# CONTROLLING FUNGAL DISEASES OF GRAPEVINE UNDER ORGANIC MANAGEMENT PRACTICES

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## INTRODUCTION

The purpose of this review is to aid those growers who have chosen to grow grapes organically in the control of the major fungal diseases. As a source for standards of acceptable organic practices, I have tried to adhere to the guidelines of the Northeast Organic Farming Association of New York (NOFA-NY).

There are five major fungal diseases of grapevines in New York: powdery mildew, downy mildew, black rot, phomopsis fruit rot, and botrytis bunch rot. The ranking of these in economic importance varies with cultivar susceptibility and weather. For example, botrytis fruit rot is rarely seen on the cultivar Concord, but is common on Aurore. Both powdery mildew and downy mildew will race to destroy Chardonnay; the winner will be the one favored by the peculiar weather of a certain year. Any discussion of organic disease control will therefore require a prior discussion of the biology of each of these pathogens, and exactly what factors favor development of disease.

## POWDERY MILDEW

Grape powdery mildew is caused by *Uncinula necator*. The pathogen is native to North America, where it coevolved with wild ancestors of *Vitis labrusca* grape cultivars. The disease was of minor importance in viticulture until its introduction to Europe in 1848. It rapidly spread throughout the continent, and nearly destroyed the European industry before it was controlled by the use of sulfur in the 1850s. It is now distributed worldwide. Powdery mildew became more destructive in New York viticulture with the planting of more susceptible *Vitis* interspecific hybrid cultivars in the latter half of this century. The most recent introduction and widespread planting of cultivars of the European wine grape (*Vitis vinifera*) has further increased the acreage planted to mildew-susceptible cultivars.

The pathogen overwinters as small (100 µm), spherical fruiting structures called cleistothecia. The pathogen population is composed of two mating types (i.e., male and female strains) Cleistothecia form when mildew colonies of opposite mating types grow together on the same leaf. Because the pathogen population is split into two mating types, disease must increase to a level where pairing becomes probable before cleistothecia form. This usually occurs in late summer or early fall. Once formed, cleistothecia are washed by rain to the bark of the vine, where they overwinter. In spring, beginning shortly after bud break of grapevines, spores within the cleistothecia are discharged during rain. Significant discharge and infection of emerging tissues can occur whenever rain exceeds 0.10 inches (2.5 mm) and temperatures are above 50 F (10 C).

Initial infections occur on the undersides of the first-formed leaves of shoots growing close to the bark of the vine. Within 5-10 days, a colony approximately 1/2 inch will be visible. The metallic sheen of the colony is due to the formation of thousands of small stalks bearing chains of minute glass-like spores. Spores break off the chains and are wind-dispersed to other tissues to spread the disease. Unlike the spores of the overwintering stage, these secondary spores are produced every day, disperse every day, and infect every day, for so long as temperatures remain above 50 F. This omnipresent secondary cycle is one reason why this disease can seem to develop so rapidly.

All green tissues of the vine may be infected. The pathogen is nearly wholly external, and grows on the surface of infected tissue, except for small absorptive structures that penetrate the epidermal cells. Both leaves and fruit become more resistant to infection as they age (ontogenic resistance). In leaves, ontogenic resistance is of academic more than practical interest, since the leaves decline in susceptibility, but are never immune. However, in fruit ontogenic resistance is significant. The berries of certain cultivars, notably Concord, become nearly immune to infection within 2-3 weeks after fruit set. Fruit of Chardonnay and Riesling remain susceptible for up to 8 weeks longer, or until fruit sugar levels reach approximately 8%.

Powdery mildew symptoms are similar on all parts of the vine. The pathogen grows on the epidermis, producing small colonies that may later merge to give entire leaves a whitened appearance. The skins of severely infected fruit stop growing, and the berries split and rot. Rachises remain susceptible after fruit have become resistant, and may be nearly white with powdery mildew by harvest on some cultivars. Colonies on shoots die when periderm begins to form, leaving a diffuse, blackened or reddish blotch on the cane. Leaf infection reduces photosynthesis when severe, and leads to early defoliation. Direct fruit damage reduces yield and quality. More than 3% berry infection can be detected as an off-flavor in wine.

Variation in resistance to powdery mildew among grape species and cultivars is considerable, and should be the first criterion considered in developing an organic disease control program. In general, cultivars of native North American *Vitis labrusca*, and hybrids with substantial *V. labrusca* parentage and phenotype are most resistant. There are some minor differences in susceptibility to powdery mildew among cultivars of *V. vinifera*, but none approach the substantial resistance of the most resistant labrusca or hybrid cultivars (Table 1).

**DOWNY MILDEW**

The fungus *Plasmopara viticola* causes downy mildew. It is another native North American pathogen. It was also exported to Europe; later in the 19th century than was powdery mildew, but with similar consequences. *Vitis vinifera* had not coevolved with the pathogen, had little resistance to infection, and was severely damaged before the disease was controlled by the widespread use of copper fungicides in the late 1880s.

The pathogen overwinters as thick-walled spores (called oospores) in fallen infected leaves and in soil. These spores mature when grape shoots have 4-5 flat leaves (Eichorn and Lorenz stage 12) and send out a short stalk. At the tip of this stalk is borne a swelling containing 1-10 individuals of a second spore type. This second spore type can swim in water films, and is called a zoospore. These are the spores which actually infect the vine. Zoospores are splashed by rain to leaves, young shoots, or clusters. They then swim to the stomata, and enter the plant through these natural openings.

Rain is important in downy mildew epidemiology. Rain splashes the zoospores from the ground to the vine, maintains a water film for the zoospores to swim to the stomata, and provides wetness required for infection. The first wave of infection requires temperatures above 50 F, 2-6 hours of leaf wetness, and sufficient rain (perhaps 0.10-0.40 inches) to saturate soils or cause pooling of water.

Within a week after tissues are infected, the pathogen is capable of producing a second crop of spores on the infected tissue. Whether it does so is dependent on the environment. The pathogen not only infects through stomata, it also emerges from the stomata to produce new spores. Since stomata are located on the lower surface of grape leaves, downy mildew sporulation occurs there. This is one way to distinguish powdery mildew from downy mildew. Powdery mildew can be found both leaf surfaces. Powdery mildew colonies also have a translucent velvet-like appearance. Downy mildew is milky-white, somewhat fluffy in appearance, and is only found on the lower leaf surface. The leaf tissue beneath a young powdery mildew colony will appear healthy. The tissue of the upper surface of a leaf newly infected with downy mildew will bear a yellow-green blotch in exactly the same shape and location as the downy mildew colony on the underside of the leaf. The yellowed tissue may later die, but may still be surrounded by a ring of white sporulation on the lower leaf surface.

Downy mildew varies greatly in severity from year to year. The relationship of weather to cycles of secondary infection is complex. High humidity (>93%), darkness, and temperatures above 55 F are required for emergence of the pathogen through stomata, and production of the zoospore-containing vesicles. Thereafter, leaves or fruit must remain wet for a sufficient time for the vesicles to be blown to new tissues, release the zoospores, which must then swim to stomata and infect. The duration of leaf wetness required to complete these steps is temperature dependent. Forecasting occurrence of downy mildew requires some sophisticated and expensive equipment. A useful rule of thumb to remember is that warm, wet nights spread disease.

Leaves remain susceptible to downy mildew throughout the growing season. However, fruit become resistant to infection as they approach veraison. As in the case of powdery mildew, none of the cultivars of *V. vinifera* can be considered resistant to downy mildew. Many interspecific hybrids are also extremely susceptible, as are a few cultivars of native American species. In discussing susceptibility of cultivars, the tissue infected must be considered. For example, the hybrid cultivar Chancellor has extremely susceptible fruit, but moderately resistant leaves. The hybrid cultivar Aurore has highly susceptible leaves, but fruit infection is rare. Both leaves and fruit of the *V. labrusca* cultivar Catawba are susceptible.

**BLACK ROT**

The causal agent of black rot is another native north American fungus: *Guignardia bidwellii.* The pathogen overwinters primarily in mummified infected berries on the vineyard floor. Flask-shaped fruiting bodies form in the berries during winter. Each fruiting body contains dozens of small sacks, each of which contain 8 spores. These spores mature when grape shoots are about 6 inches long, and are released during rain. Major spore releases require 0.10 inches of rain or more. Infection requires the presence of free water on tissue. The duration of wetness required is dependent on temperature (Table 2). Because of the dependence on the quality and frequency of warm, heavy rains; this disease can vary greatly in its severity from year to year.

Once the overwintering spores have infected emergent leaves, they form a circular, brown lesion approximately 1/8 - 1/4 inch in diameter after about 12 days. A dark brown border may surround the lesion. Similar lesions may be seen on shoots and leaf petioles. Fruiting bodies form in the center of the lesion and release spores to spread the disease in subsequent rains. On young fruit, symptoms appear as small cream-colored spots on the berry. Infected berries shrivel and become hard blue-black mummies within a few days after these spots appear. Under favorable conditions for disease, entire clusters may be destroyed.

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There are other potential sources of overwintering inoculum in addition to the mummified berries on the vineyard floor, but these are exceptional. For example, severe outbreaks of black rot in early spring can result in infection of the basal internodes of shoots. Infection of internodes produced in mid-season occurs also, but if these are removed in pruning they are relatively unimportant. Lesions on basal internodes retained after pruning can overwinter and release infectious spores during spring rains. Crop loss due to black rot in the previous year may also result in large numbers of mummified berries being retained in the trellis, especially if vines are hedge-pruned. The spores within these mummies mature later in the summer, long after the supply from the ground-borne mummies is exhausted. It should be noted that these are additional sources of inoculum that occur sporadically following failed disease control programs, and that they will probably be accompanied by large numbers of mummified berries on the vineyard floor. Disease control programs targeting the mummified berries on the vineyard floor have provided good control in the presence of these additional sources of inoculum.

The seasonal development of the spores released from mummies on the vineyard floor has an important impact on disease severity. Spore release begins about two weeks after bud break, and continues until shortly after bloom, when the supply is exhausted. Application of conventional fungicides during this period of ascospore release provides season-long suppression of black rot, even when fungicide use is stopped after fruit set. However, neither copper nor sulfur based fungicides provide appreciable control of this disease. Under organic management practices, black rot must be controlled through cultural practices, and proper site and cultivar selection. The most critical time for control is from 6 inches of shoot growth until berries are pea-sized. If fruit are disease free during this time, the natural acquisition of ontogenic resistance will greatly reduce or prevent any late-season development of black rot.

**PHOMOPSIS FRUIT ROT**

This disease is sporadic in its occurrence, but can cause extensive crop loss. Severe epidemics occurred in New York in 1986 and 1994. The disease remained at low levels in most vineyards from 1987-1993, even in many vineyards not treated with fungicides. Phomopsis fruit rot is caused by the fungus *Phomopsis viticola*. The pathogen overwinters in lesions of the basal internodes of infected canes. Fruiting bodies within these lesions mature coincident with shoot emergence of grapevine, and release a gelatinous ribbon of spores during rain. The millions of spores within these ribbons are splash dispersed throughout the trellis. Infection requires only a brief wetting period following spore dispersal (Table 2).

Although fruit rot does not occur every year, spores released in early spring also infect leaves, shoots, and rachises. On infected leaves, a small (1/16 inch) circular yellow-green spot forms. Within 7 days, these spots turn coal-black. On shoots and rachises, the lesions are also black, but due to growth of these tissues, the lesions may be more elliptic in shape than circular.

There are two principle reasons for the sporadic occurrence of the fruit rot phase. First, the host is only briefly susceptible; and second, severe fruit infection requires more than the minimum wetting periods shown in Table 2. In both 1986 and 1994, severe fruit rot occurred when 3-6 inches of rain fell on several days between the bloom and fruit set stages. Although copper-based fungicides may provide some slight reduction of leaf infection, none have significant activity against the fruit rot phase.

Because the primary inoculum for this disease comes from lesions on infected canes, Phomopsis fruit rot is affected greatly by pruning. Mechanically hedged vines harbor more inoculum and are at great risk for complete crop loss when heavy rains occur during the most susceptible stage of growth. In previous research, only low levels of fruit rot developed on hand-pruned, Umbrella-Kniffen trained vines under heavy disease pressure. In fact, disease levels on the above vines were equal to those observed on hedge-pruned top-wire-cordon trained vines that received several conventional fungicide sprays. In other words, the benefit of hand pruning and Umbrella-Kniffen training was equal to that provided by a full season spray program on top wire cordon trained, hedge-pruned vines.

The reported resistance of cultivars to this disease varies. However, due to the impact of pruning and training on disease severity, the sporadic occurrence of severe fruit rot (twice in the last 10 years), and given the relatively short time that certain hybrids and *V. vinifera* cultivars have been grown in New York, the reported resistance of any cultivar should be interpreted cautiously. The absence of disease on certain cultivars thought to be resistant may reflect the typical pruning and training systems employed, and the short history of their culture in New York more than resistance to fruit rot.

**BOTRYTIS BUNCH ROT**

Botrytis bunch rot is caused by the fungus *Botrytis cinerea*. The pathogen has a very broad host range, and can also subsist on decaying vegetation. Thus, there are several possible sources of overwintering inoculum. Under unfavorable conditions, the pathogen forms a resting stage called a sclerotium. Sclerotia can germinate to produce two types of airborne spores in spring, both of which can infect grapevines. The quantity of inoculum in vineyard air increases throughout spring and summer. Germination of these spores and infection of grapevine probably requires free water, but is also associated with relative humidity >90%. It is likely that condensation occurs on some leaves and fruit when relative humidity exceeds this level, although surface wetness may not be observed. Because inoculum is ubiquitous, epidemics are generally limited more by unfavorable weather and cultivar resistance.

Severity of botrytis bunch rot is increased by extended rainy periods during bloom, and cool, wet, weather during ripening in late summer. Unlike most of the other fungal pathogens, spores of *Botrytis cinerea* can germinate and infect at 34 F, thus low temperature is usually not a limiting factor. Within the optimal temperature range for this disease (60-70 F) infection can occur after 15 hours of wetness.

Susceptibility to botrytis bunch rot is partially determined by cluster architecture. Cultivars such as Chardonnay with closed, compact clusters retain post-bloom debris within the cluster. The debris may harbor and serve as a food base for *Botrytis cinerea*. The compact cluster also dries more slowly, resulting in a more favorable microclimate for disease within the cluster. Infections may occur at bloom, during early fruit formation, or as fruit ripen. Early infections may lie dormant until sugar accumulation begins in late summer. The rot then progresses rapidly. Grayish sporulation of the pathogen can be observed on infected clusters in the later stages of the disease. The berries eventually shrivel to form hard, blue-black mummies similar in appearance to black rot mummies.

Neither sulfur nor copper fungicides are effective against this disease. However, adequate control can generally be obtained on loose-clustered cultivars (such as Concord) by avoiding poor air circulation within the grapevine canopy, both through proper canopy management, and through proper site selection for the vineyard. Site selection is also important with respect to proximity to woodland edges, which may place the vineyard at risk for damage from berry moth. Fruit damaged by berry moth are eventually colonized by *Botrytis cinerea*, which may then spread to the rest of the cluster. In addition to the foregoing, more intensive management is required for consistent control on

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cultivars with compact clusters, such as Riesling and Delaware. Hand removal of leaves surrounding the cluster has been demonstrated to effectively reduce losses due to bunch rot. Nitrogen fertilization, especially with manures, must be performed in such a way as to avoid lush canopy growth. Many of the above cultural practices will also reduce losses due to black rot and downy mildew.

## ELEMENTS OF AN EFFECTIVE DISEASE CONTROL PROGRAM

**Cultivar selection.** This is an important factor in determining the risk of disease in a vineyard. Certain cultivars are relatively trouble-free *in most years* with respect to the major fungal diseases. However, it is important to recognize that in some years, significant losses due to one disease or another can potentially occur on any cultivar grown under organic management practices. Copper and sulfur fungicides simply will not control black rot, botrytis bunch rot, or phomopsis fruit rot under the most severe conditions; and no cultivar is immune to all of the major diseases. Market forces will largely dictate which cultivars can be grown profitably. Nonetheless, a grower can minimize losses by selecting cultivars with some measure of resistance to the major diseases. In general, all cultivars of *Vitis vinifera* are highly susceptible to powdery mildew, downy mildew, and black rot. Most cultivars of *Vitis labrusca* are less susceptible to powdery mildew, but susceptibility to downy mildew and black rot varies within the species. The greatest variation in resistance occurs within the interspecific hybrid cultivars. In general, those hybrid cultivars that most resemble *Vitis vinifera* are more susceptible to the major diseases, while those that resemble *Vitis labrusca* are less susceptible. As previously mentioned, cultivars with compact, closed clusters are most susceptible to bunch rots.

Cultivars also differ in their sensitivity to copper and sulfur fungicides. Certain cultivars are severely injured by either copper, sulfur or both. This, coupled with high susceptibility to major fungal diseases can make some cultivars poor choices for organic growers. For example, Rougeon is highly susceptible to powdery and downy mildew, and is injured by the only two fungicides available to organic growers (Table 1). The susceptibility of major grape cultivars to the five major fungal diseases, along with their sensitivity to copper and sulfur fungicides, is summarized in Table 1.

**Site selection.** Gently sloping land with a southeast or southwest exposure, absence of woodland borders and wild or abandoned vineyards, and excellent air-drainage will all lessen the severity of most fungal diseases, both directly and indirectly. Rapid drying of vines after rain or dew is a major factor affecting growth of the black rot and downy mildew pathogens, both of which requires free water for infection. Woodland borders shade nearby rows, restrict air drainage, and increase the time that foliage remains wet. Wild or escaped cultivated grapes inhabiting woodland edges, and abandoned vineyards serve as reservoirs of inoculum for the major diseases. Abandoned vineyards can produce dense clouds of powdery mildew spores by mid-summer, and may overwhelm the disease control program in adjacent plantings. Gradients of powdery mildew resulting from the influx of spores from abandoned vineyards may be clearly visible up to 300 ft from the source, so removal or avoidance of these vines can contribute to disease control. As mentioned above, the risk of berry moth infestations and secondary development of botrytis bunch rot is also most severe near woodland edges.

**Cultural practices.** As previously mentioned, pruning and training practices have both direct and indirect effects of disease development. Open, well aerated canopies are less conducive to development of downy mildew, black rot, botrytis bunch rot, and phomopsis fruit rot. Similarly, weed and ground cover management, both under the trellis and within the alley will effect the environment for disease. Although the greatest reductions of phomopsis fruit rot occur when vines are Umbrella-Kniffen trained and hand-pruned, even hedge-pruned vines will benefit from hand follow-up pruning to remove excess dead wood from the trellis. Black rot mummies should not be left exposed in the vineyard, either in the trellis or on the ground. The mummies can be buried during cultivation, if necessary.

Some common practices can lead to problems with one or more of the major diseases. For example, the practice of dumping pomice within vineyard rows can create an ideal environment for an epidemic of downy mildew. Seeds from cold-pressed grapes can produce a dense carpet of highly susceptible seedlings on the vineyard floor. Establishment of downy mildew on these seedlings often leads to later severe infection of the vines.

**Fungicides.** The original copper fungicide was copper sulfate mixed with lime (Bordeaux mixture), and this is still used today, although other formulations are available and are easier to use. The effective component of this mixture is the copper ion in copper sulfate. This is also what injures copper-sensitive vines. Lime was added to reduce the solubility of copper, and thereby reduce the concentration of copper ion in solution. This had the effect of making the mixture less toxic to vines, without greatly reducing efficacy against fungi. The same effect is achieved in other copper fungicides (often called "fixed coppers") by using less soluble forms of copper (copper hydroxide or copper oxychloride sulfate). Lime may also be added to fixed coppers to further reduce the risk of injury, but this may also reduce efficacy. Injury due to copper application varies among cultivars, but is also dependent on environment. Even less-sensitive cultivars may be injured when cool, wet conditions persist after application, resulting in a high concentration of copper ion for long periods on plant tissue. Copper fungicides are very effective against downy mildew when used properly. They must be used as protectants, and have little or no curative activity. When applied according to label directions, they provide 10-14 days of protection. They are somewhat resistant to wash-off by rain, if the applied material dries before rain begins. They also have some activity against powdery mildew, and when used at 14 day intervals may control powdery mildew on moderately resistant cultivars such as Concord. They will not control powdery mildew on *Vitis vinifera* cultivars or on highly susceptible hybrid cultivars, nor do they have any significant activity against black rot, phomopsis fruit rot, or botrytis bunch rot.

Sulfur provides control of powdery mildew, but has no significant activity against other diseases. Its efficacy declines rapidly below 65 F, and mediocre control may be obtained on mildew-susceptible cultivars if disease is severe from May to mid-June. Sulfur is also easily washed from foliage by rain, even when applications dry before rain begins. Flowable sulfur formulations are more tenacious and effective that most wettable powdery formulations. Sulfur provides from 7-14 days of protection from powdery mildew, with the shorter interval applying to highly susceptible cultivars and less tenacious formulations of sulfur. Like copper fungicides, sulfur is injurious to some cultivars, notably Concord (Table 1).

Organic growers have no fungicide options for control of black rot, botrytis bunch rot, and phomopsis fruit rot, and should weigh the risks involved in selecting certain cultivars, sites, and cultural practices accordingly. Fungicides are therefore timed for optimal control of powdery mildew and downy mildew. Powdery mildew infection can occur as soon as shoots are 1 inch long. Initial downy mildew infection does not occur until 2 weeks before bloom (Eichorn and Lorenz stage 12). If both copper and sulfur may be used, use sulfur alone in applications until downy mildew is expected. Depending upon the cultivar sensitivity to powdery and downy mildew, a combination of both materials could be used (best for cultivars highly susceptible to powdery and downy mildews), or copper could be used alone (powdery mildew resistant cultivars only). The interval between applications can vary between 7-14 days. No applications should be needed after veraison. Of all sprays applied, those used between prebloom and fruit set contribute the most to control of fruit infection. Even in minimal-spray programs, these applications should not be neglected.

**GROWING GRAPES WITHOUT FUNGICIDES IN NEW YORK**

It is entirely possible to grow grapes in New York without any fungicides. However, very few cultivars are suited to this approach, and the risk of substantial crop loss in some years is a near certainty. Powdery mildew resistance is required, since this disease is destructive nearly every year on unsprayed vines of susceptible cultivars. Downy mildew resistance would also be required, because serious fruit losses can occur 1 year in 3, and late-season defoliation nearly every other year. Less emphasis can be placed on a high level of resistance to black rot, but highly susceptible cultivars should be avoided. It may take more than 5 years before black rot builds to significant levels in new plantings. Careful attention to sanitation may delay its introduction for many more years. Both botrytis and phomopsis can be addressed in most years through a combination of canopy and ground cover management, and proper site selection. Botrytis losses in particular can be reduced by early harvest of some cultivars.

H = High M = Moderate L = Low

Table 1. Susceptibility of grapevines to the major fungal diseases in New York.

| | Relative susceptibility | | | | | | |
|---|---|---|---|---|---|---|---|
| Cultivar | Powdery mildew | Downy mildew | Black rot | Phomopsis fruit rot | Botrytis bunch rot | Copper sensitivity | Sulfur sensitivity |
| Aurore | H | M[1] | H | M | H | M | L |
| Baco Noir | M | L | H | L | M | ? | L |
| Cabernet Franc | H | H | H | ? | L | L | L |
| Cabernet Sauvignon | H | H | H | H | L | L | L |
| Canadice | L | M | H | ? | M | ? | L |
| Cascade | M | L | L | M | L | ? | L |
| Catawba | M | H | H | H | L | M | L |
| Cayuga White | L | M | L | L | L | L | L |
| Chancellor | H | H[2] | L | H | L | H | H |
| Chardonel | M | M | ? | ? | M | ? | L |
| Chardonnay | H | H | H | H | H | L | L |
| Chelois | H | L | L | H | H | L | L |
| Concord | M | L | H | H | L | L | H |
| DeChaunac | M | M | L | H | L | L | H |
| Delaware | M | H[1] | M | H | L | L | L |
| Dutchess | M | M | H | M | L | ? | L |
| Elvira | M | M | L | L | H | M | L |
| Einset Seedless | M | H | H | ? | L | ? | ? |
| Foch | M | L | M | ? | L | ? | H |
| Fredonia | M | H | M | M | L | ? | L |
| Gewürztraminer | H | H | H | ? | H | L | L |
| Himrod | M | L | M | ? | L | ? | L |
| Ives | L | H | L | ? | L | ? | H |
| Melody | L | M | H | ? | L | ? | L |
| Merlot | H | H | M | L | M | M | L |
| Moore's Diamond | H | L | H | ? | L | ? | L |
| Niagara | M | H | H | H | L | L | L |
| Pinot blanc | H | H | H | ? | M | L | L |
| Pinot noir | H | H | H | ? | H | L | L |
| Riesling | H | H | H | M | H | L | L |
| Rosette | H | M | M | M | L | H | L |
| Rougeon | H | H | M | H | M | H | H |
| Sauvignon blanc | H | H | H | ? | H | L | L |
| Seyval | H | M | M | M | H | L | L |
| Steuben | L | L | M | ? | L | ? | L |
| Vanessa | M | M | H | L | L | ? | ? |
| Ventura | M | M | M | L | L | ? | L |
| Vidal 256 | H | M | L | L | L | L | L |
| Vignoles | H | M | L | M | H | ? | L |

1 Berries are not susceptible.
2 Leaves are not susceptible.

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Table 2. Duration of leaf wetness required for infection of grapevine by the Black Rot and Phomopsis fruit rot pathogens.

| | Minimum number of hours of leaf wetness required for infection | |
|---|---|---|
| Temperature | Black Rot | Phomopsis fruit rot |
| 50 | 24 | 12 |
| 55 | 12 | 10 |
| 60 | 9 | 8 |
| 65 | 8 | 7 |
| 70 | 7 | 6 |
| 75 | 7 | 5 |
| 80 | 6 | 6 |
| 85 | 9 | 8 |

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