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Panicle and Shoot Blight of Pistachio: A Major Threat to the California Pistachio Industry

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Pistachio is a dioecious plant with fruit drupes born in taxianthies called panicles (clusters).

Introduction

Pistachio cultivation dates back to the Holy Lands of the Middle East, where they grew wild in the high desert regions. The history of pistachios includes aspects of royalty, perseverance, and pride. Legend has it that lovers met beneath the trees to hear the pistachios crack open on moonlit nights for the promise of good fortune. A rare delicacy, pistachios were a favorite of the Queen of Sheba, who demanded all her land's production for herself and her court. The royal nut was imported by American traders in the 1880s, primarily for U.S. citizens of Middle Eastern origin. Some 50 years later, pistachios became a popular snack food, introduced in vending machines. These imported nuts were dyed red to draw attention and to cover stains from antiquated harvesting and drying techniques.

The inception of the California pistachio industry occurred in 1929, when the American plant scientist William E. Whitehouse spent a lonely six months in Persia (Iran), collecting seed and going through piles of product to find the most distinctive pistachios. He returned with 20 pounds of seed to start a breeding program. With pistachios requiring from 7 to 10 years to mature, it was 1950 before a successful cultivar emerged from that program. The variety was named Kerman for the famous carpet-making city near where the original seed was collected by Dr. Whitehouse. University of California scientists then budded (grafted) the Kerman to more vigorous rootstocks. Thus the dream of a California pistachio industry became a reality. Word of the new crop spread, plantings expanded throughout the state in the 1960s, and the first commercial crop of 1.5 million pounds was harvested in 1976 from less than 1500 acres. By 1990, approximately 50,000 bearing acres yielded 120 million pounds, by 2000 approximately 75,000 acres yielded a total of 240 million pounds, and by 2002 a total of 300 million pounds were produced. With their acreage and production expanding, California pistachio growers united in their efforts to promote the industry. In 1981 the California Pistachio Commission (CPC) was established to provide support through public relations, marketing, and production research. By 2000, the CPC became one of the most successful agricultural industries in California. The CPC is funded by an assessment (cents) per pound of pistachios produced in the State.

Panicle and Shoot Blight of California Pistachios

Panicle and shoot blight was first discovered in a commercial orchard in the town of Durham, (Butte Co.) in the northern Sacramento Valley (Fig. 1), in the summer of 1984. Systematic research on the disease started in 1985, along with research on another major problem, epicarp lesion. Researchers working on epicarp lesion first discovered panicle and shoot blight in a 20-acre orchard, presumably the first commercial pistachio orchard established in California, about 16 miles south from the Tree Improvement Center at Chico (TICC) where pistachio was first introduced in California. Between 1985 and 1988 the disease was found in various cultivars grown in the TICC. From 1985 to 1990, research on this disease focused mainly on diagnosis, isolation and identification of the pathogen, Koch's postulates, studies on the epidemiology, and the development of cultural and chemical approaches to manage the disease. It was during this period when the devastating consequences of the disease became apparent. In the orchard where the disease was discovered, as well as a few other orchards in Butte and Tehama Counties, yield losses from 40 to 100% were not uncommon (10).

Fig. 1. California map showing areas where pistachios are grown. (*) Asterisk shows the orchards where panicle and shoot blight caused by *Botryosphaeria dothidea* was discovered first in 1984.

Blights caused by *Botryosphaeria* spp. of woody plants have been known since the early 1900s. By 1935, it was known that *B. dothidea* could attack more than 50 plant species, representing 34 genera and 20 plant families (20). From 1984 to 2003, *B. dothidea* was isolated from more than 40 different plant species in California (Table 1). Panicle and shoot blight also occurs on pistachios grown in Greece, Italy, and South Africa (9). Since its initial discovery in 1984 (19), panicle and shoot blight has become a disease of major importance for pistachios grown in California. Losses due to panicle and shoot blight in the San Joaquin Valley were minimal in 1997, but continued to be severe in orchards in the Sacramento Valley. In 1998, warm wet spring weather, triggered by El Niño, provided optimum conditions for spore dispersal and infection, and the disease was very severe in orchards where it had become established in prior years. Thus pistachio plantings throughout the state suffered heavy losses, except for orchards in the southern part of Kern County and on the west side of the San Joaquin Valley. It was then obvious to all that the disease was spreading to the south (17,23). In the words of the growers, 1998 was a "Bot year" and the total production lost to disease that year was estimated at approximately 20 million pounds. The effects of the 1998 epidemic lingered into 1999, as blight-induced death of shoots and fruiting buds caused an estimated loss of 12 million pounds. From 1999 to 2002 the disease severity was relatively light because of unfavorable weather conditions, pruning out of the blighted wood and removal of inoculum sources, and registration and application of effective fungicides. The destruction caused by this disease makes panicle and shoot blight the most serious threat to pistachio trees grown in California.

Table 1. Hosts from which *Botryosphaeria dothidea* was frequently isolated in California

* Hosts where the sexual stage of the pathogen has been found.

Common name	**Scientific name**	**Family**
Almond	*Prunus dulcis*	Rosaceae
Apple	*Malus domestica*	Rosaceae
Avocado*	*Persea americana*	Lauraceae
Blackberry*	*Rubus ursinus*	Rosaceae
Black walnut	*Junglans hinsii*	Juglandaceae
Carob seed tree	*Ceratonia siliqua*	Fabaceae
Incense cedar	*Cedrus libani*	Pinaceae
Deodar cedar	*Cedrus deodara*	Pinaceae
Chinese hackberry	*Celtis sinensis*	Ulmaceae
California redwood*	*Sequoia sempervirens*	Taxodiaceae
Cotoneaster	*Cotoneaster frigidus*	Rosaceae
Cottonwood	*Populus deltoides*	Populaceae
English walnut	*Junglans regia*	Juglandaceae
Eucalyptus	*Eucalyptus coccifera*	Myrtaceae
Euonymus	*Euonymus fortunei*	Celestraceae
Silver dollar eucalyptus	*Eucalyptus orbifolia*	Myrtaceae
Feijoa	*Feijoa sellowiana*	Myrtaceae
Fig	*Ficus carica*	Fagaceae
Giant sequoia*	*Sequoiadendron giganteum*	Taxodiaceae
Juniper	*Juniperus occidentalis*	Cypressaceae
Jasmine	*Jasminum officinale*	Jasminaceae
Lemon	*Citrus* × *limon*	Citraceae
Sweet gum	*Liquidambar styraciflua*	Mamamelidaceae
Maple	*Acer* sp.	Aceraceae
Oak	*Quercus* sp.	Fagaceae
Olive*	*Olea europea*	Olivaceae
Orange	*Citrus* × *auranteum*	Citraceae
Pistachio	*Pistacia vera*	Anacardiaceae
Pear	*Pyrus communis*	Rosaceae
Pecan	*Carya illinoensis*	Junglandaceae
Persimmon	*Diospyros kaki*	Ebenaceae
Pine	*Pinus radiate*	Pinaceae
Prune	*Prunus domestica*	Rosaceae
Firethorn*	*Pyracantha coccinea*	Rosaceae
Raymond ash	*Fraxinus augustifolia augustifolia* subsp. *oxycarpa*	Oleaceae
Sycamore maple	*Acer pseudoplatanus*	Aceraceae
Wax leaf privet	*Ligustrum japonicum*	Oleaceae
Western redbud	*Cercis occidentalis*	Fabaceae
Wild rose	*Rosa* sp.	Rosaceae
White willow	*Salix alba*	Salicaceae
Arroyo willow	*Salix lasiolepis*	Salicaceae
Weeping willow	*Salix babylonica*	Salicaceae

Description of the Disease

Under California climatic conditions pistachio, which is a dioecious plant, typically breaks dormancy in early April. When buds are infected by *B. dothidea*, they either will not emerge (total blight) or emerge but the resulting flower or shoot eventually dies. Symptoms appear as dark lesions, usually at the base of shoots, rachises, and mid ribs of leaves. Shoots originating from heavily infested or partially killed buds expand to a short length, become black, and die (Fig. 2). In mid-May, leaves on infected shoots wither in 3 to 5 days, and later on brown blighted shoots and leaves become distinct among the healthy dark green foliage (Fig. 3). Infected flower buds lead to blighted inflorescences (Fig. 4). Rachis infections occur at the base or at branching points. Infected tissues turn black, and the rachis collapses. Depending upon the location of the lesion, these infections also can lead to the collapse of the clusters, with fruit adhering to them.

Fig. 2. Early symptoms of shoot blight caused by *Botryosphaeria dothidea*.

Fig. 3. Shoot blight at a later stage, distinct because of the brown discoloration among the green canopy caused by *B. dothidea*.

Fig. 4. Blighting of a young panicle caused by *Botryosphaeria dothidea*.

Early leaflet infections produce somewhat elongated black lesions on the midrib of leaf petioles (Fig. 5). Petiole infections kill individual leaflets, and infected leaves or leaflets drop beginning in July. Most defoliation, however, occurs in late summer and can be severe. Lesions on blades do not usually result in defoliation. When shoot infection occurs and leaves wilt and die, the pathogen can invade the older leaves of the shoot, leading to the development of pycnidia, usually at the basal flattened portion of the petiole. Leaf stem and mid rib infections are very common and usually are the first symptoms to appear during an epidemic of panicle and shoot blight in an orchard.

Fig. 5. Mid rib and leaf stem infections by *B. dothidea* resulting in defoliation.

Infections on the surface of the fruit, which remain latent under unfavorable conditions, will appear in mid-summer as pin-sized, round, black spots (Fig. 6). Some of these lesions begin to enlarge, usually on the tip or sometimes near the stem (Fig. 7) and can result in fruit blight. On one to several fruit in a panicle, some lesions enlarge quickly, the fruit turn black, and infection can move through the peduncle to the rachis, and eventually to the shoot on which the fruit cluster is borne causing sunken elliptical cankers. Most of the blighted fruit in infected panicles are light tan, the consequence of girdling. Only few infected fruit are black and mushy initially, but as they dehydrate on the blighted cluster, they become gray-silver in the fall, and the fungus produces abundant pycnidia under the epidermis which attains a distinct gray silver color (Fig. 8). As the pycnidia develop and enlarge in size, they push and separate the epidermis and the cuticle from the tissues underneath, but the integrity of the epidermis remains intact or shows minute slits on top of the slightly protruding pycnidial ostioles, giving rise to the black peppery appearance of the epicarp. Pycnidia of the pathogen also develop under the epidermis on the basal portion of the infected rachis (Fig. 9). The distinct gray to silvery blighted tissue with tiny black bumps should be checked for the presence of pycnidia when diagnosing panicle and shoot blight at a time when other distinct symptoms or signs of the pathogen are absent in the field during the tree dormancy, for instance.

Fig. 6. Fruit infections by *B. dothidea* associated with lenticels.

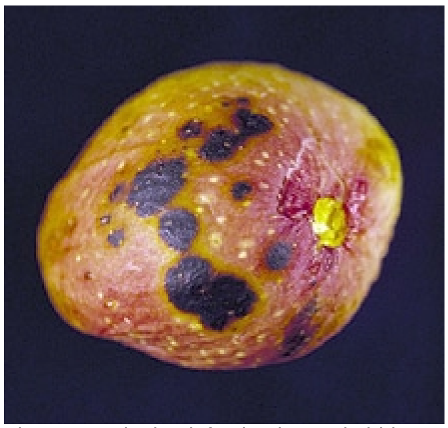

Fig. 7. Developing infection by *B. dothidea* through a lenticel in a mature pistachio fruit.

Fig. 8. Pistachio fruit infected by *B. dothidea* and covered with pycnidia of the fungus (note the peppery appearance).

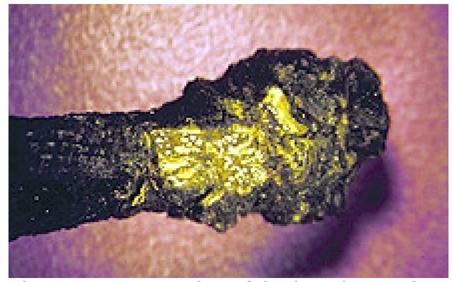

Fig. 9. A cross section of the basal part of a rachis showing characteristic pycnidia of *B. dothidea*.

Primary and secondary latent infections of leaf blades appear next as small, angular or round, black lesions. Some of these infections enlarge during the summer and become irregular to round brown lesions, up to 25 mm or larger in diameter, with chlorotic margins (Fig. 10). The lesions and halos often coalesce creating blotches of various shapes that ultimately dry to tan. Pycnidia of the fungus may develop in the center of the lesions by mid-August and during September and October.

Fig. 10. Lesion caused by *B. dothidea* on leaves of pistachio.

Primary latent and secondary infections of fruit also start as small black lesions, which enlarge turning the hulls black. Eventually, the hulls of infected nuts become characteristically light gray/yellowish to silvery with small black spots. Usually only one or two to several fruit per cluster are infected and these develop the characteristic light gray color, while the rest of the blighted nuts turn tan to brown as the cluster collapses (Fig. 11).

Fig. 11. Blighted pistachio cluster with characteristic nuts of silver color infected by *B. dothidea*.

Infections on current season shoots develop into cankers. Such cankers have a sunken appearance, develop around the invasion point and can range from 1 to 10 cm in length (Fig. 12). These cankers usually do not enlarge in subsequent years. *Botryosphaeria dothidea* sporadically causes cankers that are up to 30 cm in length, covered with dark exudate on trunks or extending into a main tree scaffold. The infection is limited to the bark and does not kill branches or entire trees. Some cankers are associated with pruning wounds where the pathogen can produce pycnidia in the proximity of the cut surface.

Fig. 12. Sunken canker in a 2 year old shoot of pistachio caused by *B. dothidea*.

Fruit infections also can start from punctures made by hemipteran insects (Fig. 13) or from shells and hulls ruptured by feeding birds. Pycnidia develop on these infected fruit, particularly surrounding the wounded areas.

Fig. 13. Infection on fruit by *B. dothidea* starting from a puncture made by a leaffooted bug (*Leptoglossus clypealis*).

The Causal Organism

Panicle and shoot blight is caused by *Botryosphaeria dothidea* (Moug.:Fr.) Ces. & De Not. (synonym *B. ribis* Gross. & Duggar). The anamorph was initially reported on avocados (5) and almonds (3) as *Dothiorella* sp., but now it is generally accepted that it is a species of *Fusicoccum* (22). It produces black, asymmetrical pycnidia that are solitary or arranged in groups of 5 to 8 or more, each with an apical ostiole through which the conidia extrude in a gelatinous matrix. Conidia are hyaline, nonseptate, fusiform, and measure 15-29 × 5-8 µm (Fig. 14). Isolates of *B. dothidea* from pistachio grow well and fast on regular and acidified potato-dextrose agar at 20 - 36°C (optimum 27 - 30°C). Initially, colonies are white, later changing to mouse gray, then almost black (Fig. 15). Many isolates do not produce pycnidia in culture, and some produce reddish pigments. Only the pycnidial stage has been found on pistachio.

Fig. 14. Pycnidiospores of *B. dothidea*.

Fig. 15. A Petri plate with two 7-day-old colonies of *B. dothidea* as contrasted to three colonies of *Alternaria alternata* isolated from lesions on pistachio leaves.

Identification of the pistachio panicle and shoot blight pathogen as the anamorph of *B. dothidea* (10) was based on comparisons of morphological and cultural characteristics of several isolates from pistachio with those of *B. dothidea* isolates that cause band canker of almond in California (3) and with those of isolates of *B. dothidea* from peach in Georgia (2). However, Smith et al. (22) compared isolates of this pathogen from California pistachio with the type isolates of *B. dothidea* and *B. ribis* and found that the pistachio isolates separated as a taxonomic clade between *B. dothidea* and *B. ribis* isolates. At the time when Michailides (10) identified the species causing panicle and shoot blight of pistachio, *B. dothidea* and *B. ribis* were considered synonymous. Currently, considerable controversy still exists surrounding the taxonomic status of *B. dothidea* and *B. ribis* (21). Some authors regard the two species as synonyms, while others treat them as separate taxa (22).

California populations of *B. dothidea* from pistachio are, for the most part, genetically uniform, with the sexual stage rare to absent. However, the rare occurrence of the sexual stage of *B. dothidea* on other hosts, and more importantly, the capacity of these isolates to infect pistachio, indicate that other host species may serve as sources of inoculum and genetic variation. The sexual stage of *B. dothidea* was found in blackberry (*Rubus ursinus*) growing next to pistachios, in firethorn (*Pyracantha coccinea*), and olive (*Olea europea*) at a distance of several miles from pistachios (14), and reported in coastal redwoods and giant sequoias (24). A few non-ascosporic isolates of *B. dothidea* from other hosts and pistachio were grouped with the ascosporic isolates, suggesting that ascosporic inoculum may contribute to disease initiation in pistachio (7).

Disease Cycle and Epidemiology

Overwintering sources of inoculum. Conidia released from pycnidia present on the previous year's blighted shoots, rachises, cankers, buds, and petioles cause the primary infections in the spring and early summer (Fig. 16). Cankers and retained panicle rachises are the major sources of inoculum during the winter and spring when rains occur and distribute conidia. Conidia from pycnidia and possibly ascospores produced on other hosts also can provide inoculum for primary infections, particularly when there is no other source of *B. dothidea* in the orchard. New pycnidia in current season infections develop during the summer and fall and contribute inoculum for secondary infections late in the season. In addition to these, pycnidia in old cankers produce viable conidia for at least 6 years (16). The pathogen can colonize dead wood, including cankers initially caused by *Botrytis cinerea* or shoots killed by other causes (i.e., freezing), and pycnidia produced in abundance on these cankers can be another source of inoculum.

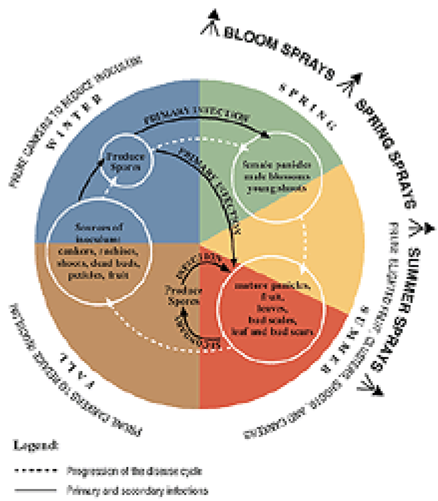

Fig. 16. Disease cycle of panicle and shoot blight of pistachio caused by *B. dothidea* and general guidelines on disease management approaches.

Dissemination. Conidia are spread mainly by rain but also by insects, birds, and water from sprinkler irrigation. Fall and winter rains spread conidia to leaf and bud scars and buds. Some buds are killed, some can be partially infected during summer and fall, and others remain healthy but contaminated by showers of spore inoculum exuding from wetted pycnidia during winter and spring. Rain anytime during the growing season moves inoculum to growing tissues.

Infection. Rainfall plays a major role in the dispersal of *B. dothidea* spores, and infections must occur during the rainy season when ambient temperatures reach 10°C or above. Buds become infected as soon as they emerge in mid- to late-April, even when there has been no rain after bud emergence. The early infections of buds are due to *B. dothidea* spores that are deposited in leaf axils and develop into active lesions.

In immature fruit, young leaves, and shoots, infections remain latent but develop later in season as ambient temperatures increase. The pathogen grows best at relatively high temperatures, thus the disease becomes severe in late spring to summer when temperatures and humidity rise. Frequencies of latent infection on leaves and fruit are positively correlated with leaf and fruit disease severity under field conditions (1). The factors that trigger the development of latent infection to disease are unknown. However, there was a positive correlation of increase in carbohydrates of pistachio fruit and disease incidence (18). Although ascospores may function in long distance dissemination of the pathogen, pycnidiospores seem to be the major sources of inoculum for the destructive epidemics in orchards (Fig. 16).

The period from bud expansion to fruit initiation constitutes a very susceptible period of bud infection with *B. dothidea* (Fig. 17). Germ tubes enter through stomata (leaves and young shoots) and lenticels (fruits and older shoots). Depending on orchard location, the period of susceptibility extends from mid March (pre-bloom) until the end of May (beginning of shell lignification). Rainfall when pistachio tissues are mostly susceptible to *B. dothidea* can result in significant infections of fruit and fruit clusters when spores of the pathogen are present. This may explain why mid season applications of effective fungicides are more effective in controlling panicle and shoot blight than are earlier or later applications.

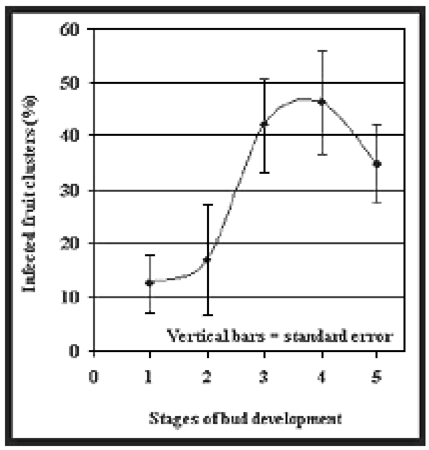

Fig. 17. Percentage of clusters infected with *Botryosphaeria dothidea* from periodic inoculations (once or twice a week) at different stages of bud development between 15 February and 19 April 2001. Stage 1 = dormant buds, 2 = separated scales, 3 = swelling to expanding buds, 4 = compact to loose clusters (pollination occurs at this stage), and 5 = clusters with fruit of 1 to 4 mm in diameter.

The optimum temperature for growth of *B. dothidea* is between 27 and 30°C on PDA, and the optimum temperature for pycnidiospore germination is between 24 and 36°C (13). Optimum temperatures for disease development range from 27 to 33°C. Pycnidia are produced most abundantly at 30°C. Pycnidia do not develop at 6°C, and only few develop at 10°C.

Wetness durations of 9 to 12 hours or longer are needed for infection, symptom development, and high levels of disease. Wet periods interrupted by dry periods result in more incidence and severity of the disease. Pycnidiospores are released within 2 to 3 hours of irrigation, and depending on the infected substrate, can be exhausted within 10 to 12 hours after irrigation (11). A 6 mm rain is required for spreading spores of *B. dothidea* from pycnidia.

It takes about 2 to 3 weeks for an infection to kill the entire fruit cluster, although when infection takes place at the base of the cluster, entire clusters can be killed within a week after infection. Wounding increases infection, although infections can occur directly through leaf stomata and fruit lenticels. Lenticel infections on 1-year shoots are occasionally observed but they develop only to small (0.5 to 1.0 cm in diameter) lesions, which do not expand any further and do not affect the shoot health (Fig. 18).

Fig. 18. Lenticel infections by *B. dothidea* and creation of a small canker on 1-2-year-old shoot of pistachio.

Under favorable pruning conditions (non rainy weather), pruning shears are not likely to transmit the disease from one pruning cut to another or from tree to tree. However, fresh pruning cuts may constitute a potential site of natural infection by rain-splashed pycnidiospores. The pathogen also can produce pycnidia on the rim of old pruning cuts.

Disease Management

Cultural practices. Control of panicle blight is difficult, and a combination of approaches should be used. Preventing the build-up of spore inoculum is a major parameter in disease management. Because *B. dothidea* produces an abundance of pycnidia on killed panicles and shoots left in trees or on the orchard floor, pruning and removing infected parts are essential to reduce the inoculum levels. Experimental evidence and long term experience on this disease help suggest the following methods for management of this disease.

- Use drip irrigation and avoid flood, sprinkler, or micro-sprinkler irrigation.
- When sprinkler use is unavoidable, use sprinklers with low trajectory angle (12°) so that water does not reach the tree canopy to spread pycnidiospores.
- If micro-sprinklers are used avoid wetting the lower tree canopy.
- Use shorter irrigation periods.
- Run irrigation systems with lower pressure to minimize fogging and humid conditions.
- Maintain a weed-free orchard floor to reduce humidity and hemipteran insect habitat.
- Survey the orchard regularly. Prune out the first blighted shoots and clusters in the summer when it is easy to spot blighted tissues; repeat pruning for at least two growing seasons or until disease is very difficult to find.
- Remove pruned brush from the orchard and burn it. Pycnidia and pycnidiospores can be viable in infected twigs and nuts even after 1.5 years on the soil surface (4).
- Do not allow trees to become water stressed, as this predisposes the trees to panicle and shoot blight (8).
- Fertilizing pistachios with high levels of potassium or spraying trees with calcium nitrate might reduce the disease severity.

Chemical control. Fungicides should be applied at early to full bloom and again in spring and summer. Dormant and or pre-bloom sprays do not seem to have any effect on the disease. As of December 2003, the following fungicides have been registered for panicle and shoot blight of pistachio: copper hydroxide (not effective), chlorothalonil (moderately effective and causing russeting of fruit), three strobilurins, azoxystrobin (Abound®), trifloxystrobin (Flint®), and pyraclostrobin (Cabrio®), and a premixed pyraclostrobin plus boscalid (an anilide) (Pristine®), which are very effective. Additional fungicides are in the process of being registered, so growers and pest control advisors need to check frequently with their extension agent and/or the agricultural commissioner for a list of currently registered, effective fungicides and use recommendations.

Integrated disease control management. An integrated approach employs a combination of fungicides, pruning, irrigation, and hemiptera management. The use of multiple fungicide applications is considered the conventional approach to control this disease. However, in some years fewer applications might be required, depending on inoculum concentrations and environmental conditions.

In orchards where panicle and shoot blight has not been observed in the past, as an insurance measure the grower could have a laboratory perform BUDMON (bud monitoring), a technique used to determine bud infection and provide a pre-season prediction of panicle and shoot blight, especially when a wet spring is expected and nearby orchards were infected. Later in spring, growers need to survey their orchards to detect any possible panicle and shoot blight symptoms.

Once panicle and shoot blight symptoms appear in an orchard, growers need to prune out the sporadic blighted shoots and clusters during the summer for at least two consecutive years. Because killed shoots and panicles are associated with dried up leaves that turn light brown color, infected shoots and clusters are easier to see in the summer before harvest. Infected shoots and clusters should be cut about 5.0 cm (2 inches) below the infection or canker. Removal or burning of the pruning brush from the orchard is recommended since insects have been shown to vector *B. dothidea* spores (15) and pycnidiospores can remain viable in pycnidia of pruned brush for at least 1.5 years (4).

Pruning should be stopped when a rain begins to reduce the risk of contaminating fresh pruning cuts, even though chances of such an infection are low. Pruning in winter can lower the incidence of axil (upper area where the leaf petiole is attached to the stem) infection and the levels of spores in rainwater, thus reducing the spore inoculum loads in pistachio orchards. If pruning is done carefully and systematically, the disease can be reduced to a manageable level. Apply a thiophanate-methyl (Topsin M®) spray at bloom. Additional sprays may be needed in-season, depending on the disease pressure.

In orchards where the level of panicle blight is severe, in addition to the measures described above, a summer pruning should be followed by additional pruning during the conventional pruning period at dormancy (January/February). A thiophanate-methyl spray should be applied, regardless of weather conditions, at early to full bloom. Growers will need to apply the maximum recommended spray program of registered fungicides, choosing those that are more efficacious at the maximum registered label rate. Because the QoI fungicides are at high risk for resistance selection among fungal pathogens, resistance management programs should be followed to minimize the risk of the development of a population resistant to these fungicides.

Pay close attention to orchards with neighboring pastures and/or riparian areas for blight caused by *B. dothidea*. Pay close attention to the flora bordering the pistachio orchard: a number of tree species, bushes, and cane-berries can be hosts of *B. dothidea* (Table 1). In general, cover crops, such as vetch or other leguminous plants that encourage the buildup of hemipteran insect populations, should not be planted in pistachio orchards; however, trap crops around orchards may be beneficial to trap the insects. Insecticide sprays to these trap crops should be applied to kill the hemipterans. Control of detected hemipteran insects may be needed in mid season to prevent the spreading of the disease and reduce fruit predisposition to infection. Signs of insect spread are infections starting from the puncture site on individual nuts of clusters.

Managing birds in pistachios may reduce spread of the disease (we found cases where panicle and shoot blight was transmitted to a cluster from bird damaged nuts. Progressive growers usually place propane cannons and/or recorded bird distress calls in their orchards to scare birds from feeding on mature nuts.

Cultivar resistance. Two of the *Pistacia vera* cultivars, Sfax and Lassen, show high resistance to various isolates of *B. dothidea* representing various biotypes in California (12).

No other resistant germplasm is known, except that suckers of *P. atlantica, P. integerrima,* and of the interspecific crosses Pioneer Gold II' (PGII) (= *P. integerrima* × *P. atlantica*), and UBI (= *P. atlanticaa* Kearney Agric. Center × *P. integerrrima*) were never infected by *B. dothidea* in the field under severe inoculum pressure.

Future Prospects

Although *B. dothidea* has been described as an opportunistic fungus, the diseases it causes are aggressive and very difficult to control. The pistachio industry in California is based on essentially one cultivar, Kerman, which is very susceptible to *B. dothidea*, and panicle and shoot blight can reach epidemic levels in pistachio orchards in only a few years. It is fortunate that the strobilurin fungicides have been very effective against panicle and shoot blight. However, because these fungicides are site specific, the risk for resistance is very high. One promising fact is that resistance to strobilurins has not yet developed in *B. dothidea* after 3 years of continuous application, and these fungicides can be still used in disease control. In contrast, within the same period, *Alternaria* spp. that cause Alternaria late blight of pistachio have developed resistance to azoxystrobin, and failures in controlling the disease in California pistachios have been reported (6). The California Pistachio Industry can invest in breeding for resistance against this disease in order to avoid the threat that still exists. Although the initial tests indicated that there is variability regarding the susceptibility of *Pistacia* germplasm to *B. dothidea*, efforts should be made to incorporate an active disease screening of the new cultivars in a future breeding program that the industry anticipates funding. In addition, growers need to remain pro-active in their efforts to maintain their orchards free from inoculum of the pathogen, using regular surveys, sanitation by pruning of possible infections, controlling hemiptera insects, and following fungicide programs that have been shown to control panicle and shoot blight. Furthermore, the walnut and the almond industry could join efforts with the pistachio industry to combat this disease since the same pathogen has been reported to cause damage in almonds and very recently in walnuts.

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