrupta*, and supplemented from Fegley (1989) and our field observations.

Males are about 3 mm long, slender, and green with variable markings (**Figs. 22–26**). The vertex, that area of the head between the two eyes, frequently has a pale or dark spot near the anterior margin on each side of the median line. The pronotum, that section of the thorax between the wing bases just anterior to the sections that bear the legs and wings, typically has 4–6 pale spots along the anterior margins. The scutellum, the large, triangular, shield-like spot on the back of some insects, including Hemiptera, has a white line on each side of the median line to the apical



26. *Empoasca sativae* Poos, from material collected in Long Beach, California. Adult male: lateral view (top left, scale bar = 1 mm); dorsal view (bottom left); abdomen, ventral view (top right); distal part of abdomen, lateral view (bottom right). © 2024 C. H. Dietrich.

half, which has three white spots forming an irregular transverse band just back of the middle. The elytra or forewings are greenish yellow and sub-hyaline.

Male genitalia are critical for identifying leafhoppers, especially *Empoasca* because many species of this genus and related Empoascini are apparently identical in external appearance. The main features distinguishing *E. sativae* from the common and widespread *E. fabae* (the potato leafhopper) are the relatively long, parallel-sided apodemes, the inward, ridge-like growth of the exoskeleton, at the base of the male abdomen (see **Fig. 26**, especially abdomen in ventral view), which are only visible after clearing the male abdomen in a KOH solution.

Empoasca once included over 600 species (Ross et al. 1964). However, as recently redefined by Xu et al. (2021), it now includes only about 40 species restricted to the New World, but several related genera of tribe Empoascini include several hundred additional species distributed worldwide, many of which closely resemble *Empoasca* in external appearance.

Ross et al. (1964) theorized that *Empoasca sativae* evolved primarily as a tropical species that extended its range into temperate regions by a two-step process. First, some northern peripheral populations of *E. sativae* were able to survive lower temperatures and extended their range in subtropical regions like the U. S. Gulf Coast from Texas to Florida. Then some of these subtropical populations acquired tolerance of even colder temperatures and moved into temperate regions, at least for the spring, summer, and fall. Because *E. sativae* is not cold hardy, the cold temperate winters destroyed these temperate populations but the northern edge of the overwintering

27. The first symptom of *Schinus molle* canopy thinning might be pinnae drop on newer leaves on the canopy periphery, Long Beach, California.

28. An early symptom of *Schinus molle* canopy thinning might be pinnae necrosis, Long Beach, California. The dark spots on the leaf rachis might be feeding sites while the white spots on pinnae could be dried sap secretions from feeding sites.

29. One early symptom of *Schinus molle* canopy thinning might be twig dieback, Long Beach, California.

30. Extensive dieback on the canopy periphery seems to be typical of *Schinus molle* canopy thinning, Long Beach, California.

31. Extensive dieback and pinnae drop might be symptoms of *Schinus molle* canopy thinning, which lead to bare twigs and leaf rachises, Long Beach, California.

32. As *Schinus molle* canopy thinning progresses, the canopy periphery has a distinctive appearance, seeming to be composed of erect or spreading, naked twigs, Seal Beach, California.

population along the Gulf Coast survived to generate new populations that moved into temperate regions the next spring.

We can see this seasonality in *Empoasca sativae* attacking *Schinus molle* in southern California. Populations were abundant and it was easy to collect 100s of leafhoppers in a few minutes in October and November but after December cold spells with night temperatures of 2 to 7 C, numbers plummeted, and it took 30 minutes to collect 10 leafhoppers. Because we find some *E. sativae* here throughout the winter, we suspect that southern California, like the Gulf Coast, has the northern periphery of the overwintering population.

Symptoms of *Schinus molle* Canopy Thinning

A suite of symptoms characterizes canopy thinning on *Schinus molle*, some conspicuous and spectacular and others more discrete and subtle. Symptoms vary depending on the stage of development of this malady. The first symptom might be general yellowing of distal pinnae accompanied by some pinna necrosis and drop on newer leaves on the canopy periphery, especially at the top (**Fig. 27–28**), although these symptoms could easily go unnoticed because of their somewhat subtle nature and distance from the viewer.

The more easily recognizable symptom is probably more severe thinning on the canopy periphery, again especially at the top. Extensive dieback and pinna drop leave bare leaf rachises, which from a distance appear as erect or spreading, naked twigs (**Figs. 29–32**). New growth that does appear is typically malformed, misshapen, or distorted and often epinastic in nature, with twisted twigs and leaves (**Fig. 33**).

As the malady progresses, canopy thinning, twig dieback, and pinna drop and necrosis become more severe (**Fig. 34**), and twig growth is stunted, malformed, epinastic, and "bunchy" (**Figs. 35–40**), somewhat like witch's broom, with numerous, short, deformed twigs arising close together, eventually from a swollen, nearly tubercular, sometimes "corky" growth (**Figs. 41–45**). Bark sometimes peels away at this stage (**Fig. 46**) and the "bunchy" growth can occur at several places along a branch (**Fig. 47**). The canopy at this latter stage typically is severely thinned out (**Fig. 48**).

Even at this advanced stage, most symptoms are still at the top and upper part of the canopy **(Fig. 49**). Eventually, symptoms move lower in the canopy and, by the time they reach the lower part, the tree is much defoliated (**Fig. 50**).

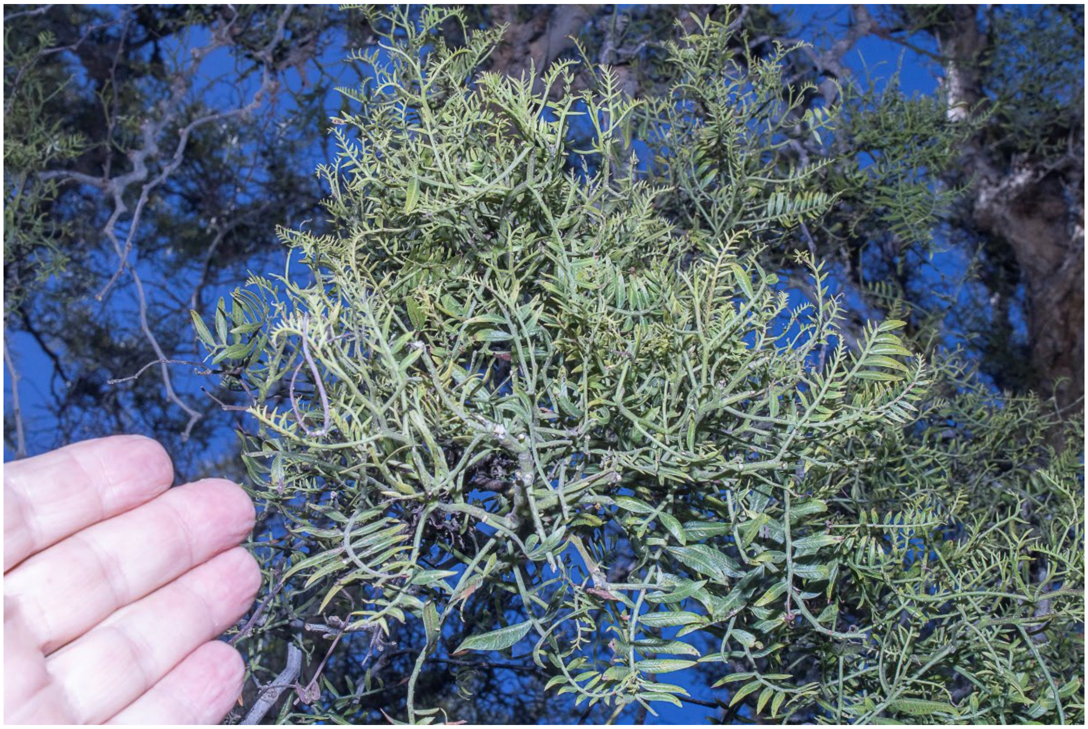
Eventually, the tree is nearly completely defoliated and near death (**Fig. 51**). We have observed at least one tree that died (**Figs. 18–20**) although other factors might have been involved in its death. Because so much leaf area is lost with this malady, photosynthesis is much reduced, which by itself can lead to stress, decline, and serious secondary problems.

33. New growth that does appear during *Schinus molle* canopy thinning is typically deformed or distorted and often epinastic, with twisted twigs and leaves, Long Beach, California.

34. As *Schinus molle* canopy thinning progresses, canopy thinning, twig dieback, and pinna drop and necrosis become more severe, Lakewood, California.

35. One of the most spectacular and characteristic symptoms of more advanced *Schinus molle* canopy thinning is stunted, malformed, epinastic, and "bunchy" or congested shoot growth, Tustin, California.

36. This "bunchy" new growth is characteristic of *Schinus molle* canopy thinning, Tustin, California.



37. "Bunchy" new growth of *Schinus molle* canopy thinning can be spectacular, Seal Beach, California.

38. This deformed, "bunchy" new growth is characteristic of *Schinus molle* canopy thinning, Seal Beach, California.

39. Severely congested, “bunchy” new growth characterizes *Schinus molle* canopy thinning, Lakewood, California.

40. Here is comparison of normal foliage (left) and symptomatic “bunchy” growth of *Schinus molle* canopy thinning (right), Seal Beach, California.

41. In older, more advanced stages of *Schinus molle* canopy thinning, the “bunchy” growth eventually arises from a swollen, nearly tubercular growth, Seal Beach, California.

42. In *Schinus molle* canopy thinning, the “bunchy” growth eventually arises from a swollen, nearly tubercular growth, Seal Beach, California.

43. In older, more advanced stages of *Schinus molle* canopy thinning, the "bunchy" growth eventually arises from a swollen, nearly tubercular growth, Seal Beach, California.

44. The swollen, tubercular growth from which the "bunchy" shoots arise in *Schinus molle* canopy thinning sometimes have a "corky" appearance, Seal Beach, California.

45. The “bunchy” growth of *Schinus molle* canopy thinning eventually arises from a swollen, nearly tubercular growth, Seal Beach, California.

46. Bark sometimes peels away at this later stage of *Schinus molle* canopy thinning, Seal beach, California.

47. In these later stages of *Schinus molle* canopy thinning, the "bunchy" growth can occur at several places along a branch, Seal Beach, California.

48. In these later stages of this *Schinus molle* malady, the canopy is severely thinned out, Seal Beach, California.

49. Even at this advanced stage of *Schinus molle* canopy thinning, most symptoms are still at the top and upper part of the canopy, Long Beach, California.

50. Eventually, symptoms of *Schinus molle* canopy thinning move lower, but at this stage the lower part of the canopy is much defoliated, Long Beach, California.

51. Eventually, *Schinus molle* trees with canopy thinning become nearly completely defoliated and near death or die, Seal Beach, California.

Symptoms can progress slow to moderately, from a healthy, symptom-free tree to showing severe symptoms over the upper two-thirds to three-fourths of its canopy within two to three years (**Figs. 52–55**) or were in the initial stages of canopy thinning but symptoms became much more severe in a similar or shorter time period (**Figs. 56–57**). Sometimes symptoms are first mostly confined to a major branch in the canopy, with the remaining part of the canopy appearing symptom free (**Fig. 58**); eventually, though, the entire canopy becomes affected.

We also observed minute, pin-point size, dark spots on young twigs (**Fig. 23**), leaf rachises, and pinna midribs and primary nerves (**Figs. 23, 27, 59–60**), which we interpret as feeding sites where the leaf hopper inserted its stylet. Some of these spots tend to enlarge, forming more conspicuous necrotic areas often accompanied by a white substance, the latter likely dried sap from the leafhopper feeding wound (**Fig. 61**).

Management of *Schinus molle* Canopy Thinning

Because we do not yet know the precise cause of canopy thinning, it is difficult to devise a management strategy. Nonetheless, providing optimal cultivation is the foundation for any management strategy, no matter the cause.

Remember that *Schinus molle* is well adapted to summer drought and needs little or no water once established. Avoid planting in clay soils in lawns and other summer-irrigated landscapes, which can promote root diseases and disorders leading to decline and death. Plant in the full sun and preferably on well drained soils, or, if planting in heavy clays, irrigate appropriately. Keep summer-irrigated landscape at least three to four meters from the trunk; maintain five cm of good quality mulch within this area. Train and prune young plants for optimal structure, using appropriate pruning techniques.

If proven that leafhoppers and/or disease are responsible for canopy thinning, employ optimal cultivation practices described above and, in consultation with a licensed, qualified pest control adviser/operator, consider appropriate pesticide applications, if necessary.

Some people have already treated symptomatic *Schinus molle* with systemic insecticides, such as dinotefuran, flonicamid, and flupyradifuron, and observed a positive growth response and improved tree health. They also implemented some of the optimal cultivation practices discussed above and applied bioactive kelp.

Summary

While the leafhopper associated with *Schinus molle* canopy thinning has been identified as *Empoasca sativae*, its role in this malady needs confirmation.

52. This *Schinus molle* was symptomless in 2021, Lakewood, California.

53. The same *Schinus molle* in Figure 52 two years later in 2023 had severe canopy thinning, Lakewood, California.

54. This *Schinus molle* was symptomless in 2017, Seal Beach, California.

55. The same *Schinus molle* in Figure 54 three years later in 2020 had severe canopy thinning, Seal Beach, California.

56. This *Schinus molle* had canopy thinning in 2020, Seal Beach, California.

57. The same *Schinus molle* in Figure 56 two years later in 2022 had more severe canopy thinning, Seal Beach, California.

58. Sometimes symptoms of *Schinus molle* canopy thinning are first mostly confined to one major branch in the canopy (right), Seal Beach, California.

59. These small, brown to dark spots on leaf rachises and pinna midribs and primary nerves on this *Schinus molle* with canopy thinning are likely leafhopper feeding wounds.

60. Minute, pin-point size, dark spots on pinna midribs and primary nerves and darkened areas on the leaf rachis of this *Schinus molle* with canopy thinning are likely leafhopper feeding wounds.

61. These spots on *Schinus molle* with canopy thinning and illustrated in Figures 59 and 60 tend to enlarge, forming more conspicuous necrotic areas often accompanied by a white substance; some of the latter are likely dried sap from the leafhopper feeding wound.

One aspect of this study that has always troubled us is why we did not detect the leafhopper for nearly four years, even while we were periodically examining symptomatic trees during that time span. Surely, the leafhopper is a small, green, highly mobile pest, which makes it elusive; however, we probably would have detected it if present, suggesting that its activity might be highly cyclical. We might have simply been examining symptomatic trees at the wrong time of year; perhaps if we had examined trees in late summer or fall when population numbers are high, we would have detected it sooner.

Because leafhoppers typically inject substances into the host plant as they feed, some of which can be phytotoxic, the symptoms might be solely the plants' response to these phytotoxic substances and are not due to a microscopic, non-culturable, vectored pathogen. However, leafhoppers are notorious for vectoring pathogens causing these types of diseases, and we feel that the damage is so distinctive and severe that a vectored pathogen cannot be dismissed.

Thus, more work is needed, such as additional leafhopper collections in the spring, summer, and fall, and new molecular analyses, to determine if the symptoms are simply a response to substances leafhoppers inject while feeding or to pathogens leafhoppers might be vectoring, such as viruses or viroids, or a combination of both. We have not ruled out even more complex causes, such as multiple factors like pathogens, pests, and/or abiotic disorders combining to cause this severe and worrisome malady. Indeed, anecdotal observations of *Schinus molle* in unkempt, non-irrigated situations seem to be less frequently and severely affected than specimens in maintained, irrigated landscapes.

In summary, while we strongly suspect that the leafhopper *Empoasca sativae* plays a major role in *Schinus molle* canopy thinning, more work needs to be done to confirm this supposition and identify any vectored pathogen.

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