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Grape disease management in Quebec

Canada

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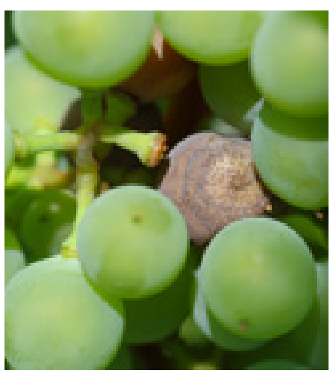
SPCS (S. Hindson)

Grape disease management in Quebec

In Quebec, grapes are affected by several diseases, including root, wood, leaf and berry diseases. The most prominent are downy mildew, powdery mildew, Botrytis bunch rot, anthracnose, black rot and crown gall.

The purpose of this guide is to facilitate the decision-making process for growers and consultants in dealing with disease management. Choosing the appropriate control strategy must take into account a combination of factors that will allow the rational use of fungicides, while respecting the environment.



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Introduction

Conventional strategies for grape disease management are based on routine applications of fungicides. These scheduled fungicide spray programs are based on grape phenological stages and therefore do not take into consideration disease pressure and weather conditions.

This approach can lead to the overuse of fungicides which can increase farm input expenses and added environmental stress. Frequent fungicide applications may not be required every year, especially when disease incidence is below the economic threshold and when taking into considerations other factors such as cultivar susceptibility and disease presence.

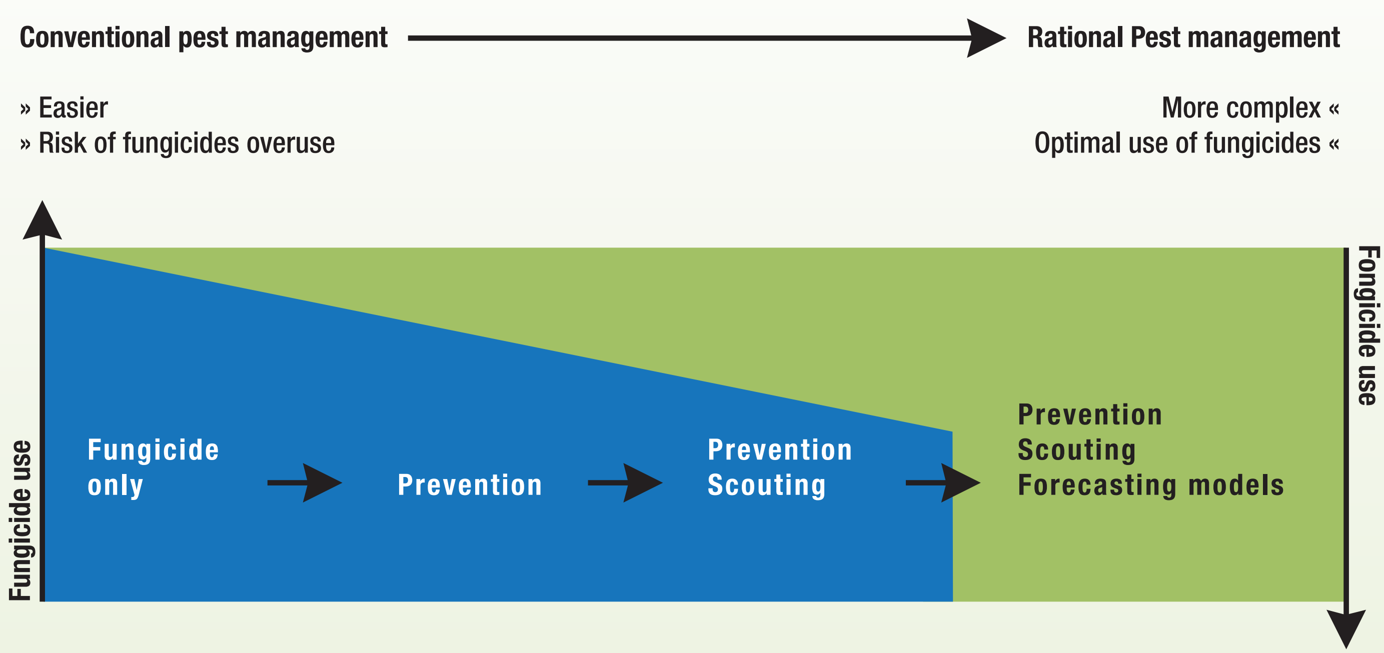
– Monitor fields for disease

Regular and frequent field scouting is the foundation of integrated disease management. However, scouting should be done at the right time, mostly before the critical periods for disease development. The information obtained must be recorded for future reference because they will be useful in planning control strategies in subsequent years (see : http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1210281691267&lang=eng). Crop scouting allows for early disease detection, ideally, before the economic threshold is reached, this way, unnecessarily fungicide applications can be avoided.

– Rational disease management: step by step

Rational disease management should be gradually integrated into the grower's practices. Management tools proposed in this guide don't have to be adopted all at once. Growers may start by implementing sanitation practices which will help reduce disease pressure. Later, disease monitoring may be introduced; this will allow fungicide timing based on disease risk rather than at fixed-intervals. Ultimately, fungicide applications could be based on both scouting and disease forecasts. This guide provides the key elements necessary to achieve a rational approach to disease management for the main diseases found in Quebec.

Steps to integrated pest management



Disease management strategies

– Calendar-based fungicide scheme

Fungicides are applied according to the vine growth stages (phenological stages). Basically, fungicides from different chemical families are alternated and applied based on manufacturer's recommendations (label). In Quebec, growers mostly use the fungicide spray calender provided in the *Ontario Ministry of Agriculture publication Fruit Production Recommendations* (publication 360). This fungicide scheme is based on a complete protection of the vines from the beginning of flowering to veraison.

Advantages • The fungicide scheme is simple, almost identical every year and growers know in advance how many sprays and when fungicides will be applied.

Disadvantages • Some sprays may not be needed if the disease is absent or in small amounts. Timing of fungicide sprays may not be optimal and hence fungicides less efficient. This type of fungicide scheme often leads to the over use of fungicides, consequently increasing input expenses and can have a negative affect on the environment. This strategy may promote the development of fungicide resistance in pathogen populations.

"Integrated Disease Management systems are largely based on prevention."

– Rational disease management

Fungicide applications are based on disease risk estimates such as cultivar susceptibility, current and previous disease scouting records, phenological stages, weather conditions, time elapsed since the last fungicide spray and vine growth rate.

Advantages • Fungicide efficacy is optimal, number of fungicide sprays may be reduced depending on year, consequently reducing the cost of disease management and the risks of developing fungicide resistance within pathogen populations when compared to fixed-interval fungicide spray programs.

Disadvantages • More complex than fixed-interval spray programs. This type of management scheme requires more effort from the grower and requires that the grower be able to tolerate some level of disease risk. Disease monitoring and weather data must be available.

– Integrated Disease Management

This program is based on the integration of different methods of disease control including biological, cultural, and chemical control. The methods could be preventive (sanitation) or reactive (rational use of fungicides). This program requires good planning, starting before vineyard establishment. This management program is largely based on prevention including the selection of vineyard site, row orientation, choice of cultivars, planting density, pruning…

Advantages • Fungicide efficacy is optimal, number of fungicide sprays may be reduced depending on year, consequently reducing the cost of disease management and the risks of developing fungicide resistance within pathogen populations when compared to fixed-interval fungicide spray programs. Disease control is stable over years.

Disadvantages • More complex than fixed-interval spray programs. This type of management strategy requires substantial amounts of knowledge in disease management practices and fungicides (mode of action, efficacy...). Growers must also be able to deal with some level of disease risk. Disease monitoring, weather data and information on disease management must be available.

Rational grape disease management

– Objectives

- Spray only when needed: the disease is present, weather if favourable and the cultivar is susceptible.
- Protect the natural micro-fauna present in the vineyard: do not use fungicides that affect predatious mites.
- Limit fungicide residues on berries by respecting recommended pre-harvest delay.
- Avoid development of fungicide resistance in the pathogen populations by alternating fungicides from different chemical groups and by spraying only when necessarily.
- Ensure the security of the workers responsible for fungicide applications and those working in the vineyard.
- Reduce environmental impact by selecting fungicides with low toxicity.
- Maintain grape quality and yield over the years.

– Reasoning disease management

Before applying a fungicide, make sure that preventive measures were implemented. Preventive measures allow a reduction in disease pressure and consequently reduce the need for fungicide sprays and increase fungicide efficacy.

– Key elements for reasoning disease management

- A good knowledge of the pathogen's biology.
- Regular and frequent disease monitoring for proper timing of fungicide sprays and selection of the right fungicide.
- A good knowledge of fungicides registered for use on grapes including mode of action, absorption by the plant, rate, efficacy, frequency, persistence, pre-harvest interval, negative effects, toxicity, and tank mix compatibility with other pesticides.
- Ideally, a good understanding of forecasting systems or other management tools such as spore samplers.

– Definitions

Action threshold: Disease level observed in the vineyard above which the cost of yield losses is expected to be greater than the cost of a fungicide spray. In other words, it is more cost-effective to spray than to let yield losses occur, however, if disease level is below the action threshold it is not cost effective to spray.

Forecasting models (decision-making tool): Forecasting models are a mathematical representation of disease development. Model outputs are generally an estimate of disease risk and are used in conjunction with field scouting observations.

Preventing diseases

– Before planting

Site selection: Choose a site with good water drainage and good air circulation.

Row orientation: If possible, row orientation should be south-east or south-west to maximize air circulation and sunlight exposer.

Choice of cultivars: If possible, choose cultivars that are less susceptible to diseases (see Internet guide at : http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1210281691267&lang=eng; Appendix 1).

Planting density: Choose a training system and a planting density (plant spacing) which favour good air circulation and reduces the occurrence of prolonged leaf and berry wetness periods.

Perennial cover crops and plastic mulches: Choose slow growing grasses without rhizomes such as fescue. Use good quality plastic mulches.

– Mature Vines

Soil: Working the soil in the spring is a form of cultural control. Destroy and burn infected debris to reduce pathogen populations at the start of the season, therefore reducing the risk of disease.

Weed management: Maintain good weed control to avoid excessive humidity in the lowers parts of the vines and to reduce competition for nutrients and water.

Fertilization / irrigation: Make sure nutrient levels are adequate but avoid the excessive use of nitrogen fertilizers which promote rapid growth and hence the production of young leaves that are more susceptible to some diseases. It might be necessary to irrigate young plants in vineyards planted on sandy soils.

Canopy microclimate: Manage the canopy (pruning, leaf removal, shoot topping and positioning) so that it improves air circulation to promote rapid drying of foliage and help shorten the duration of wet periods. Proper management will allow for better fungicide penetration into the canopy.

Grape pruning: Canes leftover from pruning may act as a reservoir for inoculum, when possible burn them or at least remove from the vineyard.

Data collection

– Weather data

When possible, collect basic weather data such as air temperature, relative humidity and rainfall (duration and intensity) in your vineyard. If you don't have an on-site weather station, use the information provided by *Environment Canada* for your region .

The main reason for collecting weather data is to estimate disease risk. The information gathered is used as input by most disease forecasters to estimate disease risk. Keeping accurate records throughout the years will provide the grower with additional information. For example, it is possible to calculate growing degree days from temperature data, which in turn can predict the occurrence of specific phenological stages, harvest dates and critical periods with regards to disease.

– Biological data

Disease monitoring data is the key element of disease management. It is essential to keep records of scouting data.

Field scouting forms should include:

» Date of observation, cultivar and vineyard section

» Phenological stage

» General appearance of the vines

» Symptoms: description and location on the vine, their severity (number or proportion of vines, shoots, leaves or berries diseased) – draw on outline of the field and map out the area where symptoms are present

» Sprays: kept track of fertilizer and pesticide applications throughout the season

– The decision process

The decision to apply a fungicide will depend on:

» Presence or severity of damages (example: 1, 5 10, 25, 50 or > 50% organs diseased)

» Cultivar susceptibility (see: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1210281691267&lang=eng; Appendix 1)

» Disease history (try to identify problem spots by reviewing disease history for each section of the vineyard): is the disease chronic or does it reappear one year out of every two to five years?

» Phenological stage: before, beginning or after flowering

» Time elapsed since the last fungicide spray and fungicide previously used

» Forecast weather data for the next few days

» Regional warnings, when available

"It is possible to calculate growing degree days from temperature data, which in turn can predict the occurrence of specific phenological stages, harvest dates and critical periods with regards to disease."

Fungicides: mode of action and their mobility in the plant

– Mode of action

Fungicide modes of action can be divided in two categories: **single-site** and **multi-site**.

Single-site fungicides target a specific function of fungal development, and this opens the door to resistance development. Just one mutation on the target site or any other means of avoiding or countering the effect of the fungicide can lead to a significant loss of efficacy of the fungicide. Biosynthesis of compounds essential to the development of the fungus, respiration and cellular division are the most common targets of single-site fungicides.

A **multi-site** fungicide acts on several functions of fungus development. They are less prone to resistance development because mutations in the fungus must occur at all target sites for resistance to develop. Most contact fungicides that are applied pre-infection such as *Mancozeb*, *Captan*, as well as elemental fungicides like copper and sulphur, are members of this category.

– Mobility in the plant

Once applied on a plant or in the soil, fungicides either stay on leaf surface or penetrate in the plant.

It is possible to distinguish between two main fungicide types. **Fungicides not absorbed by the plant**, called contact fungicides or protectants, and fungicides absorbed by the plant.

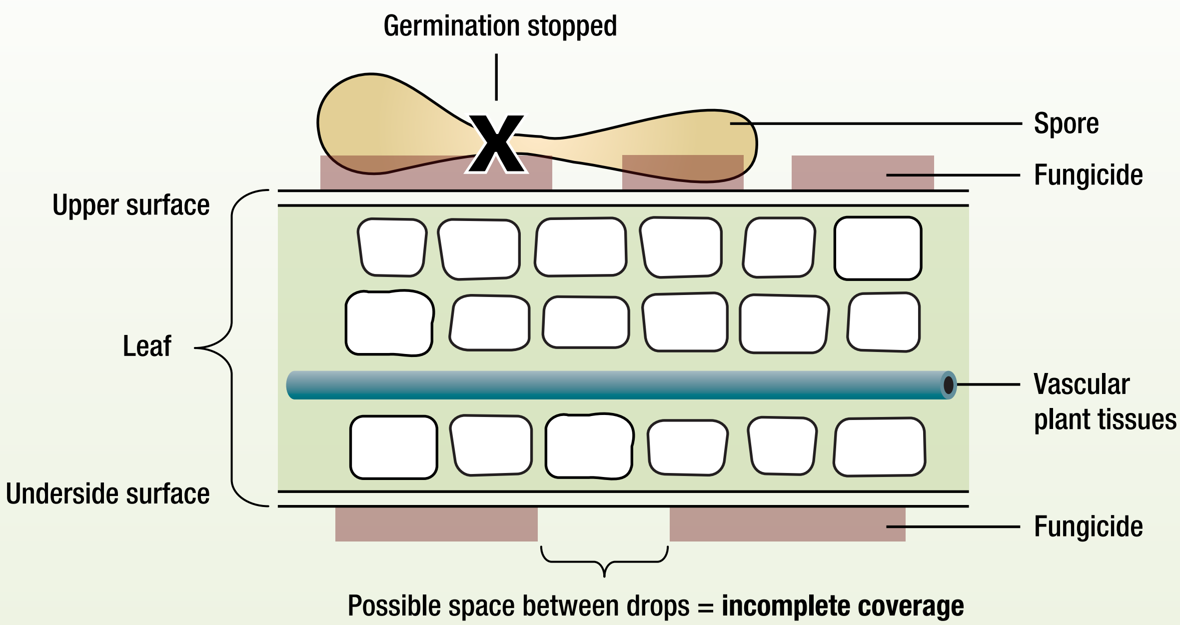
There are three types of fungicides absorbed by the plant:

» Local systemic or translaminar
(across the leaf blade)

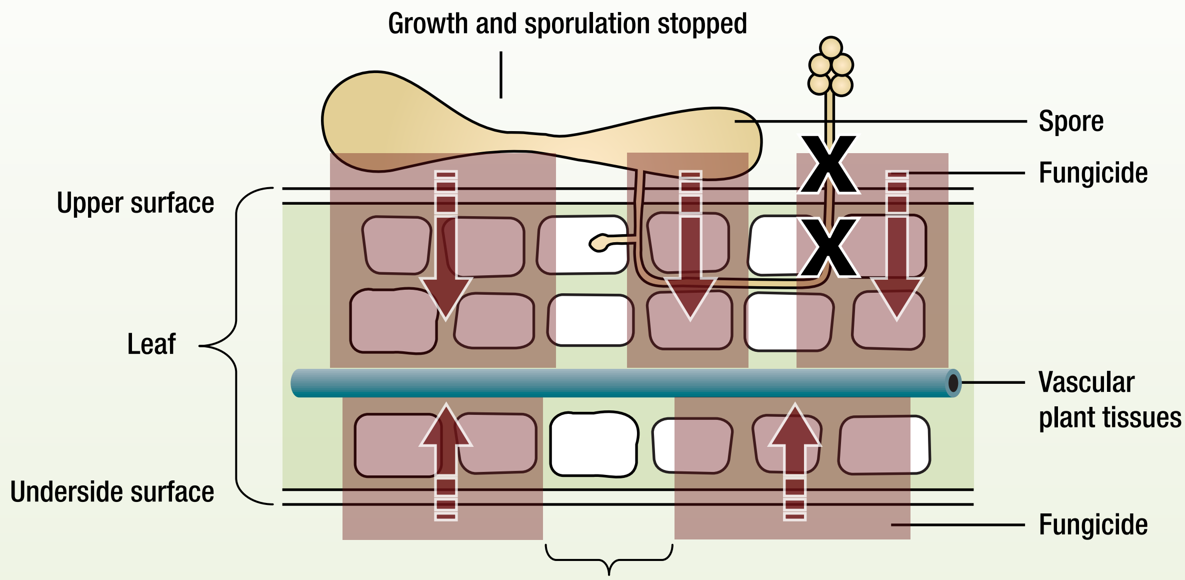
» Systemic with ascendant diffusion
(xylem-mobile)

» Completely systemic
(ascendant and descendant diffusion)

Contact or surface fungicide not absorbed by the plant

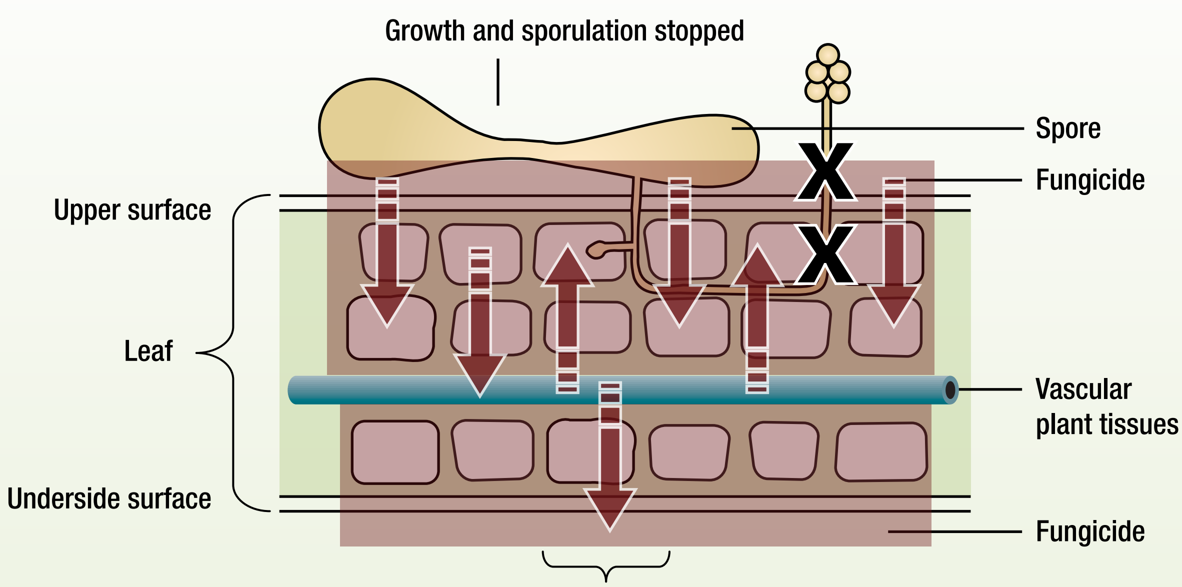


Systemic or trans-laminar fungicide



Possible space between drops = **incomplete coverage**

Completely systemic fungicide



Space between drops always filled up = **complete coverage**

How to use fungicides

– Better knowledge for better efficacy

When **contact fungicides** are applied, droplets will spread on leaf surface but will not penetrate into the plant. Leaves or other plant parts that emerge after the fungicide application are not protected by the fungicide. Contact fungicides are washed off by rain and degraded by sunlight. Examples: *Polyram*, captan, copper.

When **local systemic** fungicides (translaminar) are applied, droplets spread and penetrate into the leaves under the cuticle at the point of entry. The fungicides will stay near the point of entry and do not circulate in the plant; hence leaves or other plant parts that emerged after the fungicide application are not protected by the fungicide. After penetrating into the plant these fungicides, are not washed off by rain or degraded by the sun. Examples: *Nova*, *Sovran*.

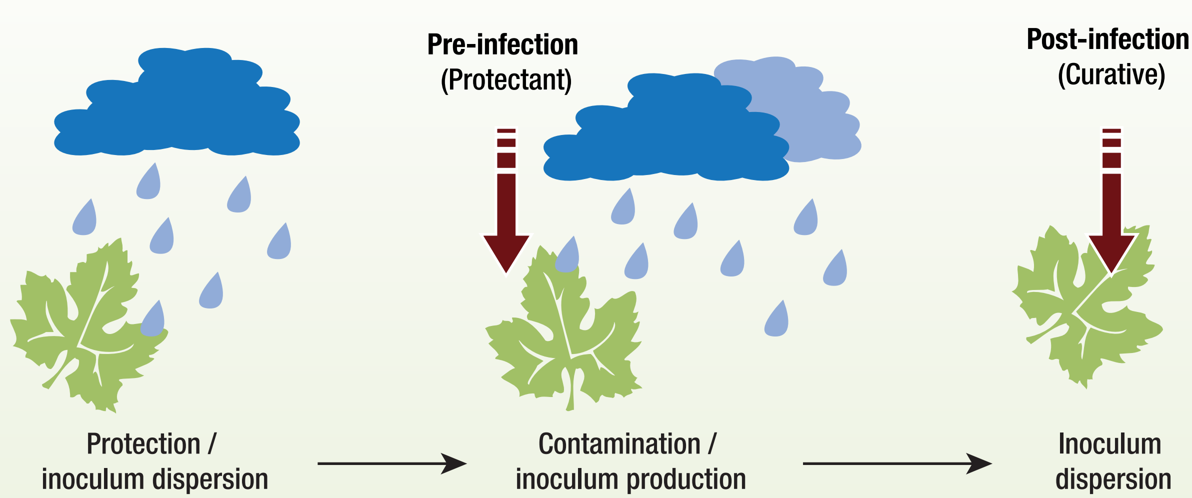
Completely systemic fungicides can be applied onto either the foliage or the soil. Once the fungicide is absorbed by the plant, it will move upwards or downwards throughout the plant. Leaves or other plant parts that emerged after the fungicide application are protected by the fungicide but the fungicide is diluted by the plant growth (more leaves for the same amount of fungicide). Example: *Ridomil*.

– Preventive or reactive strategy

Preventive strategy (pre-infection): Fungicides are applied before an infection period with the aim of preventing infection. The fungal pathogen is killed before it penetrates into the plant or during early stages of fungal development such as spore germination.

Reactive strategy (post-infection): Fungicides are applied soon after an infection period with the aim of controlling an infection that has already occurred. These fungicides have an effect on more advanced stages of fungal development and stop fungal colonization in the plant. This approach is effective against non forecasted infection, severe infections and under frequent rainy periods (fungicides used in post-infection are less prone to wash off by rain).

Fungus: Pre-infection and post-infection



Fungicide efficacy

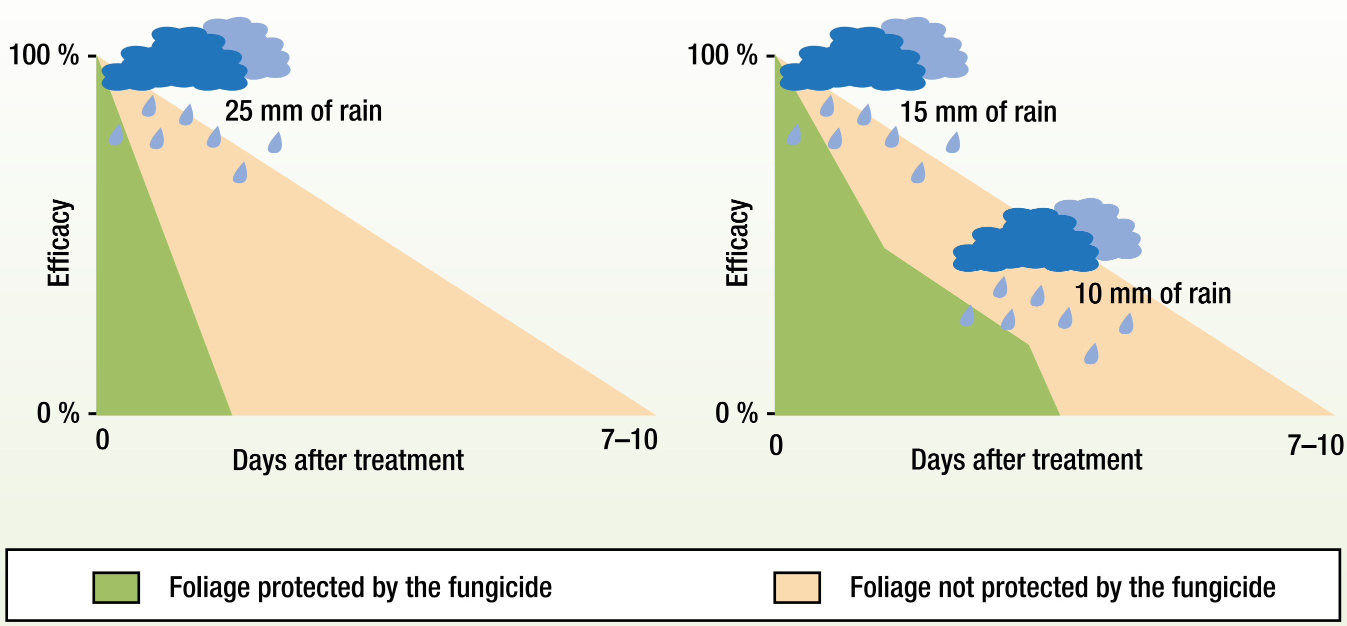
Key elements for efficient chemical control:

- Apply fungicide based on disease risk, time elapsed since last spray, and weather conditions.
- Choose fungicide based on disease risk, absorbtion by the plant, strategy (pre- or post-infection) and anti-resistance program (alternate fungicides from different chemical group).
- Use the recommended rate and carefully prepare spray solution.

In general contact fungicide are washed off by 25 mm or more of rain or irrigation water (see diagram below).

Several factors are responsible for reduced fungicide efficacy: use of inappropriate fungicide, miscalculation when preparing spray solution, water pH, poor sprayer calibration, bad timing and environmental conditions during treatment application and fungicide resistance. In general, fungicide resistance is not the main factor for poor fungicide efficacy; however, resistance to some fungicides has been reported in some Quebec vineyards.

Fungicide resistance is a natural phenomenon in which some members (spores) of the fungal population are capable of resisting the detrimental effect of fungicides. These individuals will transmit their resistance to their progeny. After being subjected to several fungicides sprays, the proportion of resistant individuals may reach high levels leading to disease control failure. The number of sprays necessary to achieve a shift in control efficacy varies according to fungicide use and initial composition of the population when the fungicide is first used.



Practical questions related to fungicides

Preventive effect: Destruction of the fungus before its penetration into the plant.

Curative effect: Destruction of the fungus after its penetration into the plant (after infection has occurred). Duration and efficacy of curative effect vary among fungicides.

Anti-sporulation effect: Destruction of fungal reproduction (sporulation) following an infection.

Fungicide: Phytosanitary product developed to kill or limit fungal plant pathogen development.

Absorbed fungicides: Fungicides that are absorbed (are taken up) by the plant, they may or may not be redistributed in the plant. These fungicides are not washed off by rain or irrigation water once they have penetrated into the plant.

Systemic fungicides: Fungicides that are absorbed by the plant and redistributed into the plant vascular system. The fungicide *Ridomil* is absorbed by the grape leaves and redistributed to new leaves and clusters during period of rapid growth. Fungicide redistribution to cluster is reduced after fruit set.

Leaf wetness: Presence of free water on leaf, shoot or fruit surface. In general fungicides applied to wet foliage are diluted making them less efficient.

Wetness duration: Length of time in hours during which leaves, shoots or berries are wet. The duration of wetness is often used in forecasting systems to estimate the risk of infection and sporulation.

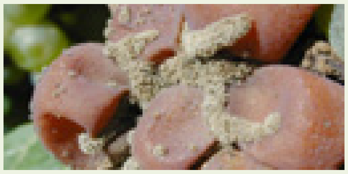
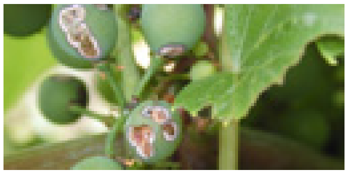
Primary infection: Infection caused by spores that over-wintered or that where produced in fruiting bodies that have over-wintered. These infections are generally the first infections occurring in the spring.

Secondary infection: Infection caused by spores produced on lesions or other symptoms induced by primary infections. These infections are responsible for disease development during the summer months.

Phytotoxicity: Properties of certain phytosanitary products such as fungicides that cause injury to plants, examples are distortion, stunting or burning of plant parts. These alterations can have a temporary or permanent effect on plant growth.

Phytosanitary product: Related to plant protection. They are active substances or chemical compounds developed to control pests including disease, insects and weeds.

Grape diseases scouting

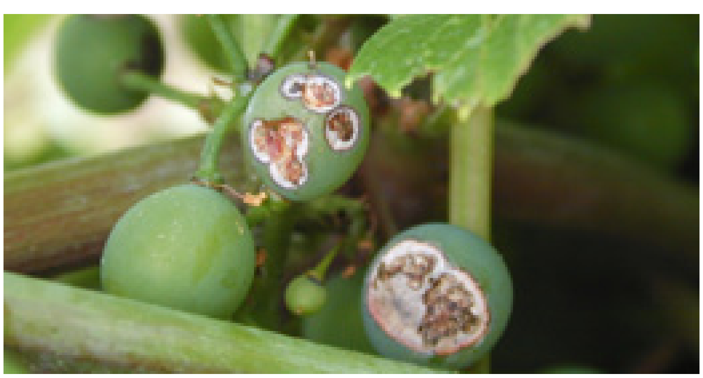
DISEASE	START SCOUTING	SAMPLE SIZE	WHAT TO LOOK FOR	REMARKS
DOWNY MILDEW 	Stage 7	Minimum of 25-50 vines Susceptible cultivars	Yellowish discoloration more or less circular. White down mainly on the lower leaf surface.	Start scouting on the most susceptible cultivars and areas with poor air circulation. Apply a fungicide immediately if symptoms are detected.
POWDERY MILDEW 	Stage 7	Minimum of 25 vines Susceptible cultivars	Yellowish discoloration followed by a thin white powdery layer.	Pay attention to leaves inside the canopy (in shaded areas).
BUNCH ROT 	Stage 19-21 Stage 35	Minimum of 100 flowers 100 clusters	Blighted and / or withering inflorescences. Brown berries that turned reddish. Berries covered with a grayish mold.	Carefully write down weather conditions during flowering even if symptoms are absent.
ANTHRACNOSE 	Stage 7	Minimum of 20-25 vines Susceptible cultivars	Minute black spots on leaves, petioles or berries.	Start scouting as early as possible and spray as soon as symptoms appear. Spray preventively on highly susceptible cultivars.
BLACK ROT 	Stage 7	Minimum of 25 vines Susceptible cultivars	Brown spots on leaves. Upper part of berries are brown and sunken.	Start scouting as early as possible and spray as soon as symptoms appear.
CROWN GALL 	Stage 3	All vines, at least once per season	Galls at the base of the vine.	Destroy infected vines. Some cultural practices such as pruning may favour bacterial dissemination.

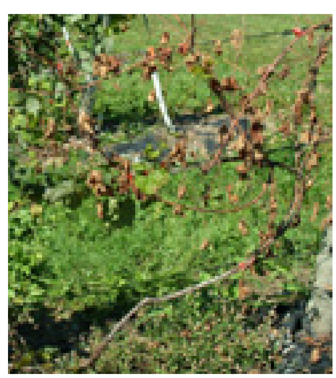
For more information on grape diseases scouting, see:
http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1210281691267&lang=eng

Major grape diseases found in Quebec

Grapes are highly susceptible to several diseases. In general, if no control measures are used (biological or chemical), yield losses are significant and grape production unprofitable.

Downy and powdery mildews, bunch rot, anthracnose, black rot and crown gall are the most common diseases. All these diseases are caused by fungi with the exception of crown gall, which is caused by a bacterium. These diseases can decrease yields and grape quality. (http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1210281691267&lang=eng).





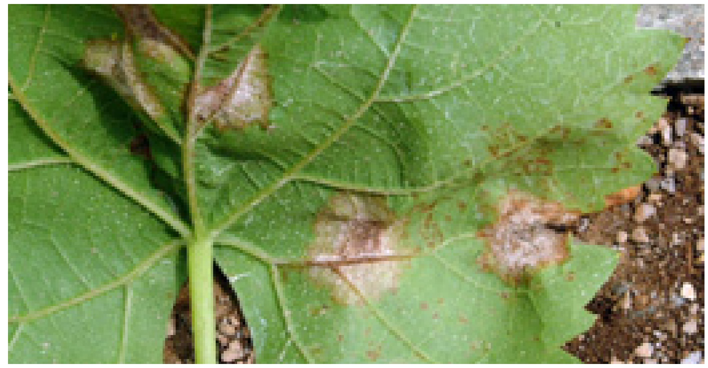
Downy mildew – *Plasmopara viticola*

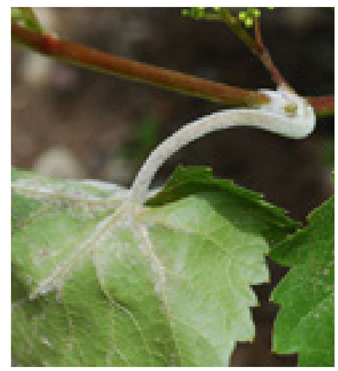
Grape downy mildew is native to North America and affects most species of the *Vitis* genous but *vinifera* cultivars are highly susceptible. The degree of susceptibility to downy mildew varies between cultivars.

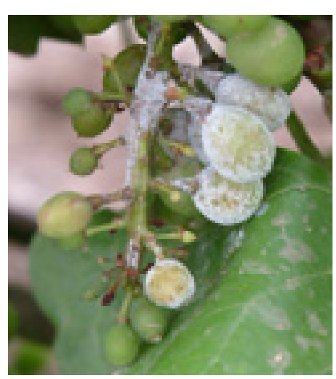
Downy mildew can infect shoots, leaves as well as flower and fruit clusters. In addition to direct damage on berries, downy mildew can cause premature leaf fall which delays fruit ripening and increases susceptibility to winter damage.

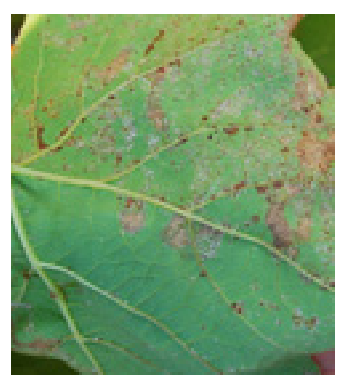
– Symptoms

The pathogen can infect all green parts of the vines. First symptoms are light green or yellow spots, commonly referred to as "oil spots" because of their greasy appearance. Under warm and humid conditions, white, fluffy sporulation develops on the lower surface of the leaf. As lesions age, they turn brown and the infected tissue dies, sporulation becomes greyish and leaves may fall. Inflorescences are highly susceptible to downy mildew, following severe infection they turn yellow, than brown and dry up. White spore masses develop on infected fruit clusters which causes infected berries to turn blue, than brown and wither.









Downy mildew disease cycle

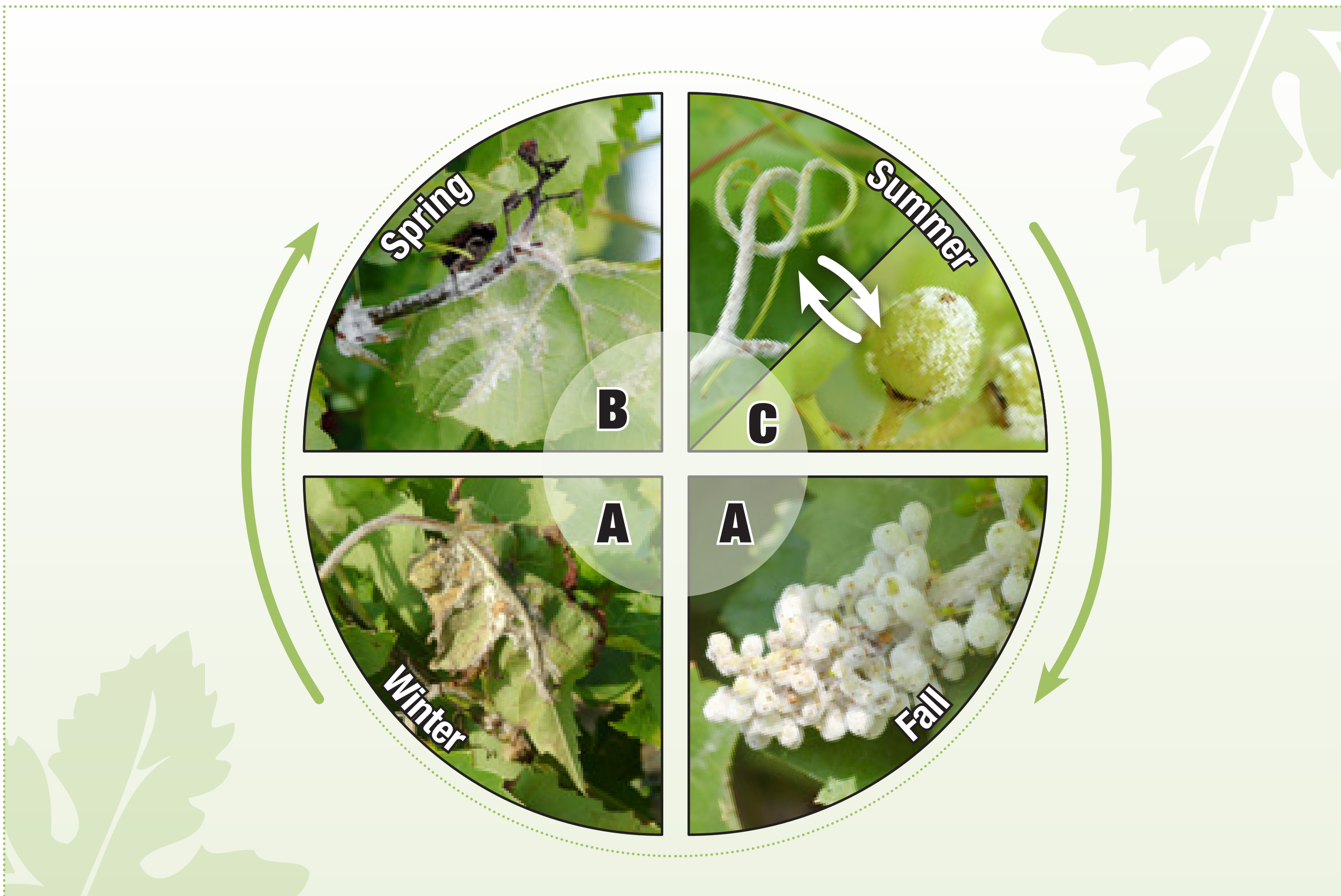
Winter • The fungus overwinters as spores (oospores) in dead leaves on the vineyard floor. These spores can survive cold temperatures as low as -26 °C, but they are less likely to survive if they are covered with soil (or buried). **(A)**

Spring • Spores that survive the winter (oospores) germinate in water when temperatures reach 11 °C, and produce sporangium with in turn liberate a new type of spore called zoospore. These zoospores move in water and spread to new shoots and new leaves by wind and rain. These spores are responsible for primary infections, they infect leaf tissue by swimming to the vicinity of stomata where they germinate and enter inside the leaf. Under optimal conditions, at temperatures of 18 - 25 °C, the infection can takes place within 90 minutes. **(B)**

Summer • Following the primary infections, the fungus grows within the tissues and produces new spores (sporangia containing zoospores). Sporangia are spread by wind and rain onto shoots, leaves, flowers and berries where they cause secondary infections.

Optimal conditions for secondary infection are: wetness durations of at least 4 hours under darkness, 95 - 100 % relative humidity and temperatures between 18 and 22 °C. New spores will be produced on new lesions and cause new lesions and so on. Lesions appear within 5 to 17 days after infection and this cycle will continue as long as the conditions are favourable. **(C)**

Fall • The fungus produces survival spores (oospores) in dead grape leaves. **(A)**



Downy mildew management

Susceptibility • Vines are susceptible from the appearance of the first leaf (growth stage 7) up until approximately 3 weeks after flowering, when young grapes loose their susceptibility. However, rachises remain susceptible.

Critical period • From the first unfolded leaf (stage 7) to veraison (stage 35). In general mildew appears in early summer and reappears near harvest on regrowth.

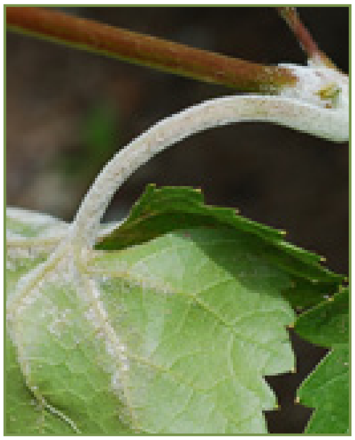
Primary infections • They occur in the spring while rainfall is more than 2 mm on humid sol at temperatures of 11 °C or higher.

If these conditions occur, start scouting in the vineyard and apply a fungicide if symptoms are present.

Secondary infections • They are favoured by rainy weather conditions, therefore if the frequency of rainfall increases so does the risk of infection. So the decision to treat with a fungicide should be based on scouting results (presence or absence of lesions) and rainfall frequency. Lesions appear 1-2 weeks after rain; making it possible to adequately time fungicide sprays and to evaluate the efficacy of the treatment. For highly susceptible cultivars, fungicides maybe applied preventively.

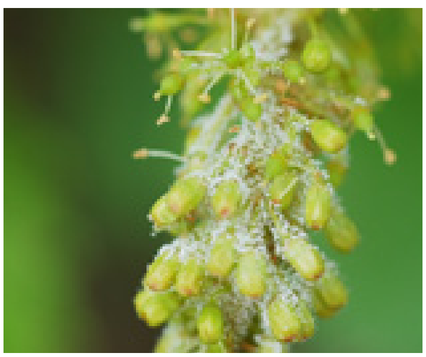
Management strategy • The strategy for downy mildew management is based on a good control of leaf infections before the critical period in order to avoid berry infections as much as possible. Under severe epidemics, spray treatments targeting berry protection may be needed.

Tip • The 10 - 10 -10 rule to decide when to start scouting for downy mildew: the shoot growth exceeds 10 cm, there has been 10 mm of rainfall and temperatures have been at least 10 °C during a 24-hour period.



"Start scouting for downy mildew when the shoot growth exceeds 10 cm, there has been 10 mm of rainfall and temperatures have been at least 10 °C during a 24-hour period."

Downy mildew management in brief

SPRAY TIMING	REMARKS	CRITERIA FOR DECISION
BEGINNING OF TREATMENT 	Start scouting: **Stage 7.** Favourable conditions: 5 - 10 mm of rain and temperatures of 11 °C and above.	Susceptible cultivars and reoccurring problem spots: Spray preventively starting with new growth in the spring (stage 9). Moderately susceptible cultivars: After the first primary infection (symptoms are present, light yellow to green greasy spots). **First spray:** **Before a major rainfall event is forecasted.**
OTHER SPRAYS 	Pay attention to developing clusters from beginning of flowering to fruit set (stage 19 - 27). Risk of infection increases with rainfall frequency.	Downy mildew is present (white downy patches). Consider vine growth rate, mode of action and persistence of fungicide, and weather conditions during spraying. **Spray before rain is forecasted or soon after in the case of *Ridomil*.**
END OF SPRAYS 	According to the amount of diseased shoots, leaves and clusters (sporulating lesions) in the vineyard. Older leaves are less susceptible. The risk of infection ends at mid-veraison. At the end of the season, soon after hedging, risk of disease infection can recur, due to regrowth.	Beginning of veraison in healthy vineyard (absence of symptoms). or mid-veraison if the disease is present.

MILVIT approach to downy mildew management

MILVIT for 'Mildew' and 'Viticulture' was developed in Europe. It uses disease risk indicators to predict infections of downy mildew and generates warnings to assist growers in taking day to day decisions to manage downy mildew. Disease monitoring is the key element of MILVIT. Scouting is initiated as soon as the first leaves emerge in the spring (stage 7). Daily monitoring of weather conditions is initiated when the first lesion is detected in the vineyard.

If **5 - 10 mm of rain are expected and temperatures are above 12 °C**, a fungicide application is required to protect new growth. After the first application, keep monitoring the vineyard for symptoms. As soon as new lesions are detected, an another fungicide application is needed **if 5 - 10 mm of rain are expected and temperatures are above 12 °C**.

If rain events are frequent, making it difficult for fungicide applications, a systemic fungicide may be used. The only systemic fungicide registered for use on grape is *Ridomil*. If this occurs after flowering (post- bloom) a protective fungicide may be applied.

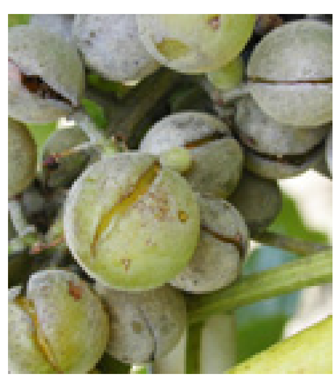
Frequency of applications thereafter depends on the same criteria (symptoms and **5-10 mm of rain when temperatures are above 12 °C**). From fruit set to harvest, the berries are less susceptible to downy mildew, hence if berries are not diseased, it is acceptable to tolerate some downy mildew on leaves.

It is important to scout until harvest because the amount of inoculum present on the leaves at leaf fall will be responsible for next year's primary infection. This will allow a better preparation of next year's control strategy.

"It is important to scout until harvest because the amount of inoculum present on the leaves at leaf fall will be responsible for next year's primary infection."

Powdery mildew – *Erysiphe necator (Uncinula necator)*

Grape powdery mildew, caused by the fungal pathogen *Erysiphe (Uncinula) necator* is native to North America. Powdery mildew is present in almost all vineyards and may significantly reduce yields and grape quality. Susceptibility to powdery mildew varies between cultivars, however most cultivars grown in Quebec are susceptible. All aerial plant parts could be infected and yield losses vary from year to year.



– Symptoms

The powdery mildew fungus can infect all green tissues. On leaves, first symptoms are whitish gray, dusty or powdery lesions. Severely infected leaves may wither or curl then fall on the ground.

On shoots, infections may cause star shape lesions which turn dark brown with age. Infected berries are grayish and dusty, may crack, dry off and fall on the ground.

Infected berries become whitish gray with a dusty or powdery appearance. Severe berry infections can result in splitting of berries.

At the end of the season, the fungus produces small golden-brown to black fruiting bodies (cleistothecia) on infected plant parts. The cleistothecia overwinter in bark crevices of the vine.

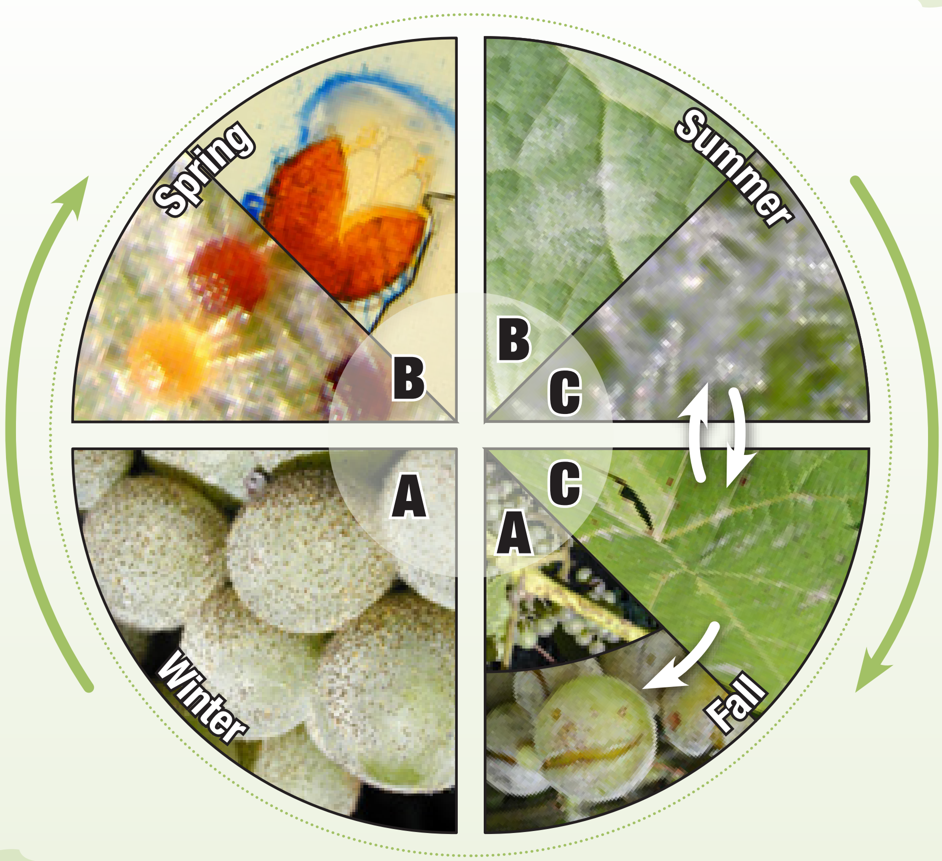
Powdery mildew disease cycle

Winter • The fungus overwinters in bark crevices of the vine in the form of a fruiting body (cleistothecia)**. (A)**

Spring • As temperature increases cleistothecia mature and release ascospores that are disseminated by wind and rain. Once these spores are deposited onto the leaves or other green tissues, they germinate and cause the primary infections. Leaves located near the bark tend to get infected first. Optimal conditions for primary infections are the presence of rain and temperatures of 20 °C or higher. **(B)**

Summer • New spores (conidia) are produced on infected organs. These spores are wind-disseminated and cause the secondary infections. From new lesions, new spores are produced, these spores will then produce new lesions from which will appear new spores so on and so forth. Under optimal conditions this cycle takes approximately 5 - 6 days. **(C)**

Fall • Cleistothecia are produce in late summer during the months of August and September. Once they have matured cleistothecia detache from leaves, shoots and berries and only the ones that fall into bark crevices can survive over the winter. **(A)**



Powdery mildew management

Susceptibility • Leaves are susceptible to powdery mildew as soon as they emerged (stage 7). Berries are susceptible from initiation to veraison.

Critical period • From 4-6 unfolded leaves (stage 12) to veraison (stage 35). In general, powdery mildew appear before the beginning of flowering and progress' until late fall.

Primary infections • They occur in the spring if rainfall exceeds 2.5 mm for at least 4 hours, when temperatures are between 6 and 24 °C. When these weather conditions arise survey the vineyard for symptoms of powdery mildew and initiate fungicide sprays if lesions are detected.

Secondary infections • Optimal temperature for infection is 23 °C (20-27 °C). Infection can occur when relative humidity of 40 % or higher; however spore (conidia) germination is inhibited by the presence of water. Light may also inhibit spore germination; hence, powdery mildew generally develops inside the canopy (IMPORTANT FOR SCOUTING).

Management strategy • The strategy for powdery mildew management is based on a good control of leaf infections before the critical period in order to avoid berry infections as much as possible. Under severe epidemics, sprays that target berry protection may be needed.

MEAN AIR TEMPERATURE (°C)	TIME REQUIRED TO COMPLETE AN INFECTION CYCLE, FROM INFECTION TO SPORULATION (DAYS)
6	32
9	25
12	18
15	11
17	7
23	6
26	5
30	6

Powdery mildew management in brief

SPRAY TIMING	REMARKS	CRITERIA FOR DECISION
BEGINNING OF TREATMENT 	Start scouting: First unfolded leaf **(Stage 7).** Favourable conditions: Warm temperature (20 - 27 °C) and relative humidity is at 60 % or above. **Critical period:** **From 4 - 6 unforded leaves (stage 12) to veraison (stage 35).**	Susceptible cultivars: After the first primary infection (symptoms have been detected) or beginning of flowering. Moderately susceptible cultivar: After the first primary infection (symptoms have been detected) or 50 % flowering.
OTHER SPRAYS 	Frequent scouting is required. Susceptibility is highest from flowering to veraison. Risk of powdery mildew increases with increasing temperature (20 - 27 °C) and humidity	Powdery mildew lesions are present in the vineyard. Consider vine growth rate, mode of action and persistence of fungicide, and conditions while spraying.
END OF SPRAYS 	Monitor the presence and incidence of sporulating lesions in the vineyard. Older leaves are less susceptible; The risk of infection ends at veraison. Avoid high levels of leaf (or berry) infection at the end of the season in order to minimize primary inoculum the next season.	Beginning of veraison in healthy vineyard (absence of symptoms). Mid-veraison if the disease is present.

Powdery mildew management based on disease risk estimations

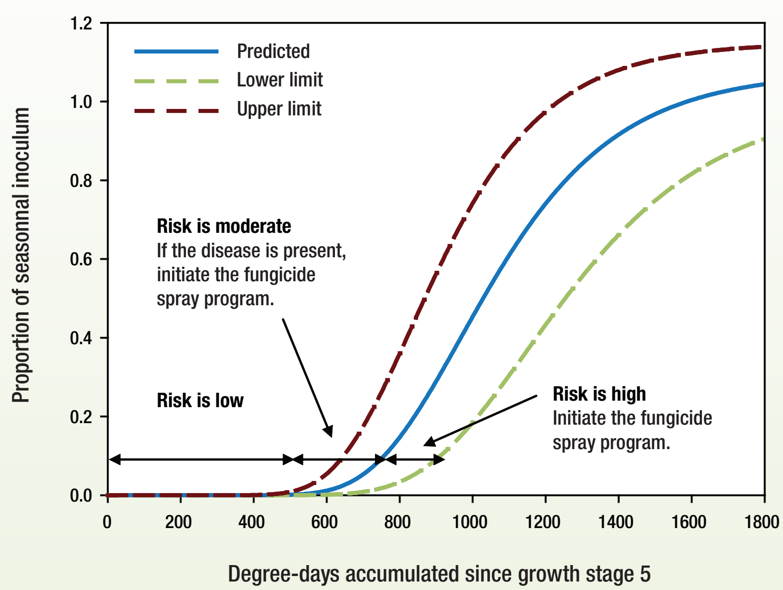
Grape powdery mildew is a wind-disseminated disease. In other words, spores produced on lesions are dispersed by wind. Airborne spores fall on leaves and cause new lesions which in turn produce new spores that are wind-disseminased and so on.

Studies, conducted in Quebec, showed that the amount of spores in the air, hence increasing the risk of powdery mildew infection is influenced by the accumulation of heat units. A degree-day model was been developed to determine the best time to initiate a spray program. By using this model, it is possible to eliminate early fungicide sprays when the risk of infection is low and to spray when the risk is high. Degree day values are calculated daily from hourly temperatures using 6 °C as the base temperature but excluding hours with temperature above 30 °C. Degree days are accumulated from the green tip growth stage.

» When heat units are at less than there is a low risk of infection: it is advised to scout for the presence of powdery mildew symptoms. If lesions are detected then start fungicide sprays.

» When heat units are between 500 and 600 there is an increase risk of infection; it is advised to scout more often and to initiate the spray program on susceptible cultivars.

» When the risk of infection reaches the action threshold i.e heat units are anywhere between 600 and 700, it is advised to scout more often and to initiate the spray program for cultivars that are moderately susceptible.

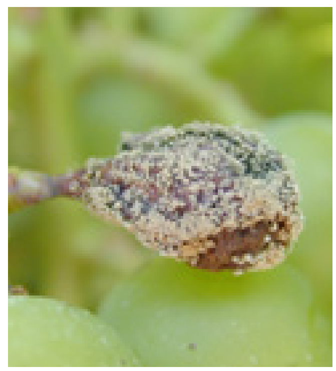


Bunch rot, grey mold – *Botrytis cinerea*

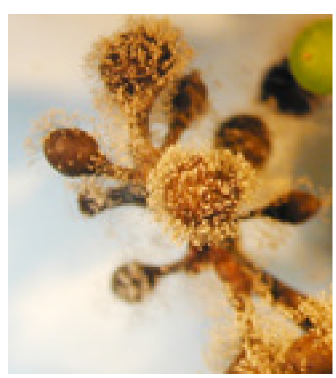
Gray mold or *Botrytis* bunch rot sporadically causes substantial yield reductions in Quebec vineyards. The causal agent *Botrytis cinerea*, can cause fruit rot in several plants, among which strawberries and raspberries. The disease can progress rapidly during berry ripening and cause significant yield losses. The disease can be difficult to control because of the development of resistance to some fungicides in *B. cinerea* populations.

– Symptoms

B. cinerea is present in all fruit producing areas, including most vineyards. Symptoms are generally more obvious on berries, however buds and young shoots can also show signs of infection and turn brown. In late spring, V-shaped or irregular brown patches may appear on leaves. Infected inflorescences may be blighted and dry up.



Some flower infections can remain latent (invisible) until veraison. Fruits become more susceptible as they begin to ripen (veraison); *B. cinerea* infect berries by penetrating directly through the surface of the skin or through wounds, and may continue to invade until the entire cluster is covered with gray spores.



Bunch rot disease cycle

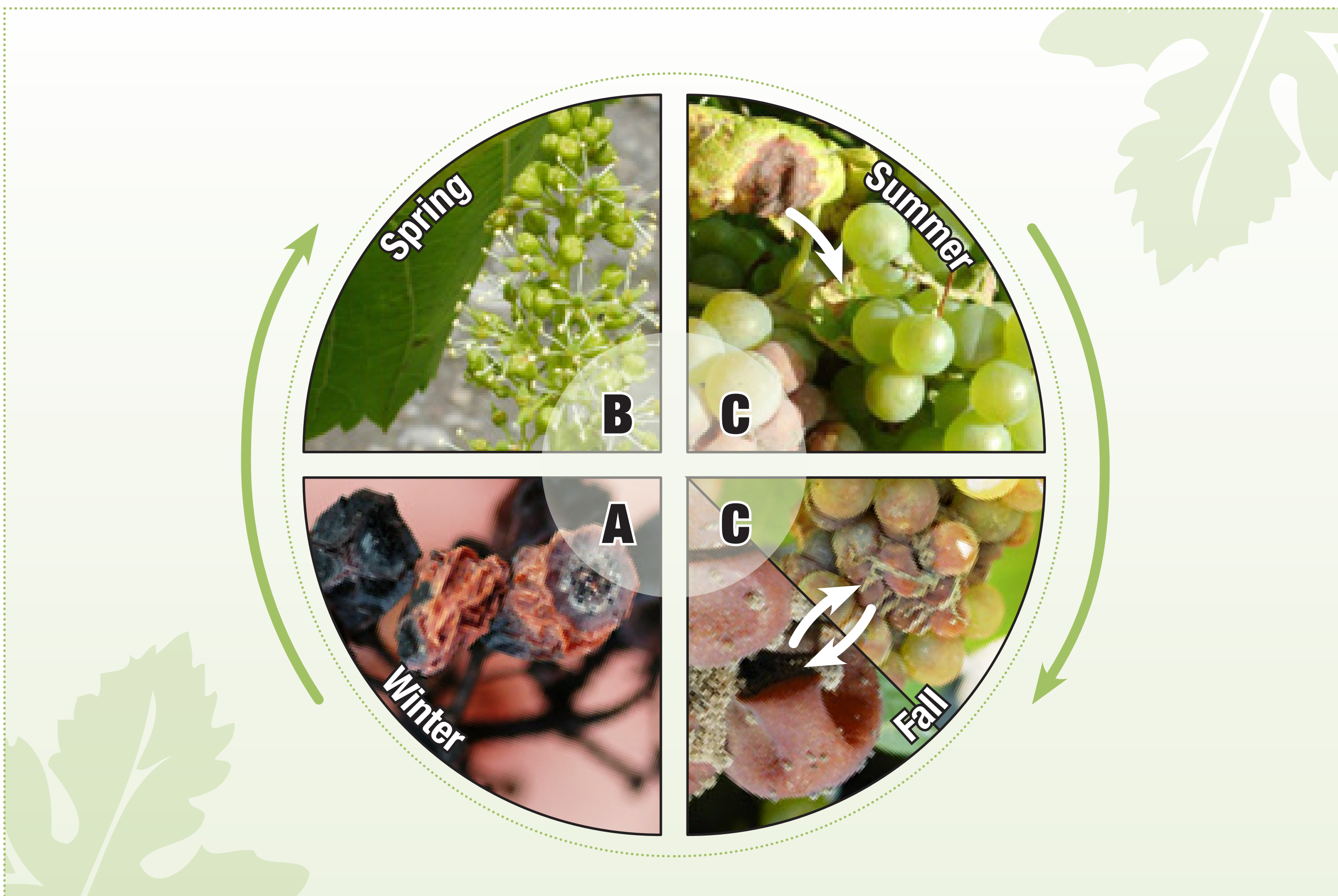
Winter • *Botrytis cinerea* overwinters as sclerotia (masses of compact mycelium) in crop debris. Sclerotia are often found in mummified berries on the ground at the end of the season. **(A)**

Spring • Sclerotia produce spores (conidia) that are spread throughout the vineyard by wind and rain. Spores that are deposited onto leaves and flowers are responsible for causing primary infections. **(B)**

Summer • On flowers, conidia cause latent infections that are visible only later in the season after veraison. These conidia germinate when relative humidity is high (> 90 %) or under wet surfaces, provided that the temperature is between 1 and 30 °C (optimum at 18 °C) . Infected berries turn brown and purple. During dry weather conditions, infected berries dry out; in wet weather, they tend to burst and become covered with a grayish mold. **(C)**

Infection is more severe on tight clustered varieties or clusters affected either by powdery mildew, hail or insect damage (example: grape berry moth).

Fall • Sclerotia are mainly formed in mummified berries that have fallen on the ground.



Bunch rot management

Susceptibility • Leaves are more susceptible when they are senescent or damaged. Inflorescences are susceptible during the entire flowering period. Berry susceptibility increases as their sugar content increases.

Critical period • From the beginning of flowering (stage 19 - 21) to berry touch (stage 33) and throughout berry ripening until harvest.

Infections • Infection severity depends on factors such as temperature, duration of leaf or berry wetness or high relative humidity (> 90 %) (see table below) and cultivar cluster type. Closely monitor cultivars that are tight clustered (*Vidal* and *Seyval*).

MEAN AIR TEMPERATURE (°C)	WET PERIOD DURATION REQUIRED FOR INFECTION (HOURS)
10	30
15.5	18
22.5	15
26.5	22
39	35

Preventive measures • Avoid excessive growth by fertilizing appropriately. Use pruning and canopy management practices that favour air circulation and rapid drying of leaves and berries. If there is history of disease, remove leaves around the clusters for susceptible cultivars to promote air circulation. Control weeds to reduce humidity in the lower portion of the canopy. Try as much as possible to minimize berry damage caused by birds, machinery or insects and destroy pruning debris.

Management strategy • For fields that have a history of bunch rot or if highly favourable weather conditions are present then apply fungicide during these four growth stages: bloom, berry touch, veraison and before harvest.

Note: Some adjuvants added to fungicide mixes may damage the wax on berries which serve as a natural barrier to infections by *B. cinerea*.

Bunch rot management in brief

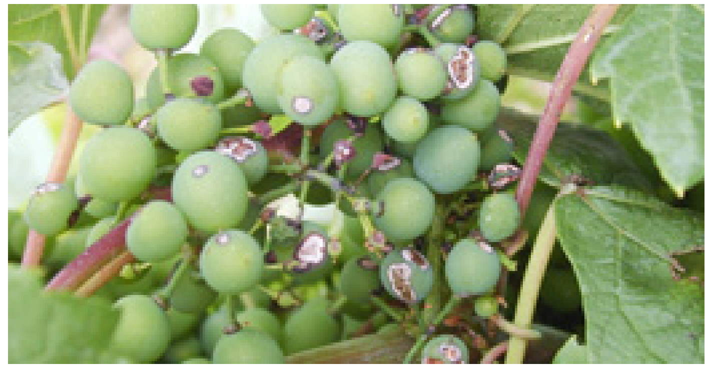
SPRAY TIMING	REMARKS	CRITERIA FOR DECISION
BEGINNING OF TREATMENT 	Start scouting: **Stage 19-21 and 35 to harvest.** Favourable conditions: Warm temperature and high relative humidity. **Critical period: Beginning of flowering (stage 19-21) to berry touch (stage 33) and during berry ripening until harvest.**	Susceptible cultivars (tight cluster): Protect flowers against latent infection at 80 % flowering (Stage 25) and at berry touch.
OTHER SPRAYS 	Pay attention to weather conditions during flowering. Risk of infection increases with rainfall frequency, warm temperatures and during periods of high relative humidity. Scout for infected inflorescences.	Before berry touch on very susceptible cultivars.
END OF SPRAYS 	While scouting takes down the % of infected clusters. As sugar levels increase during berry ripening, so does their susceptibility to bunch rot. At the end of the season, avoid large amount of mummified berries to reduce primary inoculum the next season.	Before harvest if symptoms are present. Check with an œnologist for the effect of late fungicide applications on wine quality. Respect pre-harvest delay recommended by the manufacturers (see labels).

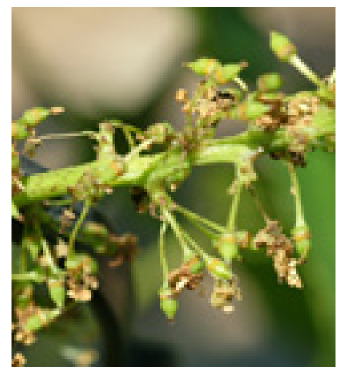
Anthracnose – *Elsinoe ampelina*

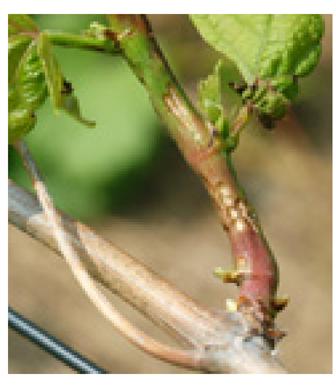
Anthracnose is a fungal disease that originated from Europe. Vitis vinifera species are generally susceptible to the disease whereas wild species are generally less susceptible. Mild infections by *E. ampelina* are enough to reduce vigour and yield when compared to healthy vines. Severe infections reduce shoot growth, quality and quantity of fruits, and winter-hardiness.

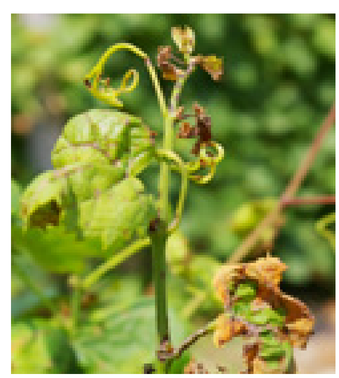
– Symptoms

E. ampelina attacks all above-ground parts of the vine. Leaf symptoms appear as small circular black or brown spots. As the lesions mature, the center drops out, creating a shot-hole appearance. On the petioles and shoots, *E. ampelina* causes deep, elongated cankers, with a grayish centre and black edges. In some cases, the lesions will be so deep that the shoot breaks, causing total loss of production on that shoot. During severe infections, the leaves shrivel up and fall. Infected berries also develop sunken spots with a grayish centre and black edges. Severely infected berries dry up and drop prematurely.









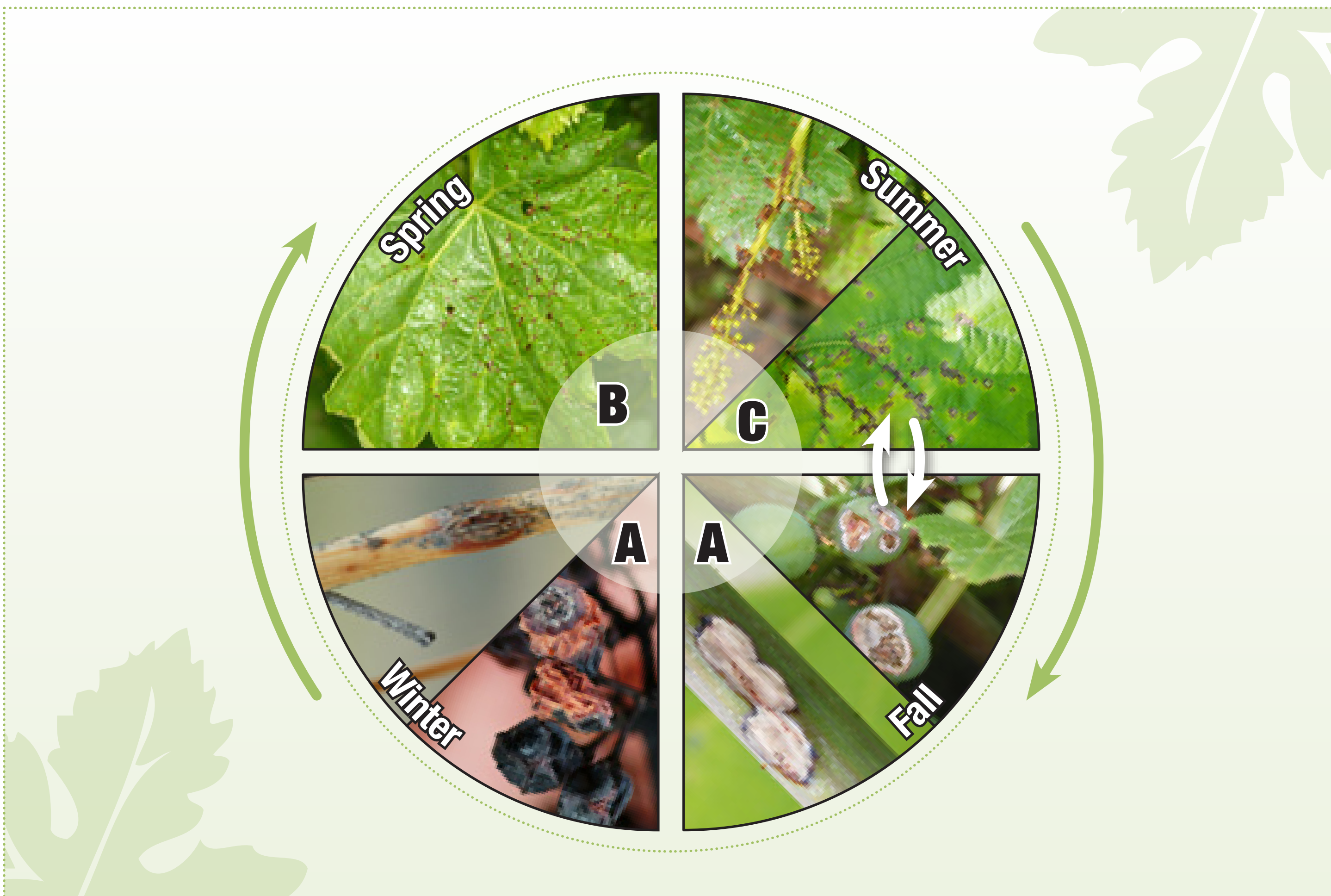
Anthracnose disease cycle

Winter • The complete life cycle of *E. ampelina* is not known. However, the fungus likely overwinters as sclerotia (compact mass of mycelium) produced in mummified berries and in cankers of young canes in late summer or fall, when the host tissue lignifies. **(A)**

Spring • Sclerotia produce spores that are released when temperatures are above 2 °C and after a rainfall of at least 2 mm. These spores will infect opening buds, leaves, wood and fruit, causing primary infections. **(B)**

Summer • Secondary infections are caused by spores produced on infected tissues early in the season (young shoots, tendrils, petioles, leaves and inflorescences), these spores spread by splashing rain. Symptoms appear 3 to 7 days after infection has occurred. **(C)**

Fall • Sclerotia are produced in mummified berries and in cane cankers. The sclerotia can remain viable for 3 to 5 years. **(A)**



Anthracnose management

Susceptibility • Young developing leaves and shoots along with Inflorescences are highly susceptible to anthracnose. Berries are susceptible to infection from initiation to veraison.

Critical period • From the first unfolded leaf (stage 7) to veraison (stade 35).

Infections • Temperature does not appear to be a limiting factor because infection can take place at temperatures ranging from 2 to 40 °C. However, the duration of wetness may limit infections. The minimum duration of wetness needed to cause an infection will vary with temperature.

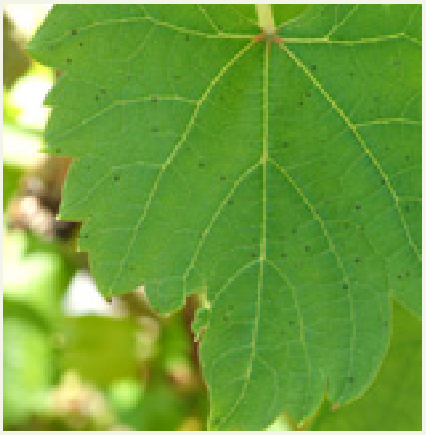
MEAN AIR TEMPERATURE (°C)	WET PERIOD DURATION REQUIRED FOR INFECTION (HOURS)
12	7 - 10
16.5	4 - 7
21	3 - 4
30	1.5

Preventive measures • Anthracnose management is required only on susceptible cultivars such as 'Vandal-Cliche' and during rainy seasons on moderately susceptible cultivars such as 'Prairie Star'. Anthracnose must be managed if it was present during the last 2-3 seasons.

Sclerotia responsible for primary infections in the spring overwinter in infected pruning debris; therefore it is important to remove them from the vineyard after pruning to reduce inoculum for next year. Avoid excessive growth by proper fertilization and keep weed populations under control.

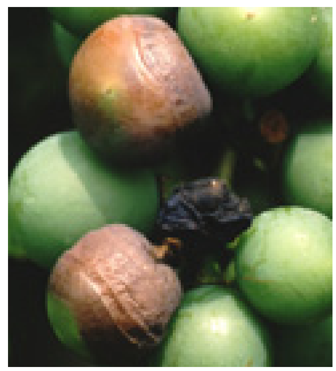
Management strategy • If anthracnose was present the previous season, primary infections could be limited by an application of Lime-sulphur at budbreak. The strategy for anthracnose management is based on a good control of leaf infections early in the season to avoid berry infections and cane cankers formation as much as possible. Stem cankers reduce vine vigor and they are sources of inoculum for subsequent infections throughout the season.

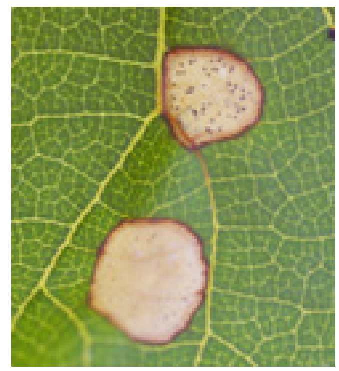
Anthracnose management in brief

SPRAY TIMING	REMARKS	CRITERIA FOR DECISION
BEGINNING OF TREATMENT 	Start scouting: **Stage 7.** Favourable conditions: Frequent rainfall. **Critical period:** **Stage (7) first unfolded leaf to veraison.**	**Anthracnose was present last season:** Apply a lime-sulphur based product at budbreak. Susceptible cultivars: preventive fungicide sprays starting with new growth Moderately susceptible cultivars: When lesions are detected in the vineyard **If rain is forecasted, spray before.**
OTHER SPRAYS 	Susceptibility remains throughout the season. The more frequent the rainfall, the greater the risk of infection.	Symptoms are present. Consider vine growth rate, mode of action and persistence of fungicide, and conditions during spraying.
END OF SPRAYS 	Scout for the presence of symptoms (mummified fruits and cane cankers). Older leaves are less susceptible but berries are at risk until harvest At the end of the season, remove cane cankers to reduce inoculum for the next season.	Susceptible cultivars: At harvest. Check with an œnologist for the effect of late fungicide applications on wine quality. Respect the pre-harvest interval recommended by the manufacturers (see labels). Moderately susceptible cultivars: Veraison if disease was not detected.

Black rot – *Guignardia bidwellii*

Black rot is a fungal disease native to North America caused by a pathogen called *Guignardia bidwellii.* The disease is generally more severe during wet spring weather conditions and periods of rapid vine growth. Black rot can infect berries and all new green tissues of the vine (leaves, petioles, shoots, and tendrils).

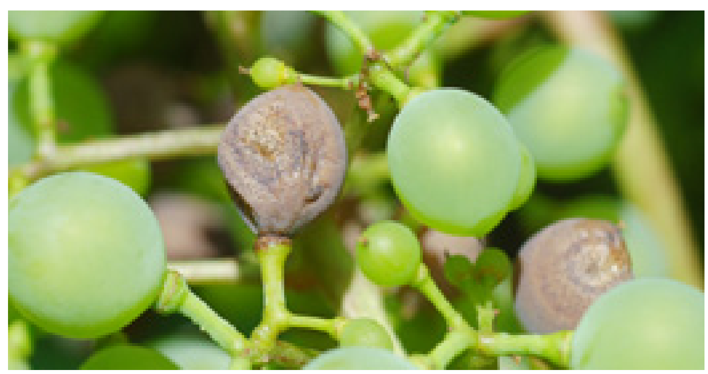


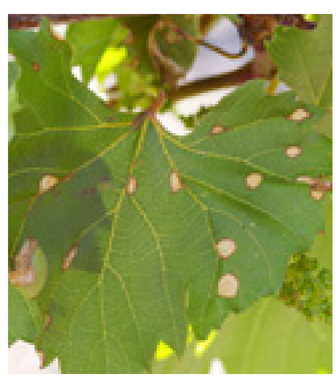


– Symptoms

On the leaves, *G. bidwellii* induce more or less circular spots of 2 to 10 mm in diameter, these lesions start appearing one to two weeks after infection has occurred. Lesions are light brown at first, than turn reddish with a ring of small black fruiting bodies (fungal sporulation), visible to the naked eye. Lesions are surrounded by a dark brown coloration. Cluster stem and pedicel, lesions are small and sunken. Black cankers may develop on stems.

The first symptoms on berries are small whitish dots surrounded by a reddish-brown halo, later infected berries become 'milky' and within a few days, the berries start to shrivel and turn into hard, blue-black commonly called mummies. Berries become resistant to infection about 3 to 5 weeks after bloom. If berries are infected when resistance is established, lesions remain localized.





Black rot disease cycle

Winter • The fungus overwinters as perithecia (fruiting body containing spores) on fruit mummies that remain inside the canopy or on the ground. **(A)**

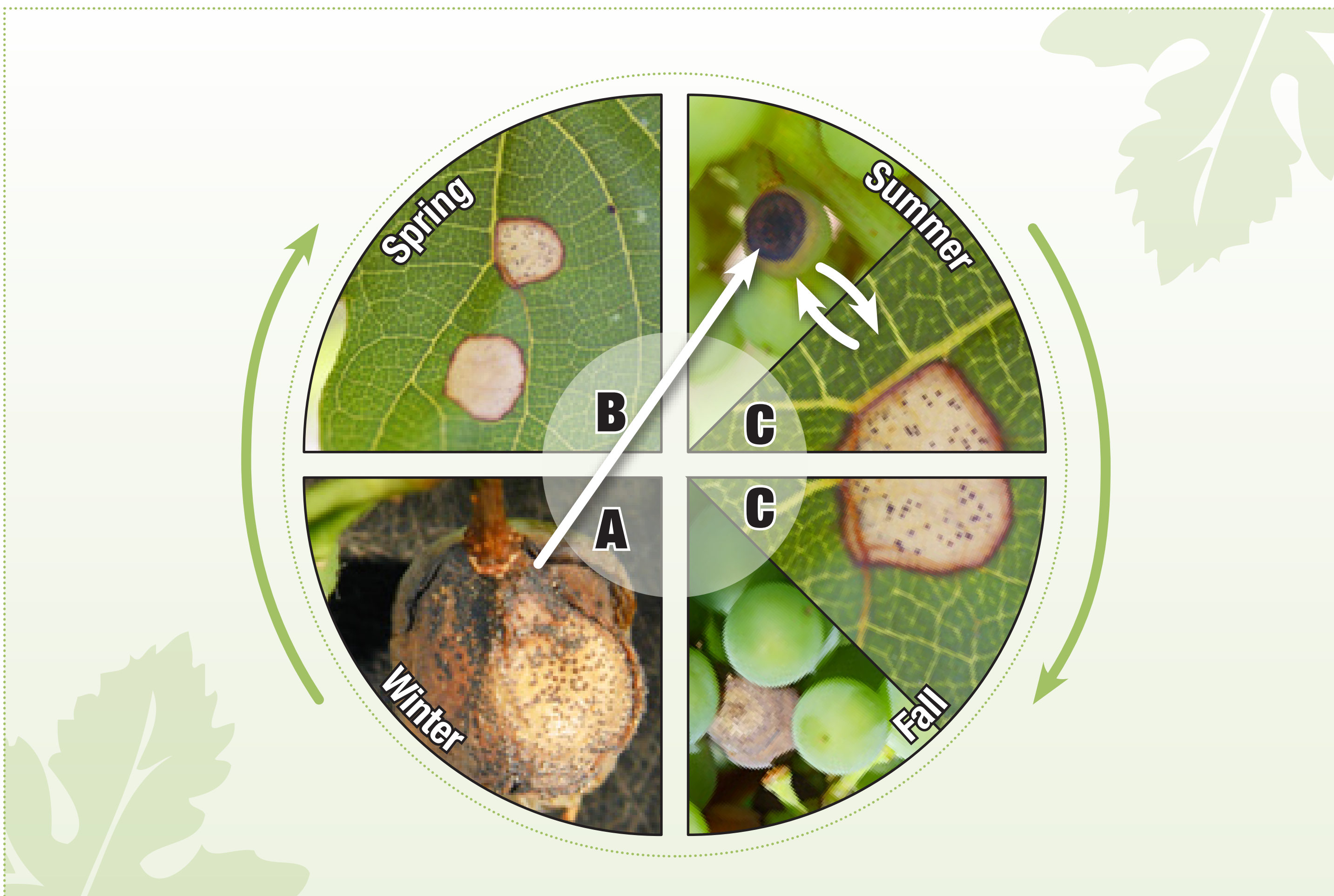
Spring • Spores (ascospores) are produced within perithecia and are dispersed by wind and rain. Perithecia start releasing spores shortly after bud break until about 2 weeks after bloom. These spores cause the primary infections. **(B)**

Summer • About 2 to 3 weeks after primary infections have occured, brown lesions with small fungal fruiting bodies (pycnidia) will appear. New spores (conidia) will be produced in these fruiting bodies and splashing rain will spread conidia onto leaves, stem, tendrils, inflorescences and berries causing secondary infections.

Under favourable conditions, it is possible that primary (caused by ascospores) and secondary infections (caused by conidia) overlap.

New spores will be produced following secondary infections and cause new infections. Under optimal temperatures of 20-25 °C, new lesions will appear in 5 to 7 days. **(C)**

Fall • At the end of the season, fruit mummies fall on the ground. Perithecia are produced in fruit mummies. **(C)**



Black rot management

Period of susceptibility • Young growing leaves are highly susceptible. Berries are susceptible from initiation to veraison (stade 35). Berries become resistant to infection about 3 - 5 weeks after bloom.

Critical period • From budbreak (stage 5) to veraison (stage 35).

Primary infections • Ascospores are released from budbreak to about 2 weeks after bloom. A minimum of 6 hours of wetness is required for primary infections to occur and as temperatures increase so does the risk of infection.

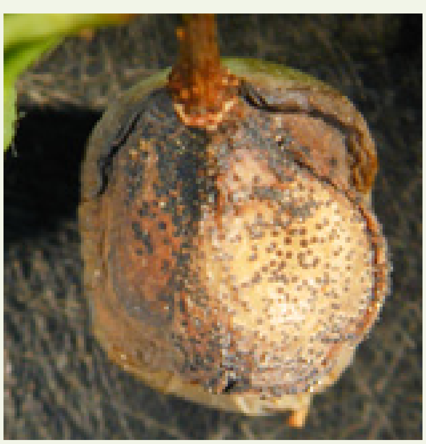
Secondary infections • Optimal temperature for infection is 27 °C (minimum of 9 °C and maximum of 32 °C). Severity of infections is influenced by the temperature during the wet periods and by the duration of the wet period (see table).

Preventive measures • Remove fruit mummies and infected pruning debris from the vineyard. Fruit mummies may be incorporated into the soil.

Management strategy • If black rot was present last season and frequent rains are forecasted, initiate a fungicide spray program at the green tip growth stage (stage 5). It is important to protect the vines from the beginning of flowering until cluster closure (stage 33), especially if lesions on leaves were detected in the vineyard (brown lesions). On moderately susceptible cultivars, fungicides used to manage downy and powdery mildew generally allow for a good control of black rot.

MEAN AIR TEMPERATURE (°C)	WET PERIOD DURATION REQUIRED FOR INFECTION (HOURS)
10	24
13	12
15	9
18	8
21	7
24	7
29	6
30	9
32	12

Black rot management in brief

SPRAY TIMING	REMARKS	CRITERIA FOR DECISION
BEGINNING OF TREATMENT 	Start of scouting: **Stage 5.** Favourable conditions: Temperature of 9 °C or above with wet periods lasting for at least 6 hours. **Critical period: budbreak (stage 5) to veraison (stage 35).**	Susceptible cultivars: Initiate the spray program if black rot was present last season and rains are forecasted. Moderately susceptible cultivars: After the first primary infections (symptoms are detected). **Spray before major rain.**
OTHER SPRAYS 	Berries are susceptible until about 3 - 5 weeks after bloom (berry touch). Risks increase with increasing temperatures from 9 to 32 °C and with duration of wet periods.	Symptoms are present in the vineyard. Consider vine growth rate, mode of action and persistence of fungicide, and conditions during spraying.
END OF SPRAYS 	Scout for the presence of inoculum (brown lesions with black spots). Berries are resistant after berry touch (stage 33). At the end of the season, avoid large amount of fruit mummies to reduce primary inoculum the next season.	Beginning of veraison in healthy vineyard (no new symptoms of black rot). Mid-veraison if symptoms were present but disease under control.

Crown gall – *Agrobacterium vitis*

Crown gall is caused by the bacterium *Agrobacterium vitis*, the pathogen is present in several vineyards and can be a serious problem because it is difficult to control. The bacterium is most probably disseminated in grapevine propagative material, and unfortunately there is no certification program to ensure that nursery stock has been tested and is free of bacteria.

– Symptoms

In general, crown gall is most severe in areas where winter injuries are common. *Vitis labrusca* cultivars are less susceptible than hybrids or *V. vinifera*.

Crown gall reduces vine growth, longevity, and yield of infected plants will depend on the severity of galling. Galls may girdle the trunk preventing the flow of nutrients to the vine. Infected vines are stressed and are more prone to winter damage.

In some cases, galls may affect only a portion of the trunk (cambium) and the vine will continue to produce berries. However, once a vine is infected, production of new galls will continue during subsequent years which will reduce vine growth. The bacterium responsible for crown gall survives in the soil and hence disseminated by machinery.

"In general, crown gall is most severe in areas where winter injuries are common."

Crown gall disease cycle

The causal agent, *Agrobacterium vitis*, is an opportunistic pathogen that attacks damaged cells. The bacteria can survive in the vascular system of the vine for many years without showing any symptoms until some cell damage occurs. The bacterium then invades plant cells associated with the plant's natural wound-healing process.

In early summer new galls are smooth and light brown, with age they hardened, turn dark brown, brittle and corky. In general, galls are seen on the lower parts of the vines near the ground.

"The bacteria can survive in the vascular system of the vine for many years without showing any symptoms until some cell damage occurs."

Preventive measures for crown gall

Development of crown gall is associated with winter injury and damage caused by machinery; hence, any cultural practice aiming at reducing winter injury will help manage the disease. Heavily diseased plants must be removed and replace with plants free of bacteria. Covering the lower part of the vine with soil will help protect new shoots from winter damage and help with trunk renewal. Begin monitoring for crown gall in lowers parts of the vineyard and in areas with poor drainage.

It is important to removed diseased plants because the bacterium can remain in decaying root pieces in the soil for several years and serve as a source of inoculum for new infections. When a vine is removed, make sure that all roots have been removed as well to avoid contamination of new vines.

"Covering the lower part of the vine with soil will help protect new shoots from winter damage and help with trunk renewal."

Crown gall management strategy

Since the bacteria survive in the vascular system of the infected vines, hot water treatment of vines before planting is an effective control measure. Since hot water treatments kill most but probably not all of the bacteria, it is not guaranteed that planting stock will be completely disease-free. Sensitivity to hot water treatment varies with cultivar. Sensitivity of cuttings to hot water treatments depend on when cuttings were treated during the dormant season.

"Hot water treatment of vines before planting is an effective control measure."

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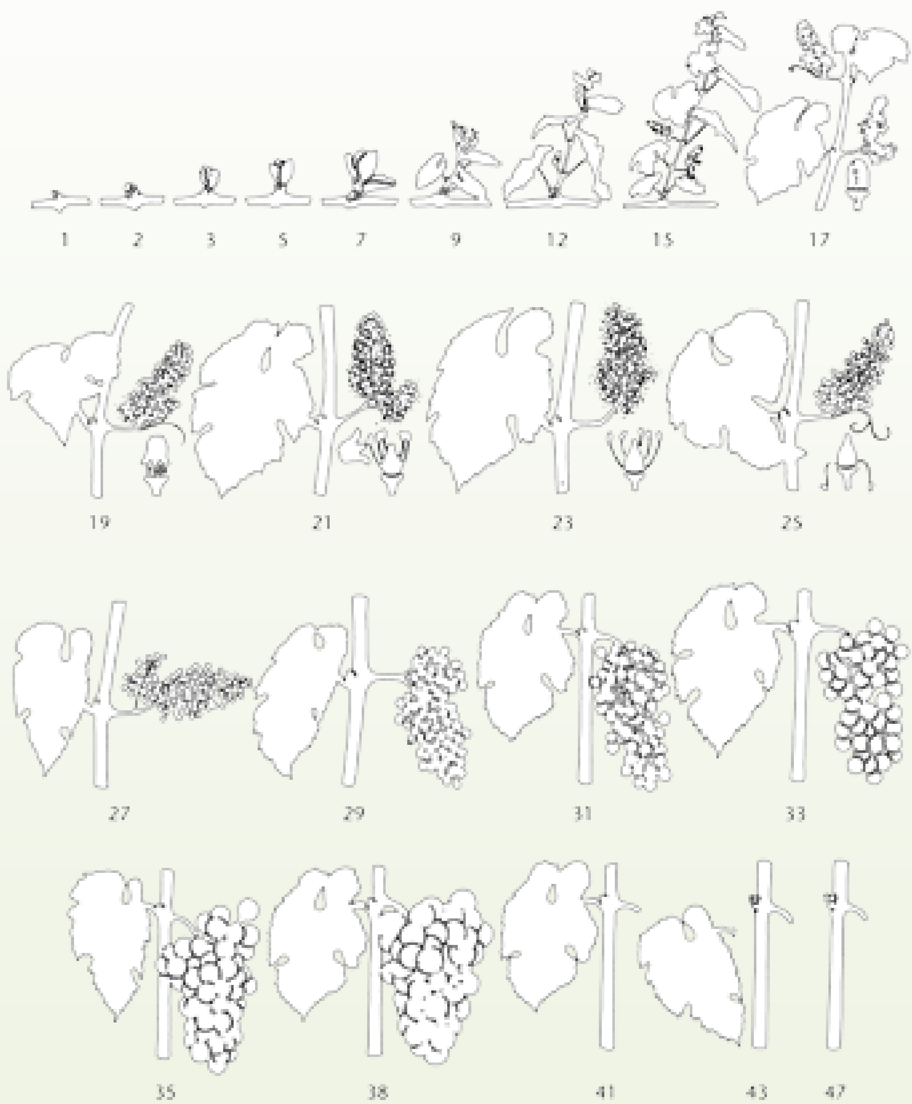
Phenological stages



1. Winter dormancy

2. Bud swelling

3. Wool (doeskin stage)

5. Bud burst

6. Green shoot

7. First leaf unfolded

9. 2 to 3 leaves unfolded

12. 4 to 6 leaves unfolded, inflorescence clearly visible

15. Inflorescence elongating; flowers closely pressed together

17. Inflorescence fully developed; flowers separating

19. Beginning of flowering; first caps falling

21. Early flowering; 25 % of caps fallen

22. Full flowering; 50 % of caps fallen

25. Late flowering; 80 % of caps fallen

27. Young fruits beginning to swell

29. Berries small; bunches begin to hang (4 - 6 mm)

31. Berries pea-sized; bunches hang (7 - 10 mm)

33. Beginning of berry touch

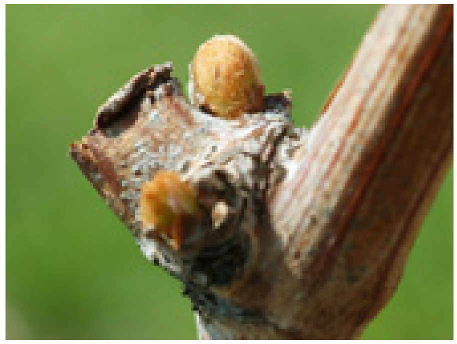
35. Beginning of berry ripening (veraison)

38. Berries ripe for harvest

Illustration adapted from Eichhorn and Lorenz (1977) and Lorenz (1994).
Please see photos on next pages.

– Phenological stages: photos

Stage 1 • Winter dormancy



Stage 3 • Wool (doeskin stage)

Stage 5 • Bud burst

Stage 6 • Green shoot

Stage 7 • First leaf unfolded

Stage 9 • 2 to 3 leaves unfolded

Stage 12 • 4 to 6 leaves unfolded, inflorescence clearly visible

Stage 15 • Inflorescence elongating; flowers closely pressed together

Stage 17 • Inflorescence fully developed; flowers separating

Stage 19-21 • Beginning of flowering; first caps falling - Early flowering; 25% of caps fallen

Stage 23 • Full flowering; 50% of caps fallen

Stage 25 • Late flowering; 80% of caps fallen

– Phenological stages : photos (cont'd)

Stage 27 • Fruit set; young fruits beginning to swell

Stage 29 • Berries small; bunches begin to hang (4 - 6 mm)

Stage 31 • Berries pea-sized; bunches hang (7 - 10 mm)

Stage 33 • Beginning of berry touch

Stage 35 • Beginning of berry ripening; if it applies, beginning of loss of green color (veraison)

Stage 38 • Berries ripe for harvest