Grape Disease Management

Annemiek C. Schilder
Department of Plant Pathology, Michigan State University, East Lansing, MI 48824

Introduction

Grape growers through the ages have battled grapevine diseases with varying success. Most diseases that affect grapes are caused by fungi, although bacteria, viruses, and nematodes also take their toll. Some diseases cause direct losses by destroying fruit and flower clusters. Others affect fruit quality by lowering sugar accumulation or imparting off-flavors. Yet others reduce vine vigor, yield, and winter hardiness by damaging or destroying foliage, roots, and canes. Many factors affect the prevalence of diseases in a vineyard. The most obvious of these is cultivar, since innate resistance determines to what degree a vine is attacked by a particular pathogen. Another important factor is climate, as some pathogens are adapted to cool climates and others to warm climates. The amount of rainfall is naturally a critical variable, since most fungi and bacteria need moisture for growth, infection, sporulation, and spread. Viruses are less affected by these variables but are more dependent on vectors such as insects and nematodes, which in turn are most influenced by temperature and soil moisture, respectively. To manage diseases in grapes effectively, a grower should understand the characteristics of his or her vineyard and how these characteristics influence disease development. I will discuss the characteristics of the most important diseases that a grower is likely to encounter in northeastern growing regions.

Powdery mildew – *Uncinula necator*

The powdery mildew fungus can infect all green tissues, resulting in a whitish gray, dusty or powdery appearance. Powdery mildew colonies are mostly present on the upper leaf surface. Infections of young, expanding leaves can result in distortion or stunting. Early berry infections can result in splitting of berries, secondary rots, and undesirable flavors in wine. Late infections are largely invisible except for a web-like necrotic pattern on the berry surface, which can still predispose the berries to rots. Severe infections reduce vine growth, yield, fruit quality, and winter-hardiness. In late summer, the fungus produces small golden-brown to black fruiting bodies (cleistothecia) on infected plant parts. The cleistothecia overwinter in bark crevices of the vine and release wind-disseminated ascospores in the spring. Leaves in proximity of the bark tend to get infected first. Powdery mildew is favored by high humidity and moderately high temperatures (68-81ºF). Temperatures above 95ºF inhibit new infections. Begin monitoring for the disease early in the season, checking inside the canopy first.

Downy Mildew – *Plasmopara viticola*

Downy mildew can infect leaves as well as flower and fruit clusters. Initial leaf symptoms show up as light green or yellow spots. These are termed “oil spots” because of their sometimes greasy appearance. The lesions eventually turn brown as the infected tissue dies. On older leaves, lesions are typically smaller and more angular as they are delimited by leaf veins. Leaf infections may lead to premature defoliation, which can reduce winter hardiness in severe cases. Under warm, humid conditions (>98% humidity and > 55°F) at night, white, fluffy sporulation develops on the lower surface of the leaf.

White spore masses also develop on infected flower and fruit clusters. Infected clusters or berries eventually wither and die. The fungus overwinters in leaves on the ground. Spores are spread to new leaves and clusters by wind and rain. The fungus requires a film of water for infection. Lesions appear within 5-17 days after infection. The disease can spread rapidly under warm conditions with frequent rain or dew. Use the 10-10-10 rule to decide when to first start scouting for downy mildew: 10 cm (4 in.) of shoot growth, 10 mm (0.4 in.) rainfall and temperatures of at least 10°C (50°F) during a 24-hour period. Monitor especially leaves close to the ground as well as in the top of the canopy.

Black rot – *Guignardia bidwellii*
The black rot fungus can attack all new growth, including leaves, petioles, shoots, tendrils, and berries. On the leaves, light brown, roughly circular spots appear in the spring and summer. These can be distinguished from herbicide damage by the presence of a ring of small black fruiting bodies, visible with the naked eye or a hand lens. Even though peak fruit infection occurs around mid-bloom in 'Concord' grapes in Michigan, symptoms only become apparent weeks later. The first symptom of berry infection is a small whitish dot within a rapidly expanding brown area that sometimes contains distinct "growth rings". Within a few days, the berry starts to shrivel and becomes a hard, blue-black mummy. Berries actually become resistant to infection about 3-5 weeks after bloom. If berries are infected close to the time of natural resistance development, lesions remain localized. The fungus overwinters in fruit mummies within the vine or on the ground. Ascospores are released from shortly after bud break until about 2 weeks after bloom, and are dispersed by wind and rain. Leaf spots and newly infected berries can also yield infectious conidia, which are rainsplash-dispersed. The optimum temperature for disease development is 80°F, at which the wetness period required for infection is only 6 hours. At higher or lower temperatures, the wetness requirement increases.

Botrytis bunch rot – *Botrytis cinerea*
B. cinerea can infect all green parts of the vine, though bunch rot tends to be the biggest problem. In early spring, buds and young shoots may be infected and turn brown. In late spring, V-shaped or irregular brown patches may appear on leaves Inflorescences may also be blighted and wither away. Some flower infections can remain latent until veraison. From veraison onward, the fungus can infect grape berries directly through the epidermis or through wounds, and may continue to invade the entire cluster. Compact clusters, powdery mildew infection, hail and insect damage (e.g., grape berry moth), can predispose grapes to Botrytis infection. Infected white grapes turn brown and purple grapes become reddish. During dry weather, infected berries dry out; in wet weather, they tend to burst and become covered with a grayish mold, which contains millions of spores. These spores are spread by wind to new infection sites. The disease spreads rapidly during moist periods, especially close to harvest. In certain cultivars, slow- developing, late-season infections are termed "noble rot" because they contribute to the production of exceptionally sweet wines. The fungus overwinters as mycelium or sclerotia (small black structures) in mummified fruit and other infected plant parts. The disease is favored by temperatures of 59-68ºF and free water or at least 90% humidity.

Phomopsis cane and leaf spot – *Phomopsis viticola*
Phomopsis viticola can infect all green parts of the vine, but infections of the fruit clusters are economically most important. Infected leaf blades show small irregular light green or yellow spots with dark centers and may be puckered. On petioles, shoots, and rachises, chlorotic spots with dark centers develop into elongated black streaks or blotches, which make the tissue brittle and prone to cracking or breakage. Most shoot lesions occur on the basal three to six internodes. Actively growing tissues are most susceptible to infection. Rachis and berry infections become apparent several weeks before harvest and continue to get worse over time. Rachis infections can lead to withering of the rachis, causing berries or sometimes entire clusters to drop prematurely. The fungus can also infect berries, either directly through the skin or through the berry stem. Infected berries turn brown and become soft and rubbery. Pycnidia may appear as numerous small black specks on the berry surface, sometimes oozing cream-colored droplets of spores. The fungus overwinters as in bark of infected canes. Bleached areas, sometimes delineated by black lines, on dormant canes are indicative of infection. In spring and early summer, conidia are rain-splash dispersed from pycnidia on the overwintered canes. Prolonged periods of rainy, cold weather in spring promote disease development. At least 6 hours of wetness are needed for infection at the optimum temperature (59-68ºF). Symptoms may appear 21-30 days after infection. Monitor carefully within 3-6 weeks from bud break. Many spots on the leaves and canes indicate high inoculum levels for rachis and berry infection. Flower clusters are susceptible to infection from the moment they are exposed until harvest.

Eutypa dieback – *Eutypa lata*
Eutypa dieback is a progressive disease of the woody tissues of the grapevine commonly found in older vineyards. The disease develops slowly and symptoms may not be visible for several years after infection. Shoot symptoms are best observed in mid- to late spring. Symptoms typically show up on one arm. The leaves are smaller than normal, cupped upwards, and chlorotic. As the leaves expand, the edges become tattered. Chlorotic streaks may be present between veins and along margins. Shoots are stunted to varying degrees and have fewer and smaller fruit clusters, sometimes with a mixture of large and small berries. Eventually the affected arm or entire vine will fail to develop shoots altogether and die. Upon close examination of the perennial wood bearing symptomatic shoots, a canker can usually be found surrounding an old pruning wound (the fungus infects the vine through pruning wounds). Removal of the bark may be necessary to see the canker. When cut across, a wedge-shaped area of dead wood may be present. Shoot symptoms are thought to be induced by a toxin in the sap flowing from the canker. Most Eutypa infections take place at pruning time. Spores of the fungus are released from fruiting bodies in old cankers during late winter and early spring when temperatures are above freezing and rainfall of 1/25 inch or more has occurred. Moisture from melting snow may be sufficient.

Sour bunch rot – fungi, yeasts and bacteria
Sour bunch rot is caused by a variety of fungi, yeasts and acetic acid bacteria. Low-grade powdery mildew infections or grape berry moth or fruit fly infestations can predispose clusters to infection. Insects can also spread the sour rot organisms on their feet and mouthparts. Sour bunch rot is a wet rot which can spread rapidly throughout the cluster

and cause the berries to smell like vinegar. Unlike with Botrytis bunch rot, mold is usually absent. Prolonged periods of wetness or high relative humidity are conducive to sour bunch rot development. Some cultivars are more susceptible than others.

Crown gall – *Agrobacterium vitis*
Crown gall is a problem in areas where climatic conditions favor freeze injury. It is particularly damaging to *Vitis vinifera* and interspecific hybrids. The major symptom is fleshy galls on the lower trunk near the soil line. Aerial galls may also form as high as 3 ft up the vine. Young vines may be completely girdled by galls in one season. Young galls are cream colored and fleshy but turn brown and woody with age. Affected vines appear weak and portions of the vines above the galls may die. Crown gall is caused by the bacterium *Agrobacterium vitis*, which is a different strain from *A. tumefaciens,* the cause of crown gall on fruit trees and many other plants. The bacterium lives in the soil and enters the plants through wounds caused by mechanical damage, grafting, or freeze injury. The bacterium may also be present on the surface of planting material, which could explain sudden and severe outbreaks of crown gall in young vineyards after frost events. Contaminated pruning or grafting tools may contribute to spread. Removing galls usually does not cure the plant as new galls will continue to form. Sometimes, galls may be confused with abundant callus growth at graft unions. Isolation of the pathogen will be needed to confirm the cause of the galls in this case.

Ringspot virus decline - Tomato ringspot virus (TomRSV) or Tobacco ringspot virus (TRSV)
This disease occurs sporadically in *V. vinifera* cultivars and interspecific hybrids. *Vitis labrusca* cultivars are resistant. A typical symptom in older vineyards is missing or dead vines in a roughly circular pattern. In the first year of infection, the disease is difficult to detect. A few shoots may show leaves with mottling or an oak leaf pattern. In the second year, the disease becomes more evident. New growth is generally sparse because many infected buds are prone to winterkill. Diagnostic symptoms are shortened internodes with small distorted leaves, and sparse fruit clusters with uneven ripening of berries. In the third year, growth is very stunted and limited to basal suckers. The vine continues to decline and eventually dies. The disease is caused by either of two nepoviruses (TomRSV and TRSV) which are transmitted by dagger nematodes (*Xiphinema* spp.). Both can also be transmitted via seed and cuttings. The nematode vectors retain the virus for long periods of time and can acquire it from roots of infected grape or weeds. TomRSV infects a wide range of fruit crops, whereas both TomRSV and TRSV both infect many common weeds in vineyards, including dandelions, sheep sorrel, common chickweed, and red clover. Because of this, is it not uncommon for these viruses to be present in land used to establish new vineyards.

Leafroll - Leafroll virus
Leaf roll is found in most areas where grapevines are grown. Symptoms are most obvious in the fall. Infected vines are slightly smaller than healthy vines. While leaves look normal early in the season, they start to show a yellow or reddish-purple discoloration as the season progresses while the main veins in the leaf remain green. By late summer the leaves start rolling downward (Photo), starting with the leaves at the base of the shoot. At harvest, fruit clusters are small, poorly colored and low in sugar. The disease does not kill

the vine but will remain chronic. Not all infected vines show symptoms. Leafroll is caused by a virus that spreads primarily via infected nursery stock. No vector has been established for the virus and natural spread is slow in commercial vineyards.

Nematodes – Root knot nematode, dagger nematode, lesion nematode
Plant parasitic nematodes are microscopic roundworms that live in the soil and feed on plant roots. In addition to being directly damaging to grapevine roots, some nematodes are important as vectors of viruses. Nematode damage can also predispose roots to root rots. In newly established vineyards, nematodes may be responsible for poor establishment and weak growth of young vines, especially at sandy sites. Nematodes seldom kill vines, but cause a steady decline in vigor. Symptoms on above-ground plant parts are not very specific, e.g., poor growth, low yields, and "off" color. Infected plants are more susceptible to environmental and other stresses. Symptoms may also resemble certain nutrient deficiencies or virus diseases. Below-ground symptoms are poor root development, dark-colored root lesions, and stunting or death of feeder roots. Root knot nematodes characteristically cause small swellings (galls) of the young feeder roots or secondary roots. When the galls are opened, the glistening white bodies of female nematodes can often be seen with a hand lens. Nematodes are spread via infected planting material or movement of soil on farm equipment and in run-off or irrigation water. Once established in a vineyard, nematode infestations tend to be permanent, so care must be taken to prevent new infestations.

Management approaches
Host plant resistance can be very helpful in controlling diseases (see Table 1). If it is not possible to choose a resistant cultivar, at least avoid highly susceptible cultivars, so that you won't be battling certain diseases for the lifetime of the vineyard. Choosing a cultivar that is adapted to the local soils and climate is important to ensure that the vines are not stressed. Certain cultivars are more suitable for organic production because they won't require heavy doses of fungicides to produce an acceptable crop.

Cultural control includes: selecting sites with good drainage and air circulation, avoiding sites with previous soilborne disease problems, planting in the direction of the prevailing wind to encourage air circulation, pruning to create open canopies to reduce humidity build-up, pruning out infected plant parts to remove sources of inoculum, and using a training system that exposes the clusters. Most of these methods work for the fungal diseases mentioned above. Pruning out and destroying dead canes and vines are especially important for control of Phomopsis and Eutypa dieback. Be sure to remove and burn infected plant material since spores can be released for a long time and can travel quite far by wind. Leaf removal around clusters is practiced to reduce humidity and incidence of Botrytis bunch rot. Buying virus-tested planting material is critical for prevention of virus diseases, since virus diseases can't be cured. In contrast, control of crown gall requires avoiding wounding of the vines and disinfecting pruning sheers between vines. Galltroll or Norbac do not work against the grape strain of the crowngall bacterium. At this time, no nursery stock is guaranteed to be free from crown gall. However, buying vines from a reputable nursery in the northeast is recommended.

Chemical control is most commonly used for disease management in grapes. A range of protectant and systemic fungicides is labeled for control of diseases in grapes. They vary in their effectiveness in controlling specific diseases (Table 2). Generally, early in the season, protectant fungicides (e.g., mancozeb) are recommended, while from bloom onwards, systemic fungicides (e.g., Nova, Elite), and surface-systemic fungicides (e.g., Abound, Sovran) become more important. Systemic and surface-systemic fungicides tend to redistribute in/on the plant more readily, which is important as the canopy becomes increasingly dense. They also have varying degrees of post-infection activity. Choice of fungicides depends on relative efficacy, label restrictions, and cost. Sensitivity of grapes to certain fungicides also needs to be considered (see Table 1). Many of the newer fungicides have restrictions on the number of applications per season as well as the number of consecutive applications to prevent or delay the development of fungicide resistance. Some fungicides, such as copper and sulfur, are OMRI listed for use in organic fruit production. Scouting for the presence of diseases before applying fungicides is an important component of integrated disease management. In addition, disease prediction models where available can be used to guide spray decisions.

Biological control is the use of microorganisms to control plant pathogens. A few commercial products are available: Serenade (*Bacillus subtilis* – an antagonistic bacterium), and AQ10 (*Ampelomyces quisqualis* – a fungus that parasitizes powdery mildew). Serenade has moderate activity against downy mildew, powdery mildew, and Botrytis bunch rot, while AQ10 has moderate activity against powdery mildew. Both are OMRI-listed for use in organic fruit production.

Table 1. Relative susceptibility to disease and sulfur and copper sensitivity of grape varieties. (The ratings apply to an average growing season under conditions favorable for disease development. Any given cultivar may be more severely affected).

	Black Rot	Downy Mildew	Powdery Mildew	Phom-opsis	Botrytis	Eutypa	Crown gall	Sulfur Sensitive[3]	Copper Sensitive[3]
Aurore	+++[1]	++[2]	+++	++	+++	+++	++	No	++
Baco Noir	+++	+	++	+	++	++	++	No	?
Cabernet Franc	+++	+++	+++	?	+	?	+++	No	+
Cabernet Sauvignon	+++	+++	+++	+++	+	+++	+++	No	+
Canadice	+++	++	+	?	++	?	++	No	?
Cascade	+	+	++	++	+	++	+	No	?
Catawba	+++	+++	++	+++	+	+	+	No	++
Cayuga White	+	++	+	+	+	+	++	No	+
Chambourcin	+++	++	+	?	++	?	++	Yes	?
Chancellor	+	+++	+++	+++	+	+	++	Yes	+++
Chardonnel	++	++	++	++	++	?	++	No	?
Chardonnay	+++	+++	+++	+++	+++	++	+++	No	+
Chelois	+	+	+++	+++	+++	+++	++	No	+
Concord	+++	+	++	+++	+	+++	+	Yes	+
DeChaunac	+	++	++	+++	+	+++	++	Yes	+
Delaware	++	+++[2]	++	+++	+	+	+	No	+
Dutchess	+++	++	++	++	+	+	++	No	?
Elvira	+	++	++	+	+++	+	+	No	++
Einset Seedless	+++	+++	++	?	+	?	+	?	?
Foch	++	+	++	?	+	+++	+	Yes	?
Fredonia	++	+++	++	++	+	?	+	No	?
Gewürztraminer	+++	+++	+++	?	+++	?	+++	No	+
Himrod	++	+	++	?	+	?	?	No	?
Ives	+	+++	+	?	+	++	+	Yes	?
Limberger	+++	+++	+++	?	+	+++	+++	No	?
Marechal Foch	++	+	++	?	+	+++	?	Yes	?
Melody	+++	++	+	?	+	?	+	No	?
Merlot	++	+++	+++	+	++	+++	+++	No	++
Moore's Diamond	+++	+	+++	?	++	++	?	No	?
Muscat Ottonel	+++	+++	+++	?	++	+++	+++	No	?
Niagara	+++	+++	++	+++	+	+	++	No	+
Pinot gris	+++	+++	+++	?	++	+++	+++	No	?
Pinot Meunier	+++	+++	+++	?	+++	+++	+++	No	?
Pinot blanc	+++	+++	+++	?	++	?	+++	No	+
Pinot noir	+++	+++	+++	?	+++	?	+++	No	+
Reliance	+++	+++	++	++	+	?	?	No	+
Riesling	+++	+++	+++	++	+++	++	+++	No	+
Rosette	++	++	+++	++	+	++	++	No	+++
Rougeon	++	+++	+++	+++	++	+	++	Yes	+++
Sauvignon blanc	+++	+++	+++	?	+++	?	+++	No	+
Seyval	++	++	+++	++	+++	+	++	No	+
Steuben	++	+	+	?	+	?	+	No	?
Vanessa	+++	++	++	+	+	?	+	?	?
Ventura	++	++	++	+	+	?	++	No	?
Verdelet	+	?	?	?	+	?	?	No	?
Vidal 256	+	++	+++	+	+	+	++	No	+
Vignoles	+	++	+++	+++	+++	++	++	No	?
Villard noir	?	+	+++	?	+	?	?	?	?

[1]+ = slightly susceptible or sensitive, ++ = moderately susceptible or sensitive, +++ = very susceptible or sensitive. ? = relative susceptibility not established.
[2]Berries are not susceptible.
Most of the data in this table were obtained from the New York Cooperative Extension Service.
[3]Even tolerant cultivars can be injured by sulfur when the temperature is >85F and by copper under cool, slow-drying conditions.

Table 2. Relative Effectiveness of Fungicides for Grape Disease Control.

Fungicide	Black Rot	Downy Mildew	Powdery Mildew	Botrytis Rot	Phomopsis
Abound (azoxystrobin)	+++	+++	++	+	+++
Alliette (fosetyl-AL)	?	+++	?	?	?
Armicarb (potassium bicarbonate)	++	0	+ / ++	+	+
Basic Copper Sulfate (copper)	+	+++	++	+	+
Bayleton (triadimefon)	+++	0	+++	0	+
Captan (captan)	++	+++	0	+	++
Ferbam (ferbam)	++	+	0	0	0
Copper hydroxide (copper)	+	++	+	+	+
EBDCs (mancozeb)	+++	+++	0	0	++/+++
Elevate	0	0	0	+++	0
Elite (tebuconazole)	+++	0	+++	0	++
Endura (boscalid)	?	?	++	+++	?
Flint (trifloxystrobin)	+++	++	+++	+	+++
JMS Stylet Oil (paraffinic oil)	0	0	++	+	0
Kaligreen (potassium bicarbonate)	++	?	+ / ++	?	?
Lime sulfur (calcium polysulfide)	0	0	+	0	++
Messenger (harpin)	?	?	+ / ++	+	+
Nova (myclobutanil)	+++	0	+++	0	++
Oxidate (hydrogen peroxide)	?	?	+	+	?
Pristine (pyraclostrobin + boscalid)	+++	+++	+++	+ / ++	+++
Procure (triflumizole)	++	0	+++	+	++
Prophyt (potassium phosphite)	?	?	?	?	++
Quintec (quinoxifen)	++	?	+++	?	?
Ridomil Gold MZ (mefenoxam + mancozeb)	++	+++*	0	0	++
Ridomil Gold/Copper (mefenoxam + copper)	+	+++	++	+	+
Rubigan (fenarimol)	++	0	+++	0	0
Rovral (iprodione)	+	0	0	++	?
Serenade (*Bacillus subtilis*)	?	+ / ++	+	+ / ++	+ / ++
Sulfur (elemental sulfur)	0	0	++	0	+
Sovran (kresoxim methyl)	+++	+++	+++	+	+++
Topsin M (thiophanate methyl)	++	0	+++**	++	+
Vangard (cyprodinil)	?	?	+	+++	+
Ziram (ziram)	++	++	+	+	++

0 = not effective, + = slightly effective, ++ = moderately effective, +++ = highly effective,
? = effectiveness not known.
Ratings are based on published information and modified based on observations in Michigan vineyards.
Efficacy is based on applications in total spray volumes of 50-100 gal/acre.
*Ridomil also has eradicative properties.
**If benzimidazole-resistant strains are present, efficacy will be reduced.