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Diseases

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CANKER DISEASES OF GRAPEVINES

Before 1975, *Phomopsis viticola* was thought to be the sole casual agent of dead-arm in grapevines worldwide. Research since 1975 has shown otherwise, as at least two other fungi have been identified as part of this complex problem. In the mid 70s, *Eutypa lata* (Eutypa dieback) was shown to cause the wedge-shaped cankers and the characteristic weak, distorted, chlorotic shoot growth observed in early spring. Where these foliar symptoms are observed, isolations from the margins of the wedge-shaped cankers have always yielded *Eutypa*. Further investigations have also confirmed the pathogenicity of *Botryodiplodia theobromae* (Bot canker) as another casual agent of dead-arm in grapevines. These same investigations indicated (though this has not yet been confirmed) that *Phomopsis viticola*, the cause of Phomopsis cane and leaf spot, may also cause wedge-shaped cankers on highly susceptible varieties such as 'Thompson Seedless.'

The wedge-shaped cankers of Bot canker are indistinguishable from those caused by Eutypa, but Bot canker has no foliar symptoms that can be observed on the vine. These cankers always grow from the point of infection downward toward the root, and the wedge enlarges within the wood until it eventually causes the death of the spur, cordon, or trunk. In time the vine dies, though it may be unthrifty for many years before death. It is common to find multiple cankers caused by *Eutypa* and *Botryodiplodia* on the same vine.

Eutypa Dieback

Eutypa dieback, as it is commonly called today, is caused by the fungus *E. lata*. The most characteristic symptoms are wedge-shaped brown cankers in the wood of the vine (Plate 22.1) and weak, stunted growth characteristically observed in early spring. Affected leaves are small, chlorotic, and distorted, and have necrotic margins. These foliar symptoms are caused by a toxin produced by the fungus in the water-conducting tissue and are similar to symptoms of severe zinc deficiency. Foliar symptoms are best observed in early spring before stunted shoots are overgrown by adjoining, unaffected shoots. Shoot symptoms are always associated with the development of the wedge-shaped canker. Isolations from such tissue yield *E. lata*.

Production of infective spores (ascospores) occurs in the higher-rainfall areas north of Fairfield, California. With the beginning of winter rainfall (November to December), spores are released and distributed by wind southward into the San Joaquin Valley. Because spores are dispersed by rainstorms, the disease is most prevalent north of Fresno, and the highest incidence is in the North Coast region. Ascospores land on fresh pruning wounds, infect the plant, and within 2 years develop cankers below the wound. The larger the wound, the greater the risk for infection to occur. Refer to *Grape Pest Management* (see References) for more information.

Bot Canker

Bot canker, caused by the fungus *B. theobromae* in California, is also a pruning wound canker disease that produces wedge-shaped cankers that are indistinguishable from those caused by *E. lata*. However, Bot canker lacks foliar symptoms. The disease develops more slowly than Eutypa dieback, and *B. theobromae* infections often go unnoticed until the arm or cordon dies. The only positive identification procedure is to culture the causal fungus from margins of cankers, since all of the fungi discussed here have been recovered from cankers found on grapes in California.

Within 2 to 3 years after the development of the canker, fungal fruiting bodies (*pycnidia*) begin to form on the dead wood. How these spores are transported onto the pruning wounds has not been fully determined, but wind, wind-driven rain, and insects are all possibilities. In one experiment, up to 6 percent of springtails feeding on vine sap at wound sites were found to have *Botryodiplodia* spores on the surface of their bodies.

Based on statewide surveys of the grape-growing areas in California, the relative incidence of Eutypa to Bot canker is 50:50 from Madera northward in the northern San Joaquin Valley. From Fresno County southward (southern San Joaquin Valley), the ratio of Bot canker to Eutypa dieback is 90:10. Bot canker is the major cause of arm, cordon, and vine death, especially in the southern San Joaquin and Coachella Valleys of California. Eutypa has never been reported in the Coachella Valley. Bot canker is also the predominant cause of dead arms and cordons in vineyards in Arizona and northern Mexico (Sonora).

Management of Canker Diseases

The main loss in vineyards takes the form of reduced production when the fruiting wood (spurs and arms) dies and is not replaced by retrained canes during the dormant season. On cordon-trained vines, doubled spurs ("rabbit ears") on strong arms offer a simple way to regain lost fruiting positions. A good time to locate and remove the dead or diseased portions of vines is in late spring when a diminishing risk of rain decreases the chance that spores will disperse and re-infect fresh pruning wounds. It may be impossible to completely remove diseased cordons or arms without cutting off the whole vine. In these cases, it is better to retrain a cane from the other side of the cordon to replace fruiting wood than to retrain the whole vine.

Sucker shoots are often used to replace vines in which the disease affects the trunk. Unless the diseased wood can be removed completely from the trunk, any shoots that arise along the trunk will be affected and eventually die. If shoots arise from below the soil surface, however, they appear to develop their own root systems and are generally unaffected by the disease on the old trunk.

On cane-pruned varieties, weak and dead arms should be removed, but many older vines have many cankers that have killed portions of the trunk. Because complete elimination of the disease from older vines is impossible, keep these vines as vigorous as possible and replace fruiting wood as necessary to keep them productive. As one of these vines becomes unthrifty, the best tack is to replace it with a layer from the adjacent vine. Bear in mind that extensive cutting creates large wounds on cordon- or head-trained vines, and these present more opportunities for infection. Perform this work during dry weather and use a reliable pruning wound paint. Evidence suggests that vigorous vines survive for a long time with numerous cankers; hence drought, mechanical injury, poor soil conditions, insect pests, and overcropping, all of which can hurt vine vigor, should be avoided.

Pruning wounds offer easy access into the vine structure for many organisms. December and January pruning causes wounds that remain highly susceptible to infection for 4 to 6 weeks, whereas wounds made in late winter or early spring heal within 10 to 14 days. Fungicidal pruning wound paint is only effective for 2 weeks and does not offer long-term protection. Biological control that does offer long-term protection may eventually be possible. Two fungal organism have been reported to be as effective as pruning wound fungicides at preventing *Eutypa* infection, but neither is currently commercially available.

According to current recommendations you should delay pruning until late winter and treat the wounds with a pruning wound paint. When you have to prune earlier for efficient labor management, try to avoid the period between Thanksgiving and Christmas when the first rains of the season generally come and spore counts are at their highest. If you prune in early to midwinter, retreat the wounds at 2-week intervals. "Pre-pruning" has become popular with some growers: canes are hedged below the wires early in the season and spurs are pruned to two buds in late February or March when there is less chance of infection.

Research continues and evidence is mounting to the effect that the protection of pruning wounds against infection is an economic necessity to the long term health, vigor, and production capacity of the vine. In 1998 (as of this writing) only one material, Benlate (benomyl), is registered for use as a pruning wound paint. It has been shown to be effective against both *Eutypa* and *Botryodiplodia.* When used as a protectant it effectively prevents infections for up to 2 weeks.

POWDERY MILDEW

Powdery mildew caused by the fungus *Uncinula necator* is probably the most common disease on grapes. The pathogen is an obligate parasite and can only grow on living tissue of grape and two other closely related species. On some grape varieties the disease is hardly noticeable, but on highly susceptible varieties the pathogen can stunt growth, cause defoliation, delay coloration of the berries, and greatly reduce the quality and quantity of the crop. 'Thompson Seedless' is moderately susceptible to powdery mildew (Plate 22.2), while 'Fiesta' and 'Zante Currant' are noted for their high susceptibility.

Symptoms

The fungus can infect all green tissues of the vine and is hard to detect early in its development. The pathogen appears as small greyish to ash-white blotches of fungal growth on the surface of the leaves or shoots. The best ways to detect these early infections are to look for small yellow-green spots on the leaves and to use a 10× hand lens to look for the weblike fungal growth. The fungal growth (*mycelium*) produces short stalks that bear chains of conidia or spores, giving the infection site a powdery appearance. These conidia break off, are transported downwind onto young unprotected tissues, and give rise to more infections. If severe infections develop when the leaves are young, then crinkling, distortion, and defoliation can result. Severe shoot infections can stunt vine growth and cause black to rusty blotches on the surface of the cane during the dormant season. Infections of the cluster cause lower yields, delayed maturity, berry cracking and increased rots, off-flavors in wine, and a shorter storage life for table grapes. Raisin quality, quantity, and rain tolerance are greatly reduced by high levels of mildew.

Life Cycle

In California, powdery mildew of grape has two overwintering stages (Figure 22.1). The pathogen can overwinter as fungal mycelium in infected buds. After bud break in spring the mycelium begins to grow, resulting in *flag shoots*. The pathogen can also overwinter as dormant cleistothecia, which are washed by fall rains from the foliage into the bark of the vine. The cleistothecia begin to form in the mycelial growth in late summer. In spring, ascospores are released from the cleistothecia and are carried on wind-driven rain or sprinkler water onto the lower surfaces of basal leaves where they give rise to primary infections. Flag shoots, which may break dormancy later than noninfected buds, have mildew on leaves or stems that causes distortion of the foliage and slower growth. Both flag shoots and ascospores initiate disease, but the subsequent asexual cycles allow the pathogen a means of continuing reproduction as it spreads to other leaves, shoots, and fruit throughout the vineyard. The severity of the disease depends on the time of infection and the environmental conditions that affect its development. Under highly favorable conditions, this fungus can progress from a spore to spore-producing colonies in as few as 5 days. While this can be devastating, it can also be very easily controlled. Powdery mildew growth and reproduction are temperature dependent, so by carefully monitoring the temperature you can tell when control measures are necessary.

The UC Davis Risk Assessment Model (Gubler-Thomas Model)

A risk assessment model based on temperature and pathogen biology has been developed to enable growers to make accurate assessments of pathogen activity and to allow growers to be judicious and timely in their fungicide applications. This model uses weather data (canopy temperature and leaf wetness) collected at 15-minute intervals. Statewide tests conducted over a 5-year period show that the model accurately assesses pathogen population increases and disease decreases.

To use the model, a grower begins collecting data at budbreak. Each time there are at least 6 continuous hours of temperatures between 70° and 85°F (21° and 29°C), 20 index points are added to a running total. Examples of temperature duration and ranges are shown in Table 22.1. If there are fewer than 6 hours in that range or if the maximum daily temperature in the canopy is greater than 95°F (35°C) for at least 15 minutes, 10 points are subtracted from the index. The index never goes above 100 or below zero. The index tells you how long you can go between fungicide applications. The spray interval is doubled when the index is between 0 and 30, normal at 40 to 50, and shortened when at 60 or more. A short interval for sulfur is 7 days; 10 to 14 days could be the longer interval. Do not go more than 3 weeks without a sulfur application during low-pressure times.

Table 22.1 shows 4 consecutive days (days 1 to 4) where temperatures are conducive to rapid mildew development and the vineyard is at 80 index points. On days 5 and 6 the hour duration requirement was not met and 10 points were subtracted each day from the index. The following day was favorable and the 20 index points added brought the index back to 80. Days 8 to 17 were marked by a long period of cool weather where conditions for disease development were not met and the index fell to zero. Note that once the cumulative index reached zero, even though conditions remained unfavorable for 2 more days, the index did not go below zero. Favorable weather on days 18 to 22 brought the index to 100 in just 5 days, indicating the need for fungicide applications with shortened intervals. Day 23 met the hourly duration criterion, but also recorded canopy temperatures exceeding 95°F (35°C), so 10 points were subtracted from the index. Favorable weather for mildew development followed for an extended period, indicating high disease pressure and shortened fungicide intervals.

In seasons with a high potential for disease, the grower may be forewarned to make more applications than normal. The real advantage of this index is seen during periods of low disease pressure when spray intervals can safely be lengthened, saving the grower time and money by reducing the number of chemical

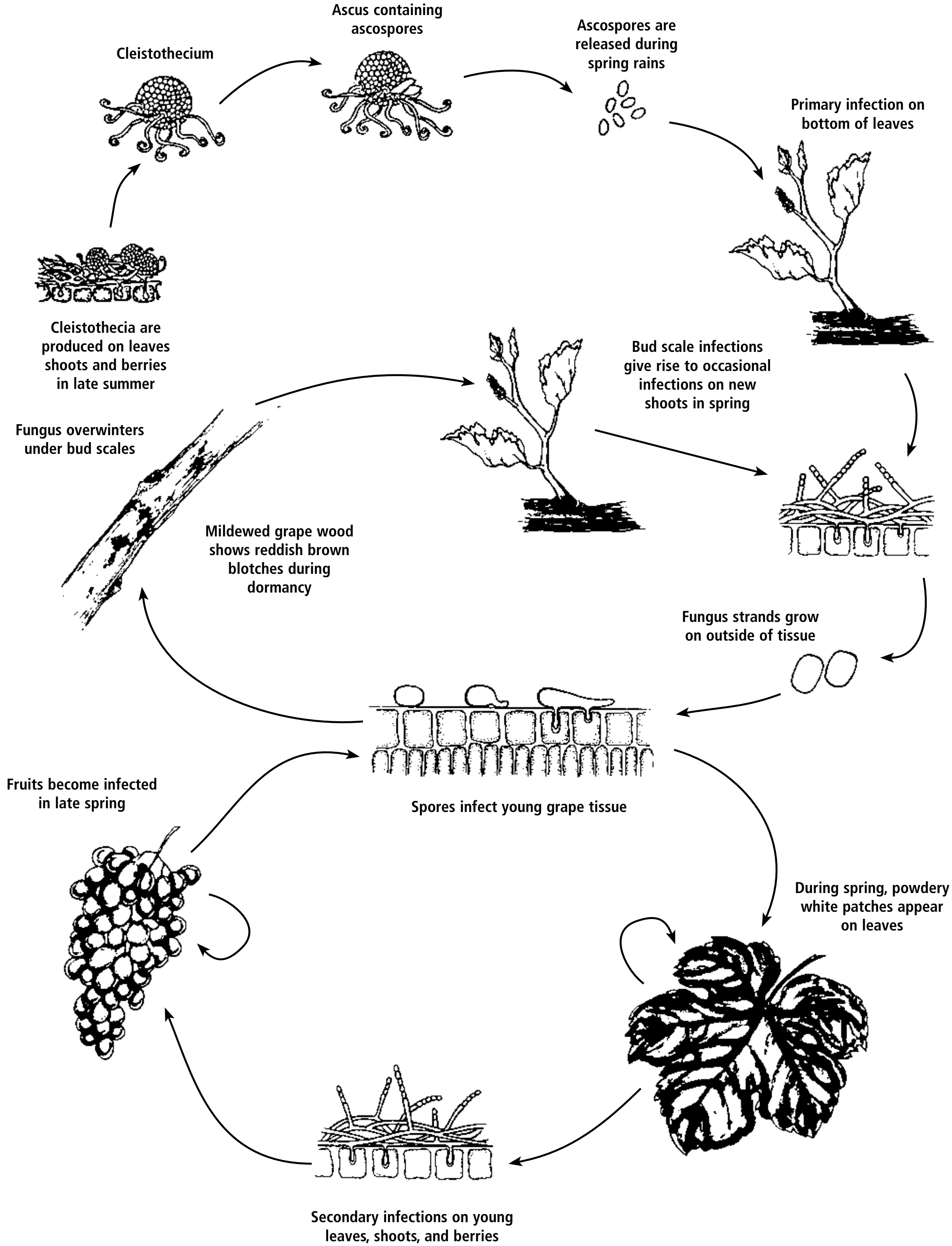

Figure 22.1 Life cycle of powdery mildew

Table 22.1 UC Davis powdery mildew disease index*

Day	Hours at 70° to 85°F (21° to 29°C)	Index points Daily	Cumulative	Remarks
1	7	+20	20	High
2	6	+20	40	
3	6	+20	60-	disease
4	8	+20	80	
5	5	–10	70	pressure,
6	5	–10	60	
7	7	+20	80	going to
8	3	–10	70	
9	5	–10	60	moderate,
10	4	–10	50	
11	5½	–10	40	to low,
12	5	–10	30	
13	3	–10	20	to little
14	2	–10	10	
15	0	–10	0	or no
16	1	–10	0	
17	5	–10	0	activity,
18	6	+20	20	
19	6	+20	40	building
20	7	+20	60-	
21	7	+20	80	back to
22	8	+20	100	
23	10 max. temp. 98°F (37°C)	–10	90	high
24	7	+20	100	disease
25	8	+20	100	
26–35	6–9	+20	100	pressure

*Calculated by adding 20 index points for each day that has at least 6 continuous hours at temperatures between 70° and 85°F (21° and 29°C). If there are fewer than 6 hours or if the maximum temperature in the canopy that day is greater than 95°F (35°C) for at least 15 minutes, 10 points are subtracted from the index. The disease index never goes higher than 100 nor lower than 0 and is measured in increments of 10 or 20. An index of 0 to 30 indicates nonexistent to light disease pressure, 40 to 50 indicates normal disease pressure, and 60 to 100 indicates high disease pressure.

-Warning level: High pressure. When disease risk index is 0 to 30, spray interval is doubled. At 40 to 50, the interval is normal. When the index is 60 or greater, spray interval is shortened. A short interval for dust is 7 days; a longer interval is 10 to 14 days.

applications. The key to using this index is the careful monitoring of temperatures inside the vineyard canopy. Temperature monitoring devices are available from a number of suppliers and can provide the information needed for accurate disease assessment. Some of these devices must be read in the field, while other systems will automatically download and compute the disease index from as many as 50 monitoring devices through a computer base station that can be accessed by telephone modem.

The secret to controlling grape powdery mildew is the proper timing of fungicide applications. Remember, the disease will continue while you are irrigating, on vacation, or sick, or when your equipment is broken. If you are not applying the control measures on a timely basis, powdery mildew will develop.

Resistance Management

Several fungicides for control of mildew are already available and more will be registered in the near future. The benefit of using several different types of chemicals in the same season is that you can reduce the development of chemical resistance in the fungus. Once applied to the vine sulfur lasts only a short time (5 to 7 days), can be phytotoxic to the plant tissue, is flammable, causes worker discomfort, and may interfere with predatory mites. It has been used for more than 170 years without any development of resistance and remains an effective, economical control material. Sulfur's exact mode of action is unknown, but good coverage and proper timing are the keys to its effective use.

Another group of compounds is the sterol inhibitors (also known as SI, DMI, SBI, and EBI). This chemistry became available for agricultural use as a result of pharmaceutical research into a cholesterol inhibitor for humans. While most of these compounds have not been used in medicine, some have been very effective for grape mildew control. EBIs are locally systemic and have similar sites of action in creating weak cell walls, thereby causing the fungus to die. Unfortunately, some mildew strains have developed resistance to the EBIs, but these can be managed by alternating with other fungicide groups. Mildew strains that have expressed resistance to triazole sterol inhibitors have been controlled with benomyl and fenarimol.

Many fungicides control mildew by direct contact. Light horticultural oils, fatty acids, and many different formulations of potassium or sodium carbonates have been tested for efficacy with varying degrees of success. Many of the materials in this group may eventually qualify as "organic." The drawback common to all of these materials is their relatively short residual activity and their need for direct contact with the fungus in order to achieve control. Resistance management or the insertion of soft chemistry into any integrated pest management program makes these products valuable. Water (400 to 600 gallons per acre [3,740 to 4,675 L/ha]), a wetting agent, and wettable sulfur are often used as an "eradicant" against grape powdery mildew, though they do not actually achieve complete eradication. Light summer oils (e.g., JMS Stylet Oil) are excellent eradicants. Although complete eradication via washing is not possible, this treatment does reduce inoculum and thereby reduces disease. An application of some other fungicide should follow within 5 to 7 days.

A new tool for combating powdery mildew is AQ-10, a fungal parasite of powdery mildew. It has been shown to protect against disease if applied prior to the onset of disease, but should only be used when disease pressure is low. Its effectiveness is limited to applications early in the season or when disease incidence is below 3 percent and disease pressure is low on varieties that are highly susceptible to powdery mildew. It probably could be used longer on varieties that are less susceptible to the disease, and may be useful as a preharvest application to reduce the number of overwintering cleistothecia.

The newest class of chemistry in mildew fungicides is the strobilurins. These compounds originally extracted from wood-rotting mushrooms have been chemically altered to make them both stable and biologically active. Several materials currently under development have excellent activity against Phomopsis, powdery mildew, and downy mildew. These will help growers in their fight against powdery mildew and chemical resistance by giving them an additional chemistry and mode of action for control. Resistance to these compounds has been reported, however, where below-label rates have been used.

Resistance management is the responsibility of the individual producer. It is vitally important that everyone use any pesticide in a judicious, timely manner. Combining fungicides or alternating the use of several of the different groups of fungicides throughout the growing season is important. Remember: resistance management needs to be a part of every powdery mildew program.

PHOMOPSIS CANE AND LEAF SPOT

Formerly known as *dead-arm,* Phomopsis cane and leaf spot remains one of the most common disease problems for 'Thompson Seedless' growers. Though its ability to cause cankers on vines remains in question, it does have the ability to colonize young shoots and leaves. Fruit infections rarely occur in California, and those that do usually occur on the rachis.

Phomopsis cane and leaf spot was once a major problem only in northern San Joaquin Valley vineyards, particularly on the 'Flame Tokay' variety. In raisin districts, it was first recognized in the Centerville-Sanger and Biola areas in the early 1960s. It is now widely distributed through all raisin districts, tending to be more severe on vigorous vines in deep, fine-textured soils. In a year with a wet spring, Phomopsis cane and leaf spot can be particularly severe on 'Thompson Seedless,' 'Fiesta,' and 'DOVine' varieties. 'Muscat of Alexandria' and 'Black Corinth' ('Zante Currant') are much less susceptible, while 'Monukka' is intermediate in its susceptibility.

Disease Cycle and Symptoms

Infection takes place as spores from previous years' infections are rain-splashed onto the young shoots and leaves in early spring. Symptoms are visible 3 to 4 weeks later as tiny black spots on the shoots and leaves (Plate 22.3). Leaf infections begin as small black spots with yellow margins. Leaf distortion, necrosis, and even defoliation of some of the basal leaves can accompany a very heavy infection (Plate 22.4). In 1978, Phomopsis-induced defoliation of the first 4 to 6 leaves was the attributed cause of a 36 percent crop loss in heavily infected vineyards. Shoot infections also begin as small black spots which, if infections are abundant, will coalesce and give a scabby appearance to the shoot (Plate 22.5). As the shoot continues to grow, the epidermal tissue at the infected areas will split to form lesions or cracks ¼ inch or longer on the shoots. In California, shoot infections provide the source of spores for the next year's infection cycle. Heavily infected shoots also tend to be brittle at the infection site and can break off in strong winds when the shoots are 1½ to 2 feet (0.45 to 0.6 m) long. Diseased shoots may have retarded growth and may not produce good replacement canes. This is especially problematic in 'Thompson Seedless,' since replacement canes are obtained from the head of the vine where infections tend to be most profuse.

During winter, the infected canes have a distinctive whitish or bleached appearance that has been attributed to fungal growth through the epidermal tissue. Poor winter survival of heavily infected canes is common, and care should be taken at pruning time to ensure the good selection of mature canes and the pruning out of heavily infected shoots where possible.

With the advent of bud break the small black spots (*pycnidia*) on the infected tissue begin to enlarge. Inside the flask-shaped pycnidia, spores for the next infection cycle are produced. In spring these are exuded onto the tissue surface during periods of high moisture to be rain-splashed onto the young growing shoots and leaves.

Disease Control

The pruning out of infected canes is a common method for reducing inoculum for new infections, but this by itself will not provide adequate control. In fact, even when no obvious symptoms are visible on the previous year's wood, this fungus has the ability to survive long periods without an apparent infection cycle. After 6 years of drought in California, a very wet spring prompted a reappearance of Phomopsis on the new shoots and canes.

No materials are currently registered that will kill the overwintering pycnidia. Sodium arsenite and dinoseb have in the past been registered for this use, but they are no longer available. These materials were called eradicants, but in truth they only affected the pycnidial production of spores for the current year. By the following year, spore production and disease levels would return to normal. Foliar fungicides, applied after budbreak but before periods of rain, will provide good control. Because many control materials are registered for use and new ones are constantly being developed, you should refer to the *UC IPM Pest Management Guidelines: Grape* for the latest recommendations (on the Worldwide Web at http://www.ipm.ucdavis.edu).

SUMMER BUNCH ROT

Recent investigations dealing with summer bunch rots (rots and sours rots) suggest that *Botrytis cinerea* is not the major cause of bunch rots in the drier, warmer areas of the southern San Joaquin Valley. A complex of microorganisms (*Aspergillus, Penicillium, Rhizopus,* yeasts, and acetic acid bacteria) are involved. The disease complex known as sour rots is distinguished by the presence of a strong acetic acid (vinegar) smell, leaking clusters, and usually the presence of fruit flies or dried fruit beetles, which may act as vectors of the complex. The role of each of the involved organisms is not yet fully understood. *Aspergillus niger* has been shown to be capable of colonizing healthy berries at 86°F (30°C) and is sometimes the predominant species of the summer rot complex in warmer areas. Whether *Botrytis cinerea,* also capable of colonizing sound berries, is the major initial cause of summer bunch rot is still unclear. It is conceivable that *B. cinerea* initiates the site of infection and then dies out as other organisms enter the wound site and cause an acidic environment in which *Botrytis* simply cannot compete.

Summer bunch rots can also be initiated by mechanical injury. Cracks, lesions caused by insects laying eggs, larva feeding spots, bird damage, and rubbing from leaves, wood, or wire can cause wounds for entry of the above-mentioned opportunistic microorganisms. Omnivorous leaf roller and raisin moth are the major insect pests that contribute to rot. Their first larval hatch must be controlled each spring in most raisin vineyards to prevent bunch rot initiated by their feeding on grape berries. See chapter 24, Lepidopterous Insects, for further information.

Powdery mildew, while not a direct cause of summer bunch rots, can scar the berry surface. Resulting cracks or lesions in the expanding berry will allow the entry of decay organisms. Rainfall on fruit that are already heavily infected with powdery mildew, whether on the vine or on the drying tray, will increase the amount of rot since the berries are already cracked or split by the infection. Tight clusters also exhibit a large amount of summer bunch rots because the compacted mid-cluster berries may be broken or cracked and subsequently colonized. Once the initial rot process begins it can spread beyond the initial injury. Refer to the *UC IPM Pest Management Guidelines: Grape* for comments on control.

GRAPE VIRUS DISEASES

A virus is a submicroscopic obligate parasite consisting of a nucleic acid and a protein coat. Viruses enter a host organism and replicate themselves using the DNA of the host. Some virus particles are transmitted by a vector (e.g., a fungus, insect, or nematode) from one plant to another. However, the most common vector in grapevine propagation is the grower who continues to take cuttings from infected plants and use them to produce new vineyards. Since no postplanting viricide treatments are available, growers should plant only certified stock from registered nurseries. Visual inspection of an infected vineyard during the growing season often will fail to detect viral symptoms. The University of California Foundation Plant Materials Center at UC Davis maintains an indexed vineyard of the major cultivars for distribution. However, growers who wish to plant entire vineyards will need to purchase wood from certified nurseries to obtain sufficient quantities.

Of the many grapevine viruses known throughout the world, only four are of significant interest in California: leafroll, fanleaf, corky bark, and rupestris stem pitting. The first two are of major concern in raisin varieties and will be discussed briefly here. For further information and detailed descriptions of these viruses, refer to the second edition of *Grape Pest Management.*

Leafroll

Background. Leafroll is one of the most important and widespread grapevine viruses worldwide. It is common in California vineyards because vines have been propagated from infected vineyards or grafted onto infected rootstocks. There are four recognized strains of leafroll. Type 4 appears to be the most prevalent in 'Thompson Seedless,' although types 1, 2, and 3 often appear where new scions have been grafted onto older vines. ELISA testing by a commercial lab can distinguish the various strains. As new grapevine varieties were developed and introduced into commercial agriculture, some were grafted onto older infected vines and so became infected with the virus.

'Thompson Seedless' Clone 1A, which is typical of material planted in the San Joaquin Valley, was found to be infected with type 4 mild leafroll. 'Thompson

Seedless' Clone 2A, which was heat treated, indexed, and certified free of leafroll, has consistently outperformed 1A and all other leafroll-infected 'Thompson Seedless' clones for fruitfulness and overall yield. The Delano clone contains a severe strain of leafroll and should never be planted. Other raisin varieties such as 'Fiesta,' 'Monukka,' 'Muscat of Alexandria,' and 'Black Corinth' ('Zante Currant') are also known to have leafroll. Problems of lower fruit quality, delayed maturity, and lower yields are often expressed in these varieties. These varieties were also often grafted onto older vineyards, which became infected with the virus, and then cuttings were taken to plant or graft other vineyards. When leafroll-infected wood is grafted onto clean, susceptible rootstocks such as 'Freedom,' poor take, slow growth, and vine death often result.

Symptoms. Leaf symptoms are not evident during the early spring but develop gradually over the course of season. They begin as reddish spots (on red varieties such as 'Monukka'), which steadily enlarge until all the area between the major veins turns red while the veins remain green. The leaf margins begin to roll downward and often the leaves become thick and brittle. The disease is not very symptomatic on white raisin varieties such as 'Thompson Seedless' due to their lack of red coloration. Only in severe cases will the leaves become slightly chlorotic. Mostly, infected vines will be less fruitful, may have smaller clusters, and will have a lower overall raisin yield. Colored varieties such as 'Monukka' and 'Black Corinth' ('Zante Currant') will also have delayed, uneven fruit color.

Fanleaf

Background. Fanleaf or fanleaf degeneration virus is also common in vineyards worldwide. Depending on the strain, this virus can cause poor growth, foliar distortion, vein banding, and poor fruit set, and can affect vineyard longevity. The dagger nematode (*Xiphinema index*) is a vector for the virus, and acquires the disease by feeding first on the roots of diseased vines and then on the roots of healthy vines. Without the nematode, the disease will not spread in a vineyard. The replanting of a nematode-infested field will generally result in the reappearance of the disease, since the nematode vector can maintain the virus for some time. Roots left in the soil can survive for years and continue to provide the nematode with a source of virus and food, lengthening the amount of time the virus can survive. In one vineyard, the removal of all roots within the top 18 inches (46 cm) of soil in addition to a well-timed, properly performed deep fumigation at maximum label rates on the best of soils where no strata or problems existed was effective in preventing the recurrence of this disease for 17 years before vines tested positive for the virus. Grafting onto infected vines or using wood from infected vineyards has caused problems in 'Fiesta.' A hybrid rootstock, 039-16, has demonstrated some tolerance to fanleaf and probably should be used in replanting where fanleaf has been a problem. Although not completely resistant, it maintains higher vigor and better production in vineyard situations where fanleaf has been observed in the past. Even with the use of rootstocks, preplant fumigation should always be performed prior to replanting.

Symptoms. Vines infected with fanleaf (Plate 22.6) are generally smaller than healthy vines. Foliar symptoms are not always the same, leading to the confusion in naming this disease. Yellow vein banding and yellow mosaic symptoms, often coupled with various degrees of deformation, are frequently observed on the leaves of vines with fanleaf. Shoots may exhibit overall stunting characterized by shortening of the internode area, double nodes, fasciation, and a zigzag growth between the nodes. Poor fruit set resulting in scraggly clusters can greatly reduce yields.

BLACK MEASLES

Background. *Measles, Spanish measles,* and *Esca* are common names for what we will call *black measles,* a prevalent disease of grapevines in the San Joaquin Valley. Though often noted for greater prevalence in areas with consistently high summer temperatures, black measles is not found in Coachella Valley where summer highs are often extreme. As the disease is generally associated with vines more than 10 years old, its incidence appears to be correlated with the presence of wood-rotting fungi that gain entrance into the vine through large pruning wounds. Until recently, species of the genera *Fomes, Cephalosporium,* and *Phellinus* were thought somehow to be involved with the appearance of this disease. However, research in progress has implicated *Phaeoacremonium inflatipes* and *P. chlamydosporum* as possible causal organisms for this disease. These organisms may enter the vine through wounds. In many cases the disease appears sporadically throughout a vineyard, in that a vine may show measles symptoms one year and not the next, while some vines may express symptoms 2, 3, or even 4 years in a row.

Symptoms. Disease symptoms can appear at any time during the season, but they usually appear from mid-May to late August. The most obvious symptom is the purple spotting (*measles*) on the green berries of white varieties such as 'Thompson Seedless' (Plate 22.7). Spotting can range from a few spots on one cluster to all of the clusters on a single cane or the entire crop on the vine. The earlier the disease expresses itself on the fruit, the more discoloration, berry cracking, delayed maturation, raisining, and rot are observed. Clusters severely affected at the bloom or berry set stage often drop all of their berries, wither, and die. If disease symptoms first appear at or near harvest time, the fruit may only be slightly affected and may still be suitable for picking to dry for raisins. When measles appears on red varieties such as 'Black Corinth' ('Zante Currant') or 'Monukka,' the discoloration gives the fruit a bluish appearance, often called *blueberry.*

Foliar symptoms may range from a few chlorotic spots on a few leaves to severe interveinal chlorosis and burning to tip dieback and defoliation (Plate 22.8). *Apoplexy* is the term used to describe the severe form of the disease, when it causes complete defoliation, fruit drop, and dieback of all the growing shoots. In many cases a vine will appear to have died, but then in 2 to 3 weeks it will push new shoots and, aside from having no crop, will exhibit normal growth by the end of the season. Foliar symptoms can be expressed on a cane without any apparent effect on the fruit. No chemicals are registered for the control of black measles. However, since the fungus is believed to enter the vine through large pruning wounds, growers should protect pruning wounds against infection to help maintain the long term economic life of each vine.

PIERCE'S DISEASE

Background. Pierce's disease (PD) is a lethal disease of grapevines caused by the bacterium *Xylella fastidiosa,* which multiplies in the plant's water-conducting tissues (xylem). These bacteria are transmitted to grapevines by sharpshooters, a type of xylem-feeding leafhopper. The sharpshooters acquire the bacteria from many species of plants, most of which do not develop disease symptoms.

The green sharpshooter (*Draeculacephala minerva*) and red-headed sharpshooter (*Carneocephala fulgida*) are the primary vectors of Pierce's Disease in the San Joaquin Valley. Common plants supporting these two sharpshooters in the San Joaquin Valley include bermudagrass, watergrass, perennial rye, fescue grass, and sedges. The adult insects are about 1/4 inch (6 to 7 mm) long and bright green, as distinguished from the smaller (1/8 inch [3 mm]) dull-colored grape leafhopper (*Erythroneura elegantula*) and the variegated grape leafhopper (*Erythroneura variabilis*), which do not transmit the bacterium. The greatest amount of disease spread is usually downwind from pasture, weedy hay fields, or other vector-source areas. Weedy ditch banks, roadsides, fence lines, and riparian areas can also serve as sources of damaging insect vectors. Vineyards planted the year after field or row crops have been removed from a weedy field may suffer vine losses caused by residual insects and bacteria.

Symptoms. Vine symptoms of Pierce's disease vary with time of year, stage of infection, and grape variety. Basically, masses of bacteria and associated gum in the xylem block water transport, causing progressive water stress. Marginal leaf burn and raisining of the fruit are the most characteristic symptoms (Plate 22.9). Extensive areas of yellowing may also appear on leaves. The *burning* or *scalding* progresses until most of the leaf blade is affected. It can appear in patches or in concentric bands on the leaf margins. Petioles also dry from the leaf blade down toward the base. Often a leaf blade will fall, leaving its petiole attached to the canes. Irregular maturation of the bark on new canes is also common, producing distinctive patches of green, immature bark surrounded by mature brown bark (Plate 22.10).

The spring growth of grapevines infected the previous year is delayed and stunted, and bud break may be erratic. New leaves tend to be small and distorted and may show interveinal chlorosis (yellowing) similar to zinc deficiency. The interior cane tissue will also have a drier appearance.

Disease management. Grape varieties differ in their susceptibility to PD, so your choice of variety can be important when planting near primary disease source areas. 'Thompson Seedless' and 'Black Corinth' ('Zante Currant') are considered to be moderately tolerant. 'Fiesta' is very susceptible and should not be planted next to disease sources such as permanent pasture or weedy alfalfa fields. 'Muscat of Alexandria' is intermediate in susceptibility. Raisin-producing areas of higher PD incidence are west of the Ripperdan area in Madera County, Kerman, Easton, Raisin City, Caruthers, and Riverdale in Fresno County, and Traver and south of Dinuba in Tulare County. The Kings River riparian areas of Fresno, Kings, and Tulare Counties are also more prone to outbreaks of PD.

The source of the disease is commonly outside the vineyard. Because there is no appreciable vine-to-vine spread of chronic infections, rapid vine removal will have little or no effect on the incidence of disease. Prevention of PD is possible if you eliminate conditions conducive to the buildup of green sharpshooters and red-headed sharpshooters. In alfalfa fields, field crop areas, and orchards, it is the grass weeds growing in or at the margins of the crop that allow increased sharpshooter populations. Weed-free stands of alfalfa do not support sharpshooter populations. However, alfalfa does support *Xylella fastidiosa,* so more sharpshooters in an alfalfa field can infect other habitats. Heavy growth of bermudagrass or other grasses in irrigation ditches, at the ends of irrigation runs or outlets, or surrounding irrigation standpipes can create favorable conditions for sharpshooter reproduction that can lead to severe losses in adjacent vineyards. Weedy areas along adjacent roads, fence lines, canals, ponds, and buildings should also be controlled, as well as patches of bermudagrass within the vineyard, which can harbor sharpshooters. Unfortunately, the control of weedy areas or forage plantings outside of the vineyard owner's property is not the raisin grower's prerogative.

Vineyard cover crops are only a source of PD if they are permanent, and that is only an option in DOV vineyards. Where bermudagrass or other perennial grasses are allowed to persist, sharpshooters can be found almost any time of the year. Therefore, eliminating weeds in early to late spring will disrupt sharpshooter populations. Subsequent weeds and summer cover crops in the vineyard then will not be sources of sharpshooters.

The only way to maintain a productive stand is to remove diseased vines and replant with healthy ones. Symptomatic vines are easiest to identify in early fall when symptoms are most noticeable.

If you wait to remove dead vines, you may delay the replanting process by another full season. Layering from adjoining, healthy vines is the fastest method for re-establishment. A disadvantage of layering is that if the "mother" vine or the layered vine becomes infected, the other will ultimately become diseased too. For this reason, the layer connection should be cut after 3 years. Dormant rootings are the next best alternative and will be needed where vine loss patterns prevent layering.

No data are available on the effectiveness of insecticides in reducing the spread of Pierce's disease in the San Joaquin Valley. In California's north coast vineyards, insecticidal control of the major vector there, the blue-green sharpshooter (*Graphocephala atropunctata*), applied to adjacent vector source areas before vectors enter vineyards has yielded slight to moderate reduction in the incidence of disease. The green and red-headed sharpshooters, in contrast, have multiple generations and often occur in habitats that cannot be treated with insecticides. No insecticides are currently registered for control of green or red-headed sharpshooters.

Disease verification. Several laboratory detection methods have been developed to confirm the presence of the causal bacterium. The ELISA (Enzyme-Linked Immunosorbent Assay) test is now commercially available to confirm whether plants harbor *X. fastidiosa.* Arrange in advance for the testing laboratory to receive your shipment of plant samples and be sure to tag each sample to identify it with its source vine.

Symptomatic leaves sampled from August through October that are still attached to green portions of canes generally give the most reliable test results. Sampling tissues of diseased vines during the winter through to early summer will usually give negative results since most of the bacteria will die out during the cold, dormant period. After that, the bacteria must be redistributed into the new growth in sufficient numbers to allow detection.

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