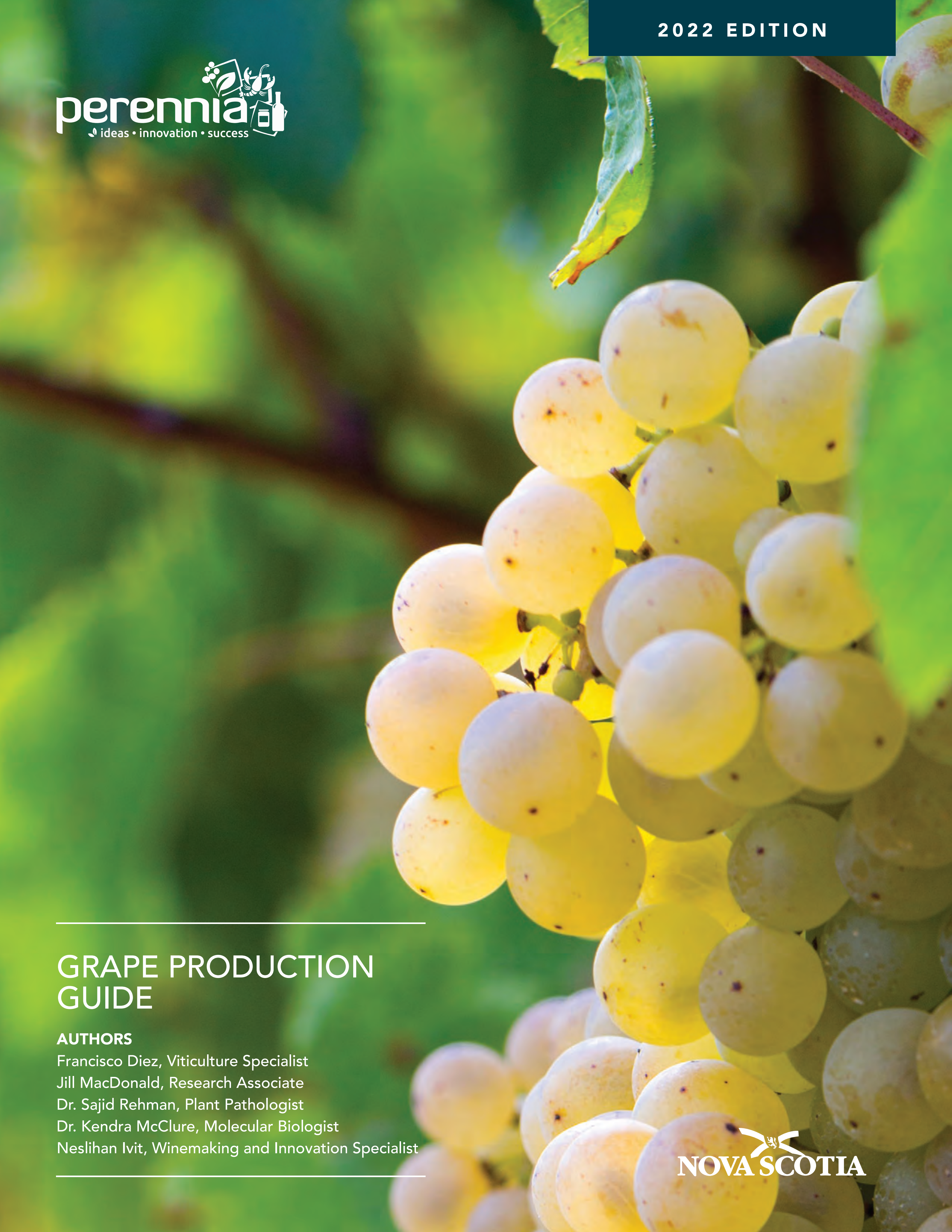

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GRAPE PRODUCTION GUIDE

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NOVA SCOTIA

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1.0 SITE SELECTION

Nova Scotia, the land of the highest tides in the world, is a cool climate wine region, which is at the limit of climatic conditions for growing grapes for wine production. Therefore, it is very important to pay attention to the details of site location for future vineyards. Planting a vineyard requires a large investment, and a poor decision during this process can have a long-lasting effect on the expected life span of the vines, yields and quality. In this chapter, the main parameters that should be considered when selecting a vineyard site will be explained.

1.1 SITE ORIENTATION AND TOPOGRAPHY

When making a site selection for a new vineyard, there are many things to be considered and taken into consideration. Two factors that are quite influential to the site would be the elevation and slope of the chosen land; these are factors that add to the success of a site and are more challenging to modify. There are two different definitions to consider when it comes to discussing elevation. The first definition refers to the elevation in a certain location when comparing the difference between the highest point to the lowest point. In contrast, absolute elevation considers the feet above sea level. When considering where to place a new vineyard plantation, it is important to locate a high point, as this will contribute to improved air and water drainage. Air drainage is relevant when it comes to frost and freeze episodes. Where cold air is denser, it will settle in areas with lower elevation. Elevation also promotes improved water drainage, which will improve the quality of the soil. When standing water exists in the vineyard, it can inhibit air and oxygen from being available to the root system; grapevine roots do not thrive when they are saturated with water.

When you choose a site, the slope is also very significant; slope refers to the degree of inclination of the land; between the high and low point. As the land inclines, so does the degree of cold air drainage, which is a necessary consideration in colder climates as they are more prone to spring frost events. An important factor to consider when it comes to the considerations of slope is the type of machinery that will be used on-site. Extreme slopes can make it dangerous for machinery to operate, and it can add to the degree of soil runoff and erosion that could occur.

1.2 CLIMATE

Average weather conditions in an area are known as the climate. There are three components to the climate that must be considered: microclimate, mesoclimate and macroclimate. Macroclimate refers to the climate of a large region, spanning over many square kilometres. Mesoclimate refers to the climate of a particular vineyard site or location, whereas microclimate is specific to the small area surrounding the vineyard canopy itself, both of which areinfluenced by vineyard management practices. It is typical for vines to be grown in areas that sit between latitudes of 30˚ to 50˚. These areas correspond to average annual temperatures of 10˚C and 20˚C. When the mean temperature falls below 10˚C, it means the growing season is very short, and the winters are very cold.

1.3 MINIMUM TEMPERATURE

Minimum winter temperature is a crucial factor when choosing a growing area and grape variety to be planted. Critical temperatures define where perennial crops, such as grapes, can be grown; these critical temperatures can also occur in areas where they weren't once expected. Grapes are a moderately hardy crop, though they are the most cold-sensitive within the temperate fruit family. Permanent parts of the grapevine can be damaged or even killed by sub-freezing temperatures. Winterkill is dangerous because the entire plant can be killed by the temperatures and will need to be replanted, adding a significant operation cost. Spring freezes cause damage to the emerged buds and shoots, therefore causing losses in fruit quantity and quality. The number of critical temperature events can be obtained by observing historical climate data. Hybrid cultivars exposed to temperatures below -15˚F or -26˚C may experience 50% primary bud injury and potential injury to the cane, trunk and cordons. It's important to note that cold hardiness varies greatly between varieties. These need to be chosen carefully according to the climatic conditions in your area. Some hybrid varieties have been bred to have a higher cold tolerance threshold; they have a higher chance of survival in areas where *Vitis Vinifera* will be too cold in the winter.

1.4 LENGTH OF GROWING SEASON

The duration of the growing season is critical when making a site selection. It's also important to consider variety choice, as several varieties require a longer season to reach peak maturity. The number of Frost-Free-Days (FFD) is the length of time between the last spring frost and the first killing fall-frost. Generally, grapevines require between 150 FFD for early ripening varieties and above 190 FFD for late varieties. Growing Degree Days (GDD) is a calculation of the accumulation of heat through a growing season. It is important to note that when comparing GDD units, one must pay attention to the temperature units used. GDD reported in Fahrenheit or Celsius will result in different values. The GDD base temperature is 10˚C; therefore, the daily maximum temperature minus 10˚C results in the GDD units for that day; 10 degrees is chosen as the minimum because insignificant vine growth occurs below this temperature. Growing degree day units can be used to compare seasons from one to the other, compare different growing regions, and predict important growth stages in the vine development. Growing degree day theory was developed by Amerine and Winkler, where they intensively studied the correlation between the sums of temperature and grape phenology. They were able to break the grape-growing regions up into five sections, according to their climatic conditions from April 1st to October 31st; those regions are as follows:

REGION	GROWING DEGREE DAYS VALUE
I	<1390 (cool)
II	1390-1667
III	1667-1945
IV	1945-2220
V	>2220 (very hot)

1.5 PROXIMITY TO BODIES OF WATER

Here in the Mid-Atlantic, our climate is greatly influenced and moderated by the Atlantic ocean, which also effects areas like New York and the Hudson Valley. Large bodies of water can increase the temperature of the air moving over them indirectly and create clouds overhead. Large bodies of water can help regulate the surrounding temperatures and wind conditions, which can be beneficial in lessening frost damage to the vines. By regulating the air temperatures, the water bodies can prevent the surrounding air from becoming frigid in the wintertime; vineyards close to water can be more protected from winter damage. Large lakes also contribute to the success of a vineyard planting. These large bodies of water can retain heat, therefore giving warmth to the surrounding land. The heat coming from the lake can help prevent roots from freezing during the winter and aid in preventing significant spring frost damage to the vines. The warmth provided by the lakes prolongs into the fall, keeping the air temperature warmer and allowing the vines more time to ripen the fruit.

1.6 SOIL CHARACTERISTICS

When considering a site for grape-growing, it is crucial to know and understand the soil foundation you will be planting into. Soil plays a large role in the vineyard's success as it controls factors such as water movement, drainage and nutrient holding capacity. Optimal vineyard soil will promote good water drainage and root movement through the ground, the most important physical property of soil. Drainage is a consideration that must be evaluated prior to planting the vineyard. If a site does not have adequate drainage, then tile drainage should be properly installed. When a new site is being considered for planting, it is a good idea to have a site assessment done of the area. Grapevines do not survive or thrive in areas where there is standing water for extended periods, often leading to root rot. A site assessment and soil pit will determine the type of soil in the field. Soil texture is made up of several components: clay, silt and sand, to name a few. Clay will increase the water and nutrient holding capacity, while silt and sand will diminish them; it is good to have a combination soil for optimal conditions. Site assessments or probe tests will check if compaction exists in the soil. Compaction, when severe enough, can block roots from successfully establishing and growing. Compaction can also prevent water from draining through the soil profile and inhibit the movement of nutrients.

Organic matter in the soil adds to the structure, porosity (water movement), structure and moisture. Organic matter provides a valuable slow-release form of nitrogen to the plant. The desired range for vineyard organic matter is between 2-3%, any greater than this can be negative for the plant and provide excessive nitrogen. Soil pH is a measure of the acidity of the soil. Higher pH values are a positive attribute to the soil because it increases the fertilizer use efficiency, meaning that more of the applied nutrients will be absorbed and used by the soil to feed the plant. Both of these soil characteristics can be evaluated by doing a pre-plant soil sample. Changes to the soil fertility and pH can be made before planting, and it is recommended to do so. Lime is a common soil amendment applied to increase the soil pH as well as calcium or magnesium, depending on the type of lime used, calcitic or dolomitic.

1.7 PRECIPITATION

When considering a new site for grape production, it's important to look at the precipitation records. Inadequate rainfall can cause adverse growing conditions, especially in sites where irrigation is not possible. Comparatively, too much rain, especially at the wrong time, can cause a lot of damage. The optimal annual rainfall amounts fall between 500mm-800mm. Rainfall is needed most at certain times during the growing season. Grapevines require approximately 150mm-300mm of rain during the winter months to accumulate moisture in the soil. Then they need approximately 250mm-350mm to continue with their vegetative growth. When there is inadequate rain in the summertime, the growth of the vines can be limited and cause less vigour in the plants. An excess of rain near harvest time can cause the berries to grow too fast and split, leaving ideal conditions for fruit rot and disease to develop. Some seasons see little to no rain when grapes are filling out and gaining weight. This causes adverse effects with sugar and acid, as well as undersized berries.

2.0 SOIL PREPARATION

Once the area for a future vineyard has been evaluated to determine what is needed for the proper establishment, it’s time to prepare the soil for planting. Grapevines are perennial plants; therefore, the vineyard will need a good foundation in the soil to achieve the best possible growth and productivity over time. At this stage, crucial modifications can be made that greatly affect the future of the vineyard, such as land cleaning, drainage and increases to soil pH by liming, to mention a few. It is recommended to evaluate by soil sampling before the work begins. After the soil amendments have been applied and time has passed, it will be necessary to re-test the soil; this work should be taking place at least one to two years before the grapevines are planted.

After choosing the area for the future vineyard, consider the following five points for soil preparation.

2.1 TILLING

Tilling is a process in which the soil surface and sub-surface get broken up with a tractor implement. This process is very important, regardless of the history of the land that will be used and if it was in agriculture production in the past. These renovation activities would be ideally done at least one year before planting the vineyard. The soil activities can be plowing, sub-soiling, disking or rototilling, the objective is to leave the best possible conditions to allow for proper grapevine establishment.

One of the first tasks to prepare the area is to clear the soil surface, especially if there are trees, bushes, rocks and other types of impediments. In the case of having compaction through the soil profile (this part can be detected through the site study before deciding if the site accomplishes the minimum requirements), it would be recommended to break up the compaction layer. The level of compaction can be shallow or deep, depending on where the limited layer in the soil profile is located. The compaction can be destroyed by a chisel plow or a sub-soiler to go deep enough into the soil profile. When using a sub-soiler, this should be performed when the soil is dry or as dry as possible to break up the problematic layers. Eliminating the compacted layer will allow the proper root system development, improve the soil drainage, amend the soil aeration, and improve the availability of moisture and nutrients to the plant. The plowing can be done to turn over the vegetation or prepare the first layers and incorporate lime and nutrients into the soil.

Ideally, the heavy soil preparation work should be done a year before the vines are due to be planted; sometimes, more time is required if the soil levels need significant increases. There needs to be adequate time to properly complete the activities and work more soil amendments in, ifnecessary. They require time to begin increasing pH and soil nutrient levels. Only the row marking should be completed before establishing the vines.

2.2 pH

The soil samples for potential corrections should start at least one year before planting and even earlier if possible. In the case of pH, its modification is a slow process, and through the soil profile, it will be even slower to achieve the ideal values. pH is a scale from 0 to 14, where seven is the neutral value, while above seven will be alkaline or basic and below seven will be acidic. In the case of grapevines, the ideal values are between six to seven (please refer to the table). This range will provide a good availability of nutrients for further uptake by the plant.

GRAPE TYPE	TARGET SOIL pH RANGE
American (e.g., Concord, Catawba, Niagara, Delaware)	5.5 - 6.0
Hybrids (e.g., Cayuga White, Seyval, Corot Noir, Marechal Foch)	6.0 - 6.5
Vinifera (e.g., Riesling, Cabernet Franc, Chardonnay, Pinot Noir)	6.5 - 7.0
Source: 1-year Pre-plant · Site Preparation, Cornell Cooperative Extension	

Changing the soil's pH through the whole soil profile at once is not possible. It will require time for the soil amendments to be taken in by the soil. To accelerate the process, plow the area to incorporate the amendment. This labour must be done ahead of time without having the vines nor trellis system in the ground to facilitate the movement of equipment; therefore, this should be done before planting. It is strongly encouraged to make these additions to the soil well in advance of planting as sometimes, soil amendment availability and the equipment to spread it and incorporate can be limited. It is worth the time to wait and create the best possible foundation for the vines, as they will be planted for a long time, and it's crucial to give them a good establishment.

In general, Nova Scotia soils are acidic with low pH values. In most cases, if the land has just been cleared of woods, it is typical to have pH values less than five. In this case, increase the values by applying lime to the soil and after their incorporation to the soil profile through plowing the area.

Two lime options are available:

- **Calcitic:** this lime has a big percentage of calcium carbonate and a small proportion of other minerals.
- **Dolomitic:** lime with calcium and magnesium. This can be helpful to increase the levels of magnesium where necessary.

As mentioned above, the applications of lime must be planned with time ahead before the vineyard will be planted, at least one year in advance. It takes at least six months for the lime to begin working in the soil; multiple applications may be required if the starting pH is very low. If the test recommends adding high amounts of lime, and time is not an issue, it might be preferable to split the application over two years.

2.3 ORGANIC MATTER

Organic matter is formed by the breakdown of plant and animal material. It has important roles in the soil, such as improvement of soil structure, allowing a good air and water flow through the profile, increasing the water holding capacity, facilitating the root system growth and can be a good source of nutrients. Having good levels in a future vineyard will allow the proper establishment and plant development. The following table shows recommended values of soil organic matter from the literature.

% ORGANIC MATTER	NOTES
<1%	Not recommended without substantial addition of nutrients and mulch or compost. It may be acceptable with intensive drip fertigation (drip irrigation with added fertilizer).
1-2%	Marginal, may be ameliorated with mulch or compost and fertilizer additions, but large amounts
2-4%	Generally, the best range as fertility is adequate but not excessive.
>4%	It should be analyzed for wine grapes; may be acceptable for native juice grapes.
Source: The basics of Vineyard Site Evaluation and Selection	

Having the proper value of organic matter will bring many benefits, including improved soil structure, improved air and water infiltration, provide nutrients and resists compaction. However, when values are too high, it can be disadvantageous because the plants will be too vigorous, which can impact the production and quality of the crop. On the other hand, when the values are too low, the plants can be more susceptible to water stress or lacking water, and the soil can be prone to compaction. The levels can be increased with the application of compost, pruning wood, grape pomace and cover crop into the soil. It's highly recommended to have the soil protected with a cover crop or mulch to reduce the risk of soil erosion and loss of organic matter; these risks are higher in wet seasons that bring heavy rain and snow.

2.4 TILE DRAINAGE

Removing the excessive amount of water from the soil profile is important for proper root development and diminishing anaerobic conditions. Two parts should be considered; moving the excess of water from the surface and from in the subsurface, and for the latter, tile drainage is necessary. Tile drainage is one of the crucial preparations. It should be designed and installed before planting. It's important to highlight that the drainage will remove the excess amount of water, but the soil characteristics, such as soil water holding capacity, will not be modified. Therefore, this is not going to lead to drought stress.

Sub-soil drainage is the installation of perforated plastic pipe, called drain tile, at specific depths, depending on the conditions of the site. Tile drainage theory recommends a perpendicular installation to the slope. This way, the gravity will feed the pipe vertically and horizontally. However, in many cases, the tiles are parallel to the rows. This practice will be practical to avoid damage at the time of post-installation. Most drainage tiles are continuous plastic perforated with a diameter of 50 mm, 75 mm or 100 mm, depending on the situation and the engineer's recommendation. In some cases, it will be installed in a nylon sleeve to prevent any foreign materials from getting inside.

2.5 COVER CROP

After all the soil preparation, the most likely situation is that the property's surface will be clean, with minimum vegetation or even bare. Establishing a cover crop before planting the vineyard can bring benefits, such as: reducingsoil erosion, runoff and dust, suppressing weed development, improving the soil structure and increasing biological activity through the soil profile.

One of the most important benefits from those previously mentioned will be the reduction of erosion (especially in sites with a slope) and the control of weed growth. Due to the soil renovation activities of preparing a site for planting, it is very common for there to be bare soil. Bare soil is very susceptible to erosion because of a lack of root mass to give it a foundation. Soil loss can also happen due to hard rain droplets that displace the soil particles. Sowing cover crops will diminish the re-establishment of the weeds, which are desired to be kept in low numbers to allow the proper vine growth. Depending on the time of year (spring or fall), cover crops will grow better under the local conditions. This is something to keep in mind when deciding on the type of seed to purchase. Some common cover crops used in the province are: clover (red, white, crimson), fescues (tall, creeping red), ryegrass, forage radish, etc., and these can be applied in different mixtures and combinations.

3.0 VARIETIES

In Nova Scotia, both interspecific hybrid grapevines and Vitis vinifera, know as European or vinifera grapes, varieties are grown. Interspecific hybrid grapevines were preferred due to their adaptability to the local conditions, especially during the first years of the industry. They were followed by Vitis vinifera varieties that have been increasing steadily the last 20 years. The province's best areas typically have minimum temperatures above -23°C and a growing season with above 1,000 Growing Degree Days (GDD) and minimum 150 Free Frost Days (FFD). Successful varieties must be hardy enough to survive through the winter, in addition to being able to ripen the fruit in a short growing season.

This section covers some of the most planted hybrids and Vitis vinifera varieties according to the information collected by AAFC through the 2018 season. Hybrids and Vitis vinifera have been divided into white and red varieties, and differences between them were highlighted. In this section, it's important to mention that rootstocks used in the province were not defined. However, they are highly recommended due to the presence of Phylloxera in our vineyards. One of the most popular rootstocks between growers is 3309, which has shown positive results in our local conditions, but other rootstocks are available.

In this section, the varieties currently grown in Nova Scotia with positive results will be outlined in terms of acreage in the province, origin (especially in the case of hybrids) and main plant characteristics, such as cold hardiness, shoot growth and grape characteristics.

3.1 WHITE HYBRIDS

3.1 WHITE HYBRIDS

3.1.1 L'ACADIE BLANC

The most planted grapevine in Nova Scotia, with a surface of approximately 160.36 acres or 64.89 hectares. This variety is characterized for its versatility in wine production, both for sparkling and still wine.

Origin

This variety was breaded in 1953 by Ollie A. Bradt in Vineland, Ontario, Canada. To obtain L'Acadie, Cascade x Seyve-Villard 14-287 were used and coded under the number V 53261. The origin of its current name comes after some cuttings were sent for trials to the Kentville Research Center, where it was named in reference to the French settlers in Nova Scotia, the Acadians. L'Acadie is a combination of *Vitis riparia*, *Vitis labrusca*, *Vitis vinifera*, *Vitis aestivalis*, *Vitis lincecumii*, *Vitis rupestris*, V*itis cinerea* and *Vitis berlandier*i hybrid.

Main characteristics

Its cold hardiness is superior compared to other hybrids, such as Seyval blanc, supporting down to -22°C, and some literature says even to -25°C. It presents more resistance to diseases. It's a vigorous plant with an upward shoot growth, which facilitates the labour of tucking through the season. Fruit is early to mid-ripening, and the bunches are loose. The latter characteristic helps prevent botrytis bunch rot, and the berries are golden with some reddish hints. According to the literature, it can produce in a short growing season (138 FFD) and low heat units (964>HU).

Figure 1. L'Acadie blanc

3.1.2 NEW YORK MUSCAT

This interspecific hybrid, also known as NY Muscat, is the second most planted grapevine in Nova Scotia, with approximately 72.02 acres or 29.14 hectares, according to data from 2018. With its characteristically Muscat aroma, it's often part of different wine blends.

Origin

It was bred in 1926 by Richard Wellington at Cornell University, US, and presented in 1961. For this hybrid, Muscat of Hamburg x Ontario hybrid were used. It's a combination of Vitis labrusca and *Vitis vinifera* hybrid.

Main characteristics

According to Cornell University, its cold hardiness on a scale from one (being too tender) to six (very hardy) corresponds to a four (moderately hardy). It has slight susceptibility or sensitivity to Downy Mildew and Crown Gall. Moderately vigorous, its shoots tend to grow with facility downwards. It has an early to mid-ripening, it has large and very loose bunches, and its berries are big with reddish-blue colours. In terms of production, yields can be inconsistent over time.

Figure 2. New York Muscat

3.1.3 SEYVAL BLANC

A very popular variety of French hybrid for cool climates, especially in the northeastern US. In our province, it has the eighth position of surface with 30.18 acres or 12.21 hectares. Their acreage has been decreasing steadily in its country of origin, moving from 3,235 acres (1,309 hectares) in 1958 to 274 acres (111 hectares) in 2008.

Origin

It was bred by Bertille Seyve and Victor Villard in Saint-Vallier, France, crossing Seibel 5656 x Rayon d'Or. Its name is coming from the contraction of Seyve and Vallier.

Main characteristics

Iowa State University reports that this variety is moderately hardy (-23 to -25°C). Related to pests and diseases, it's highly susceptible to Botrytis bunch rot, Powdery Mildew and Black rot and moderately susceptible to Downy Mildew. It is not sensitive to injuries from sulphur but may be sensitive to copper under cool and slow drying conditions. It is moderately vigorous, with a semi-upright growth habit, buds break early and fruit ripens early as well. It's clusters are large and compact, berries are small, round, and the colour is golden yellow with dull bloom. It tends to over produce, cluster and shoot thinning are recommended practices.

Figure 3. Seyval blanc (courtesy of **www.winesofcanada.com**)

3.1.4 VIDAL BLANC

Usually shortened as Vidal, it's probably one of the most popular French hybrid grapes used for ice wine production in Canada. Provincially speaking, the variety embraces 24.6 acres or 9.95 hectares.

Origin

Jean-Louis Vidal bred this hybrid in the '30s by crossing Trebbiano Toscano x Rayon d'Or to produce a suitable variety to produce Cognac in Charente-Maritime. However, this variety is not authorized in France.

Main characteristics

It's moderately winter-hardy, according to the Midwest Grape Production Guide, its winter hardiness is between -10 to -20°F. It is moderately susceptible to Downy Mildew and Crow gall, and it's highly susceptible to Powdery Mildew. Concerning Anthracnose and Botrytis bunch rot, it has slight susceptibility. Budbreak is late and requires the warmest areas as the ripening occurs later as well. It tends to over crop, which makes bunch thinning an option in some cases. The bunches are large, compact and have small berries.

Figure 4. Vidal blanc (courtesy of **www.winesofcanada.com**)

3.1.5 GEISENHEIM 318

Such as the previous hybrids, this grapevine is popularly known as Geisenheim. Originally from Germany, in Nova Scotia, the acreage is approximately 32.74 acres or 13.24 hectares.

Origin

This interspecific hybrid was bred in Germany at the Geisenheim Research Institute (Rheingau) in 1957 by the cross of Riesling with Chancellor.

Main characteristics

This grapevine is moderately winter hardy, rating eight out of ten according to some nurseries. It is susceptible to Downy Mildew and generally has a good resistance to Powdery Mildew. Also, it's susceptible to leaf burn from copper foliar applications. It has early to mid-ripening grapes. Their aromas are neutral, lightly flowery, and spices with a slight hybrid aroma.

Figure 5. Geisenheim 318 (courtesy of **www.winesofcanada.com**)

3.1.6 FRONTENAC BLANC

This is one of the popular hybrids related to Frontenac noir and Frontenac gris from the University of Minnesota. In Nova Scotia, the acreage is approximately 17.21 acres or 6.96 hectares.

Origin

This interspecific hybrid is a mutation of Frontenac gris, and it was first observed in Quebec in 2005. This mutation likely took place in several vineyards in Canada and Minnesota at the same time.

Main characteristics

It's quite winter hardy, rating ten out of ten according to the information from nurseries. Like its relatives, Frontenac noir and gris, it's productive and moderately high vigorous. Related to pest and disease, it's moderately susceptible to Powdery Mildew and foliar Phylloxera, and it has low to moderate susceptibility to Black rot and low susceptibility to Downy Mildew and bunch rot. Frontenac has early bud break and bloom, and it's typical to find three clusters per shoot, cluster thinning would be recommended. Clusters are loose medium size, and the berries are small to medium.

Figure 6. Frontenac blanc (courtesy of **www.winesofcanada.com**)

3.2 RED HYBRIDS

3.2.1 MARÉCHAL FOCH

This hybrid is quite popular and very successful in cooler areas of Canada and the US. In Nova Scotia, it is the most planted red interspecific hybrid with 47.15 acres or 19.08 hectares.

Origin

It was bred in 1911 by Eugene Kuhlmann in Colmar, France, crossing Millardet et Grasset 101-14 OP with Goldriesling. However, a consensus of the crossing doesn't exist. Some argued that it's Oberlin noir (Oberlin 595) Pinot noir hybrid, while others suggest it's Oberlin x Knipperle hybrid or Oberlin x Goldriesling hybrid. The name is in honour of Maréchal Ferdinand Foch, a general in the French army during the First World War.

Main characteristics

The literature describes this hybrid from low to highly vigorous. Their winter hardiness is very hard to about -32 °C, and bud is out early in the season. Related to diseases, it's highly susceptible to Eutypa Dieback, moderately susceptible to Anthracnose, Black rot and Powdery Mildew and slightly susceptible to Botrytis and Downy Mildew. The literature reported a sensitivity to Sulphur applications and suggested it's not prone to injuries from Copper. Bunches are short, cylindrical and tight; meanwhile, the berries are small, dark blue and round.

Figure 7. Marechal Foch (courtesy of **www.winesofcanada.com**)

3.2.2 MARQUETTE

This is a very cold-hardy hybrid from the University of Minnesota, cousin of Frontenac. It has become popular in areas with harsh winters. In our province, the acreage is around 26.05 acres or 10.54 hectares.

Origin

The original name is MN 1211. It was created in 1989 by Peter Hemstad and James Luby at the University of Minnesota's Horticultural Research Center by crossing MN 1904 and Ravat 262. This variety is the grandchild of Pinot noir and related to Frontenac, which makes this variety quite complex. Marquette's name was assigned in 2005 after Pere Marquette, a Jesuit missionary from the seventeenth century.

Main characteristics

According to the literature, its cold hardiness is very hard until -20 to -30°F (-29 to -34°C). Bud break occurs early in the season, it's moderately vigorous, and their secondary shoots are moderately productive. It has a low susceptibility to Black rot, bunch rots, Downy and Powdery Mildew. However, it's moderately susceptible to foliar Phylloxera, while Crown gall has not been observed. Bunches are small to medium size; the berries are small to medium size with dark skin.

Figure 8. Marquette (courtesy of **www.winesofcanada.com**)

3.2.3 LÉON MILLOT

This interspecific hybrid is originally from France and related to Maréchal Foch. It's quite popular in regions with cold winters and with short growing seasons. Nova Scotia has an acreage of 34.25 acres or 13.86 hectares.

Origin

Similar to Maréchal Foch, it was bred by Eugene Kuhlmann in Colmar in 1911 crossing Millardet et Grasset 101-14 OP with Goldriesling. The name is after Léon Millot, president of the Société Vosgienne de Viticulture.

Main characteristics

It's a cold-hardy (-15 to -20°F), with early bud break and early ripening. This grapevine is quite vigorous, and its secondary shoots are productive, similar to Maréchal Foch, but it tends to be more vigorous and productive. As for pests and diseases, the literature is not clear on its characteristics. According to the Midwest Grape Production guide from Ohio State University, it's highly susceptible to Powdery Mildew, moderately susceptible to Downy Mildew and slightly susceptible to Black rot, Botrytis and Phomopsis. Bunches are small, winged and loose, while the berries are small, round, juicy, with a dark colour.

Figure 9. Léon Millot (courtesy of **www.winesofcanada.com**)

3.2.4 LUCIE KUHLMANN

Like Maréchal Foch and Léon Millot, this interspecific hybrid comes from France and is planted mainly in Canada. Provincially speaking, the acreage is around 27.17 acres or 10.99 hectares.

Origin

As its siblings, Maréchal Foch and Léon Millot, it was bred by Eugene Kuhlmann in Colmar in 1911 crossing Millardet et Grasset 101-14 OP with Goldriesling. The name is in honour of the wife of the breeder.

Main characteristics

Its winter hardiness rates ten out of ten according to a nursery. It's a vigorous variety, compared to Maréchal Foch, earlier ripening and more productive. Suited to cooler climates with short growing seasons. Its bunches are tight and medium-sized. It shows some susceptibility to Bunch rot and Powdery Mildew.

Figure 10. Lucie Kuhlmann (courtesy of **www.winesofcanada.com**)

3.2.5 BACO NOIR

A French interspecific hybrid, it was widely planted in different regions, but is not included in the list of authorized varieties in France. Currently, it is planted mainly in North America. In Nova Scotia, the acreage is 16.77 acres or 6.78 hectares.

Origin

It was bred in 1902 by François Baco in Landes, it's the cross between of Folle Blance and *Vitis riparia* Grand Glabre. However, some researchers suggest the cross of Folle Blance x *Vitis riparia* Grand Glabre x *Vitis riparia* ordinaire. It has been known as Baco noir since 1964.

Main characteristics

It's moderately winter hardy, very vigorous, with early bud break and early ripening. Concerning pests and diseases, it's highly susceptible to Black rot and Crown gall, moderately susceptible to Botrytis and Powdery Mildew and slightly susceptible to Anthracnose, Downy Mildew and Phomopsis. According to the literature, it is not prone to Sulphur injuries and unknown to Copper. The bunches are small to medium and compact. The berries are small, round and have black skin.

Figure 11. Baco noir (courtesy to **www.winesofcanada.com**)

3.2.6 CASTEL

This French American interspecific hybrid has limited use in BC, and in Nova Scotia, the acreage is 12.16 acres or 4.92 hectares.

Origin

It was bred by Pierre Castel in France, crossing Cinsault and *Vitis rupestris*. It was quite common in Burgundy, nowadays it has a big presence in Canada.

Main characteristics

According to some websites, their winter hardiness can be quite low, down to -30°C. It has some resistance against Downy and Powdery Mildew. It's an early vine, producing high crops and ripening, similar to Léon Millot.

Figure 12. Castel (courtesy of **www.winesofcanada.com**)

3.3 WHITE *VITIS VINIFERA* VARIETIES

3.3 WHITE *VITIS VINIFERA* VARIETIES

3.3.1 RIESLING

A German variety with a high popularity in Canada for still and ice wine production. In Nova Scotia, the acreage is around 39.18 acres or 15.85 hectares.

Origin

One of the oldest German varieties, it's potentially coming from the Rheingau, from the north part of the Rhein. Thanks to DNA analysis, Regnet established that one of its parents is Gouais blanc. German breeders have used Riesling to produce diverse varieties in use today, such as Muller-Thurgau and Scheurebe.

Main characteristics

With positive winter hardiness characteristics, it rates six out of ten. Its vine growth can vary from low to high vigour, depending on its location and rootstock. Its budburst is late in the season, and the ripeness is mid/late-ripening, depending on the location. It tends to over crop when planted in deep and fertile soils. Related to pests and diseases, some resistance to Downy Mildew, slightly susceptibility to Powdery Mildew and Botrytis bunch rot. The bunches are small, can be compacted and winged, while the berries are small, round and white-green with prominent lenticels. Preference in the mild winter zones with enough FFD and GDD.

Figure 13. Riesling (courtesy of **vinsalsace.com**)

3.3.2 CHARDONNAY

One of the most popular worldwide white varieties, it cangrow in different latitudes and produce diverse types of wines. In Nova Scotia, it can grow in the mild winter zones. Currently, the surface is 65.21 acres or 26.38 hectares.

Origin

Historically speaking, this variety comes from the east of France. The most reliable mention of Chardonnay appeared at the end of the XVII century, coming from south of Burgundy. Through DNA analysis, it has been foundthat Pinot x Gouais blanc are its parents.

Main characteristics

It has positive winter hardiness characteristics, rating five out of ten. Grapevine growth can vary from weak to moderately vigorous, depending on the conditions. One of the earliest *Vinifera* for bud break and the fruit ripening can be early to mid-season. Related to pests and diseases, it's highly susceptible to Powdery Mildew and clones with tight bunches are more susceptible to Botrytis. It may suffer *coulure* (shatter berries) and *millerandage* (hens and chicks). Their clusters are small to medium size, usually winged and cylindrical. The berries are small, round, and the colour is yellow to amber.

Figure 14. Chardonnay

3.3.3 ORTEGA

This variety grows mainly in Germany, and it's characterized to achieve high levels of sugar. Provincially speaking, the acreage is around 13.8 acres or 5.58 hectares.

Origin

This variety was bred by Hans Breider in 1948 crossing Muller-Thurgau and Siegerrebe. The name is in honour of the philosopher Jose Ortega y Gasset.

Main characteristics

This variety has a winter hardiness of five out of ten. It has early budding and very early ripening. This variety is sensitive to Botrytis and resistant to Downy and Powdery Mildew. The bunches are susceptible to *coulure* (shatter berries).

Figure 15. Ortega (courtesy of **deutscheweine.de**)

3.3.4 SAUVIGNON BLANC

This variety is originally from France and quite popular worldwide. In our province, the acreage is around 5.23 acres or 2.11 hectares.

Origin

Its origin is not clear, first mentioned in Sancerre and Pouilly, and some DNA analysis indicates Val de Loire as its place of origin. The same with its parents, there are still discussions about them.

Main characteristics

According to some nurseries, the winter hardiness is lower than the previous varieties mentioned, rating two out of ten. Budbreak happens after Chardonnay. It's a vigorous plant and has early to mid-ripening. It's better not planted in highly fertile soils. Related to pests and diseases, it's susceptible to Botrytis, trunk diseases and Powdery Mildew, but it has some tolerance to Downy Mildew. Their bunches are small and compact, with berries small, round to short and characteristic 'green pepper' flavour.

Figure 16. Sauvignon blanc (courtesy of **fps.ucdavis.edu**)

3.4 RED *VITIS VINIFERA* VARIETIES

3.4 RED *VITIS VINIFERA* VARIETIES

3.4.1 PINOT NOIR

Probably one of the oldest *Vitis vinifera* varieties cultivated. The acreage in Nova Scotia is approximately 29.48 acres or 11.93 hectares.

Origin

This variety's origin is not clear but has been established as a parent of many other varieties. The most accepted theory on its name is that of Pignolo (Italian variety). The name derives from pin, which means pine, due to its clusters that reassemble a pinecone.

Main characteristics

It has low to moderate vigour. Its winter hardiness is medium, rating four out of ten according to some nurseries. According to the literature, it has early budbreak. In Nova Scotia conditions, it usually happens after Chardonnay. Similarly, the ripening period happens early, but it can vary depending on the conditions. Forpests and diseases, it's susceptible to Downy and Powdery Mildew, botrytis bunch rot and virus diseases. When temperatures are low, and with precipitations at bloom, it can increase the *coulure* (shatter berries) and *millerandage* (hens and chicks), diminishing the yield.

Figure 17. Pinot noir (courtesy of **fps.ucdavis.edu**)

3.4.2 CABERNET FRANC

A well-known variety, famous in Bordeaux and a parent of Cabernet sauvignon. Nova Scotia has an acreage of 6.83 acres or 2.76 hectares.

Origin

Even though this variety is quite famous in Bordeaux, the last genetic and historical analysis presents the Basque country as its place of origin. It's important to mention that this variety is quite important in Val de Loire as well.

Main characteristics

It's a vigorous plant with good cold hardiness, rating five out of ten, according to some nurseries. It has late budbreak, slightly later than Pinot noir and late-ripening as well. About pests and diseases, it has some susceptibility to Eutypa dieback and bunch rot. It can over crop easily, it is not unusual to have uneven late and heterogeneous veraison, and therefore, cluster thinning can be applied. The clusters are small to medium cylindrical in size with shoulder and the berries are small, round and blue-black.

Figure 18. Cabernet franc (courtesy of **austrianwine.com**)

3.4.3 PINOT MEUNIER

The French variety, also known as simply as Meunier, Nova Scotia has approximately 5.82 acres or 2.35 hectares.

Origin

This variety has a main characteristic of white hairs underside the leaves, giving a white appearance to the rest of the leaf. Due to this condition, its name is Meunier, meaning 'miller' in French.

Main characteristics

It has a moderately high-vigour, and its winter hardiness is five out of ten according to some nurseries. According to the literature, it's early budding and ripening, and it can ripen before Pinot noir (depending on the location and purpose of the grapes). In terms of pests and diseases, it's less susceptible than Pinot noir to Powdery Mildew, and due to their tight bunches, it can have some susceptibility to bunch rot. The fruit clusters are small and, as previously mentioned, tight, and can be winged.

Figure 19. Pinot Meunier (**thedrinksbusiness.com**)

3.4.4 GAMAY NOIR

This is a very famous variety from the Burgundian-Beaujolais and Loire Valley in France and Valais in Switzerland, especially for the Beaujolais nouveau wine. Provincially speaking, the surface is 3.16 acres or 1.27 hectares in Nova Scotia.

Origin

It's a very old Burgundian variety. Historically it had some authorization issues for growing in its original place. According to DNA analysis, Gamay is a cross between Pinot noir and Gouais blanc.

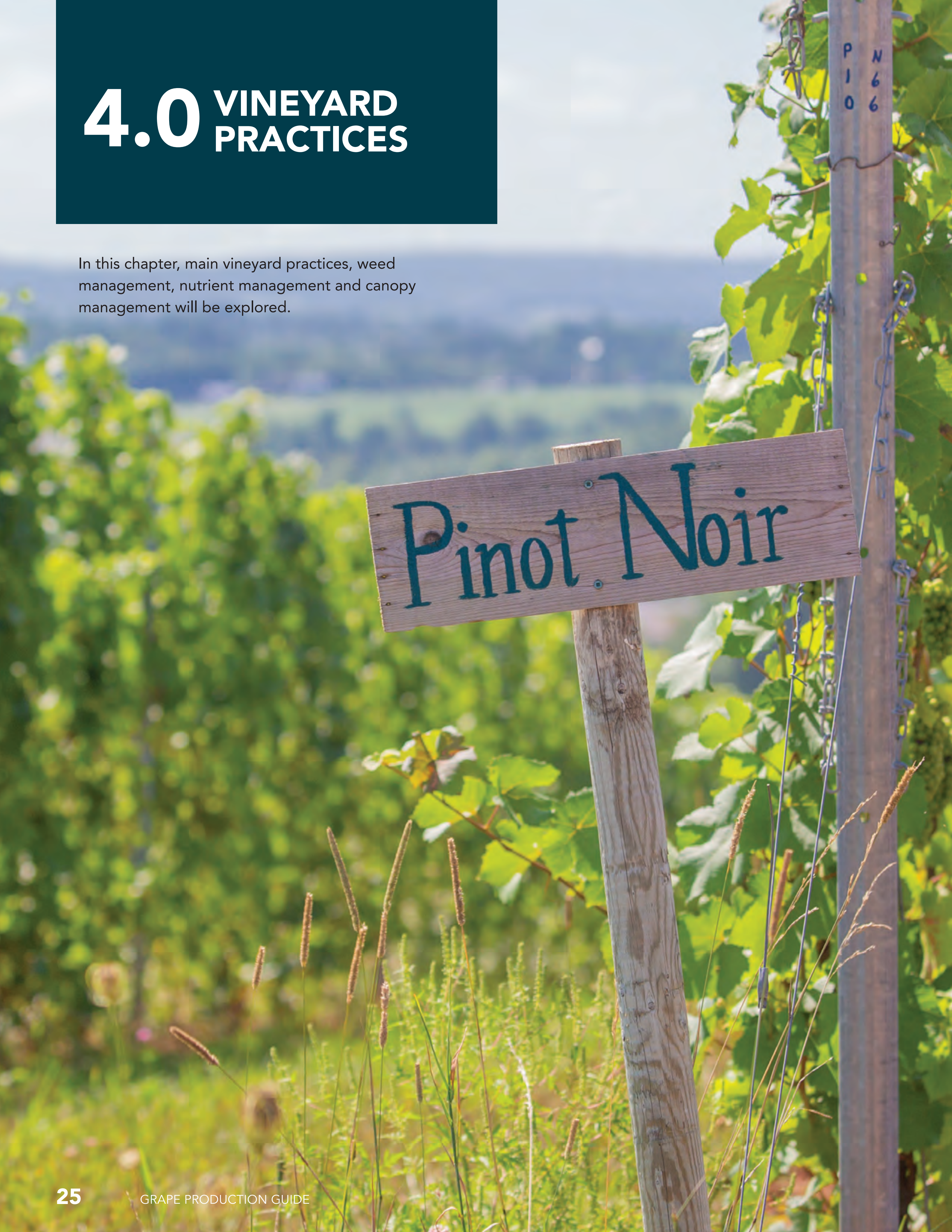
Main characteristics

It's a low vigour plant with good winter hardiness, which rates five out of ten. However, in places with high fertility in the soil, it can increase vigour and production. The literature describes this variety as early budbreak and early/mid ripening. For pests and diseases, it's susceptible to Powdery Mildew, Phomopsis cane, lead spot and Bunch rot. Clusters are small cylindrical, well filled with medium size peduncles. Meanwhile, the berries are small to medium, short and oval in shape.

Figure 20. Gamay noir (courtesy of **decanter.com**)

4.0 VINEYARD PRACTICES

In this chapter, main vineyard practices, weed management, nutrient management and canopy management will be explored.



4.1 WEED MANAGEMENT

Keeping the weed growth under control, and sometimes even the cover crop, is essential for success when establishing the grapevines, independently from the vineyard. Keeping the vineyard under control means having a balance between vines with the rest of nature. Therefore, it's okay to have some population of other plants if it doesn't interfere with proper vine growth.

It's recommended to avoid extreme situation, such as having a completely clear vineyard leaving bare soil, which can increase the erosion, the compaction of the soil and affect the microbiology, etc. The other extreme is not having a management program. If there are weeds everywhere, and they are not mowed or allowed to climb the vines, the weeds will compete directly with the vines affecting the plant nutrition and even the fruit quality.

4.1 WEED MANAGEMENT

4.1.1 WHAT'S A WEED?

A weed is a plant growing in an area where a specific crop exists, in this case, a vineyard, which can produce a problem affecting the establishment, production and quality. Weeds can severely affect the grapevines, diminishing the yields until the point of losing the vineyard.

These plants can be catalogued as weeds if they have one or more of the following characteristics:

- Compete for water
- Compete for nutrients
- Compete with cover crops
- Host vineyard pests and diseases
- Damage workers or the fruit
- Interfere with vineyard labours
- Potentially affect neighbour properties

Therefore, it's important to develop a program to manage the weeds to keep them under control and facilitate grape production from the beginning of the vineyard establishment.

Figure 1. Vineyard without weed management (courtesy of INTA Argentina)

4.1.2 DIFFERENT WEEDS

Weeds are commonly divided into grasses v/s broadleaf and annuals v/s perennials. It's important to highlight that grasses and broadleaf can be annuals or perennials as well.

The main characteristic of grass and broadleaf are:

Grass: with fibrous roots, usually with round and hollow stems, except the nodes where it is possible to see the leaf attached. Their leaves are narrow, with small and parallel veins and small flowers.

Broadleaf: their roots system can be fibrous, a large taproot or a combination of both. The stems can be round or square, with other specifics such as rhizome (growing underground) and stolons (growing above ground). As their name suggests, they have broad leaves, with one main vein, and from there, other small vein branches appear.

Some characteristics of annuals and perennials are:

Annuals: these weeds have an annual life cycle, which means the emergence, passing to seeding and death takes less than 12 months. It's possible to find summer annuals (emerge in spring or early summer) and winter annuals (emerge at mid-summer).

Perennials: these plants can live for years. Their strategy to survive is through vegetative propagules, such as below the ground rhizomes, tubers, budding rootstocks, budding taproots or above-ground stolons. For this reason, perennials are more difficult to control than annuals due to the protection by soil, foliage and debris.

Figure 2. Established vineyard without proper weed management (courtesy of INTA Argentina)

4.1.3 APPROACHES TO MANAGING WEEDS

To manage weeds, different options exist. The most important is starting from the beginning with the least possible number of competitors and considering some preventive measurements for the whole property. In addition to this strategy, there are four other main strategies: cultural, biological, mechanical and chemical. Let's start with the characteristics of the preventive strategy.

Preventive measurements consist of limiting or avoiding the spread of any current plant and introducing any new undesirable plants to the vineyard. This strategy will help in the short and long term diminishing the probability of having an overpopulation of weeds that affect the vines. Some strategies to keep in mind are as follows:

- In the application of compost and green compost, make sure that this material is clean without carrying seeds or weeds from other properties.
- Don't allow the multiplication of the weeds. Eliminate them before flowering to avoid their spread.
- Manage the whole property, considering the roads, ditches, fences, etc., since these places can be the source of weeds.
- Eliminate any isolated place with weeds to diminish the population on the property.
- Limit the movement of equipment, people and livestock through the property, especially if they're coming from weed-infested areas.
- Clean machinery and equipment before using in your property, especially if they're coming from weed-infested areas and you don't have these weeds.
- Monitoring or scouting will allow for identifying the hotspots in the property, choosing the best approach, determining the timing of action and evaluating the effectiveness.

Starting weed management with a good prevention strategy will be the best way to start. Let's look at the main characteristics of the four main strategies.

Figure 3. New vineyard with mechanical management and cover crop

4.1.3.a Cultural management

It consists of implementing practices allowing a good establishment, so that the grapevine can compete better against the weeds. One of the best advantages is the low to no impact on the environment, helping preserve natural resources. Some of the main characteristics are as follows:

- Prepare the soil well beforevineyard establishment. Manage the first weeds in emergence and keep them under control.
- Use the cover crops adapted to the region, with a good establishment in the soil and use clean seeds without contaminants.
- Mulch can help to manage the weeds. This can be organic, such as straw or slashed cover crops, or synthetic mat, such as black plastic.
- Plan for proper grapevine spacing in the vineyard to facilitate the use of machinery to manage the weeds.
- Application of localized fertilizer to prioritize the grapevines.
- Graze with sheep and geese, which can carry a positive nutrient cycling in the vineyard but requires management to avoid any possible vine damage.

Cultural management is a good strategy against weeds, and should be considered with the combination of other management techniques to keep the weeds under control.

4.1.3.b Biological management

This strategy consists of using other organisms to keep the weeds under control in a specific area. In some cases, the organisms have to be imported to obtain the desired results, and some positive results have been achieved in Australia. This strategy needs more research and evaluation in viticulture.

4.1.3.c Mechanical management

This type of management is quite popular among organic producers as they can't use chemical products. The main goal is to disturb the soil through cultivation by destroying, burying, separating or mowing the weeds from the surface. These practices are relatively demanding of fuels and highly labour intensive. In addition, cultivation can be very disruptive with soil structure and microorganisms. The correct way to proceed with this strategy is to act when its use is necessary.

Hand cultivation is another mechanical way to proceed, which is practical in small areas or when removing precise weeds around the trunk or in new vines which were unable to be cleaned by cultivators. Even though it can be time-consuming and expensive, it's effective and gentle, especially with new vines. These manual labours can be done by hoeing or even by hand.

In the case of mechanical cultivators, a wide range of implements can be used below the vines. Mechanical hoes are quite popular. They push up or pull out the root system of small to medium weeds. Rotatory devices are also available; they can be stainless steel or rubber. They can disrupt the weeds growing closer to the vines. Other tools, such as discs or chisel/tine ploughs, can cultivate the interrow of the vineyard.

Some characteristics of mechanical management can be listed as follows:

- It can be applied before establishing the vineyard, with the soil preparation to eliminate weeds.
- It doesn't contaminate the air without risks of contaminating the neighbour's crops.
- Disaggregates the soil, increases the aeration and separates weeds from the soil.
- However, it doesn't eliminate the weeds from the soil. It's not very effective with perennial weeds and might provoke compaction and erosion.

4.1.3.d Chemical management

When applied at the proper time, this approach uses herbicides of chemical origin to control the weeds. There are some classifications to be kept in mind. The first one is the time of application: pre-emergence and post-emergence:

- Pre-emergence: applied to the soil, where they interrupt the seed germination and plant growth.
- Post-emergence: these interfere with the plant growth of the weed in different ways.

The herbicide products can be classified as follows:

- Selective herbicides, as their name suggests, are specific for some plants. Therefore, their range of action will be limited.
- Contact herbicides affect only the tissues directly sprayed with the products and don't move through the plant.
- Systemic herbicides move through or are translocated in the plant, which can be applied to the soil or the foliage.
- Residual herbicides also known as persistent, are applied to the soil, where they stay over time and keep their effectiveness even after their application. In some cases, the persistence can be long enough to damage crops. These products may or may not be selective, as well may or may not be systemic.

Before choosing the herbicide to be applied in your vineyard, it's important to:

- Identify which kind of weeds are affecting the vineyard,
- Use an herbicide authorized to be applied in the vineyard,
- Calculate the proper dose recommended on the label,
- Have the sprayer properly calibrated and
- Keep all the security measurements handling the product since the purchase.

Important reminder: before applying any pesticide or herbicide, always read and follow the label instructions and recommendations.

Here are some considerations when herbicides are applied.

- Utilize a sprayer in good condition and calibrate the equipment before applications.
- Keep a clean section of three to four feet below the vines.
- A good way to protect young vines is the use of grow tubes.
- It's important to be rotating herbicides to avoid creating resistance. The overuse of one product will create a dominant weed difficult to be managed.
- Avoid the application over the vine canopy and green bark. This can produce serious damage to the plants.
- Avoid the application on windy days because the drift can damage sensitive parts of the vines and even affect neighbours' crops.

Important: using the same herbicide through the years will produce resistant weeds, which will produce weeds unable to manage with the same product.

Figure 4. Vineyard with chemical management

4.2 NUTRITION MANAGEMENT

The mineral nutrition is the base for the correct metabolic and physiological process through grapevine growth and fruit production. Like any other crop, the proper supply of nutrients will allow the vineyard to have enough reserves to keep a healthy production. Plants uptake nutrients from the soil in a soluble solution, which will be transported to the whole vine to play different roles, such as growth, coloration, pollination, etc. Between the nutrients, it's possible to differentiate two major groups of nutrients: macro-nutrients and micro-nutrients.

The macro-nutrients are all the minerals utilized in large amounts, and they have higher quantities in the tissue, which are expressed as a percentage (%) of fresh or dry weight. The macro-nutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). In the case of micro-nutrients, these are used in lower quantities compared to macro-nutrients. Therefore, their content is expressed in parts per million (ppm). The most relevant micro-nutrients are zinc (Zn), manganese (Mn), iron (Fe), copper (Cu) and boron (B). The interaction of all these minerals will impact the vineyard development through the season and, consequently, impact the wine quality.

To have a balance of nutrients in our vines, it is essential to know the nutritional status of our vineyard, to detect and correct any potential nutritional unbalance. The information about the nutritional status of vines allows us to have the right nutrient absorption, avoid effects of deficit or excess of nutrients on the grapevines, and plan the correct fertilization calendar with a focus in quality and with respect to the environment.

The first step is to consider the soil as the base of our vineyard.

4.2 NUTRITION MANAGEMENT

4.2.1 SOIL TESTING

The main way plants uptake nutrients is through the root system. From there, the minerals will be moved into the plant. All the nutrients must be available to the plant in a soluble form, dissolved in water in the soil, making the soil solution. This happens thanks to the weathering of the minerals and the decomposition of organic matter by the microorganisms. Factors to be considered for the nutrient availability are:

Water: in the case of having dry conditions, the minerals will be unavailable to the plant and the microorganisms. Meanwhile, with excessive amounts of water, some nutrients can leach, and others can accumulate in toxic forms.

Temperature: low temperatures will diminish the microbial activity, which will cause a low decomposition of organic matter. On the other hand, high temperatures can over accelerate the reactions. Important: The grapevine root system uptakes nutrients when the soil has reached and maintains 12.7 °C.

Cation Exchange Capacity (CEC): it's the ability to hold (adsorb) and release nutrients present with a positive charge (cations), such as K, Ca, Mg and Na.

pH: this directly influences the availability of nutrients and impacts microbial activity. Usually, the nutrients will be less available when the values are below 6 (acidic conditions).

To understand the soil nutrient conditions, it's recommended to take soil samples in the vineyard every three to five years to track the nutrient availability at the same time of the year. These samples can be taken in spring or fall, and will depend on the grower and time availability.

As long as it's possible, it's good idea to use the same lab over the time. This will allow to keep consistency in the results and diminish the difference that might occur due to the laboratory techniques. In this way, it will be possible to have constancy throughout the vineyard lifespan and allow proper decision making for convenient amendments to be applied depending on the results.

An important thing to consider is that the availability of nutrients in the soil is not always indicative of the plant conditions. For this reason, it's recommended to take tissue samples annually, at bloom or veraison or even at both stages if it's possible, to determine the vineyard conditions.

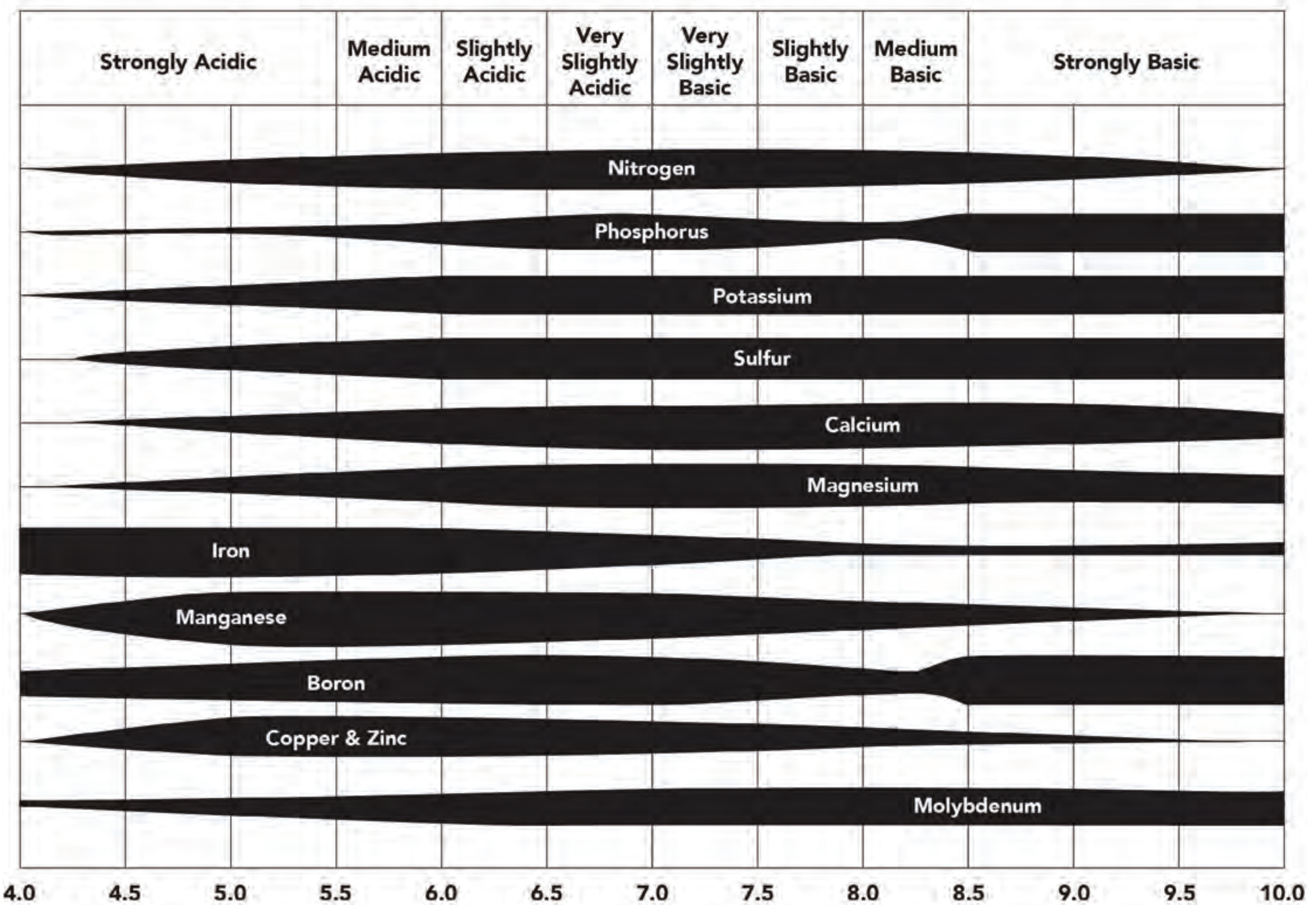


Figure 1. Soil pH influence on nutrient availability. The thicker line means more available and the thinner line less available (courtesy Washington State University)

4.2.2 GRAPE TISSUE SAMPLING

The importance of grapevine nutrient status

Knowing the nutrient status of grapevines allows us to identify potential imbalances, therefore allowing an opportunity to improve plant and health. Vine nutrition is important for grape production and vine development throughout the growing season, as the minerals will be used in many important roles during vegetative and reproductive growth. A tissue analysis allows us to evaluate if uptake of nutrients by the plants has been adequate, additionally identifies how nutrient deficiencies can affect the normal development of the vine. These results make it possible to implement a suitable fertilization strategy, which can aid in achieving our goals of yield and quality while maintaining respect for the environment.

It is important to remember, high levels of water and fertilizers do not necessarily result in beneficial response to the fruit and the plant. Tissue sampling is an inexpensive method to determine what is needed by the grapevines.

How is nutrient status evaluated?

Nutrient evaluation of vineyards can be done a number of ways: soil analysis, sap analysis and tissue (or leaf) analysis. To get the full value of doing nutrient analysis, several methods may be needed in combination. Leaf analysis is a very useful tool to quantify nutrient status in the plant, it is recommended that it be done atleast once per year. To be able to obtain the most accurate results, it is important to know the growth stage and the position of the leaf on the plant. This is necessary to standardize the sampling strategy as there are fluctuations in the nutrient levels within the plant.

Sampling protocol

How to proceed with tissue sampling will depend on three variables:

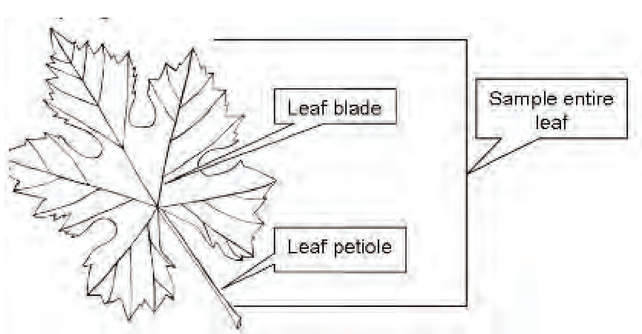


Figure 1. Grapevine leaf illustrating both parts; blade and petiole.

When to sample?

Two growth stages are the most used: blooming and veraison. If logistics make it impossible to take samples at both times, sampling at veraison should not be skipped.

Which tissue?

The leaf is the most commonly used part: blade and petiole (see Figure 1). It is necessary to analyse both leaf parts separately, because depending on the goal or for some elements, one part can be more accurate than the other. It is necessary to carefully separate the blade from the petiole (see Figure 2). The physiological age of the leaf must be kept consistent all throughout sampling.

Where to collect samples?

It is important to collect leaves from the same area of each vine to maintain consistency of leaf age. Take samples from each variety separately, walk each block fully and collect leaves from random plants. The goal is to collect a composite sample of the block. The recommended protocol is to collect the leaf opposite the first cluster (this is the cluster closest to the bottom of the shoot) during full bloom (see Figure 3a and 3b). During veraison, the sample will be collected from the fifth leaf on the shoot. The fifth leaf will be the youngest, fully developed leaf. It is very important to choose healthy and complete leaf tissues; avoid collecting leaves that have been injured by insects, disease or other factors.

Figure 2. The separation of blade from petiole.

Tips for successful sample collection

- It is important to consider consistent parameters for sampling: soil, variety, rootstock, vine vigor, trellis system, soil management, etc. Samples must be representative of the block.
- Generally, between 60 and 100 leaves per block are collected depending on leaf and block size. The leaves have to be healthy, completely developed and coming from fruitful shoots. If you question how many leaves to collect, it is always better to collect more, the lab can dispose of extras if necessary but they cannot add more.
- When there are symptoms of nutritional imbalance, it may be useful to submit two samples. Leaves with and without symptoms can be collected and analysed separately. When you receive the results you will then be able to decide if different management strategies need to be made to account for the differences.
- The bags have to be clean, with good aeration and good identification. Brown paper bags are a great choice for storing samples. It is not recommended to take samples on Fridays, as the samples will deteriorate over the weekend. Samples must be delivered to the lab within 24 hours of sample collection.
- Ensure that sample identification names are kept consistent between blooming and veraison; and from year to year. This is very important for tracking results over time, and being able to easily compare them year to year. It may be useful to draw a sketch of the vineyard and include the names of each sample location on the map, especially when samples are being sent to a consultant.
- It is useful to make note of when treatments have been made to the grapevines prior to sampling. Especially if a nutrient result comes back much higher than anticipated.
- If you are sending samples to a new lab, it will be beneficial to contact them beforehand to determine if they have a preference for sample packaging.

Figure 3a. and Figure 3b. Grapevine shoots indicating sample location during bloom.

4.2.3 GRAPEVINE NUTRIENTS

Knowing the nutrient status of grapevines allows us to identify potential imbalances. Therefore it's an opportunity to improve plant growth and health. Vine nutrition is important for grape production and vine development throughout the growing season, as the minerals will be used in many important roles during vegetative and reproductive growth. A tissue analysis allows us to evaluate if the plants' uptake of nutrients has been adequate and identifies how nutrient deficiencies can affect the normal development of the vine.

It is **important** to remember that high levels of water and fertilizers do not necessarily result in a beneficial response for the fruit and the plant. Tissue sampling is an inexpensive method to determine what is needed by the grapevines.

To get the full value of a nutrient analysis, several methods may be needed in combination. Leaf analysis is a very useful tool to quantify nutrient status in the plant. It is recommended to be done at least once per year. To obtain the most accurate results, it is important to know the growth stages and the position of the leaf on the plant. This is necessary to standardize the sampling strategy as there are fluctuations in the plant's nutrient levels.

The tissue analysis results are presented for each nutrient in dry weight, and depending on the mineral, the values can be expressed in percentage (%), milligram per kilogram (mg/Kg) or parts per million (ppm). The following table was developed in Western Australia considering the main factors for their current conditions to keep proper levels in the grapevine. The main varieties used are *Vitis vinifera* varieties; however, the optimal values can vary depending on the grapevine and on the rootstocks in case they are used.

These values can be taken, for bloom or veraison, as a base reference to evaluate the condition of the grapevines. The berry nutrient status can be modified by the winery or grower, depending on the grape variety and the wine style to be produced, to improve the wine quality and quantity.

At the time of soil and tissue analyses, it's important to consider both results simultaneously to have a holistic understanding of the condition of the vine. The following table shows how the test results can be combined and interpreted.

Nutrient	Deficient	Marginal	Adequate	High	Toxic
Nitrogen (%)	<0.7		0.8-1.1	>1.2	
Phosphorus (%)	<0.15	0.15-0.24	0.25-0.5	>0.5	
Potassium (%)	<1.0	1.0-1.3	1.3-3.0	>3.0	
Calcium (%)	<1.0		1.2-2.5		
Magnesium (%;)	<0.3	0.30-0.39	>0.4		
Sodium (%)			0.1-0.3	0.4-0.5	>0.5
Chloride (%)			<1.0	1.0-1.5	>1.5
Zinc (mg/kg)	<15	15-26	>26		
Manganese (mg/kg)	<20	20-29	30-60		>500
Iron (mg/kg)		7	70		
Copper (mg/kg)	<3	3.0-6.0	>6		
Boron (mg/kg)	<25	25-30	31-70	71-100	>100

Figure 2. Guideline for petiole results interpretation (courtesy of Managing grapevine nutrition and vineyard soil health from Western Australia)

SOIL TEST HIGH Tissue Test Low Root or water problem indicating lack of plant uptake of the nutrient	**SOIL TEST HIGH** Tissue Test High Too much nutrient — don't fertilize with that nutrient!
SOIL TEST LOW Tissue Test Low Not enough nutrient — fertilize!	**SOIL TEST LOW** Tissue Test High Likely contamination, or leaf samples were taken directly after a foliar fertilizer application.

Figure 3. Interpretation of soil and tissue results (courtesy Washington State University)

4.2.4 ROLE OF MACRO AND MICRO-NUTRIENTS

In this section, the role of the different nutrients on the grapevines, and some desired values in the petioles through the growing season are explained

4.2.4.a Macro-nutrients

The macro-nutrients; Nitrogen, Phosphorus, Potassium, Magnesium, Calcium and Sulfur, will be explained in this chapter regarding their importance to the vine and their symptoms in case of excess or deficiency.

I. Nitrogen (N)

Why is Nitrogen important?

- It is the most relevant nutrient for the plant's development and metabolism, which impacts photosynthesis, fruit-set and cluster initiation.
- N is very important in the development of new vineyards for promoting rapid growth of the vines.
- Increased fruit set, yield and quality.
- Improved berry colour and consequently wine quality.
- N is highly mobile in the plant and has a medium-high mobility in the soil.

Deficiency Symptoms

- An overall reduction in growth, berries are small.
- Reduced vigour and growth, the distance between nodes is short.
- Leaves become uniformly light green or yellow, and their size is smaller.
- From véraison the leaves become red in the veins and petioles. In some cases, even the stem of bunches will turn red, regardless of the cultivar.
- Leaves senescence can start earlier in the season.
- A low level of nitrogen in grape vines causes lower levels of yeast assimilable nitrogen (YAN) for winemaking.
- Deficiency has to be quite severe to cause observational changes in the grapevines.

Excessive Symptoms

- With high growth and vigour, the canopy becomes dense with many layers of leaves.
- Shoot growth can finish very late, which can cause problems for controlling the vineyard development.
- Leaves with bigger size, with a very intense green colour.
- It's necessary to spend more hours of leaf thinning and potentially more applications of fungicide.
- Very compact grape bunches, berries will be very big, and some will be missing in bunches.
- Berries will have an unnecessary excess of YAN and a high amount of N, which can cause a higher incidence of botrytis.

Figure 4. Nitrogen deficiency (courtesy of Yarra)

II. Phosphorus (P)

Why is Phosphorus important?

- It is important for flower and fruit formation.
- Structural role of cell membranes and part of photosynthesis.
- It is very important for establishment and root growth.
- Healthy green foliage and improved plant quality.
- Phosphorus has low mobility in the soil and high mobility in the plant.

Deficiency Symptoms

- Vines have stunted shoots, lower fruitfulness and the fruit set is poor.
- It can produce poor bud initiation at the beginning of the season.
- A reduction in the number of leaves produced.
- The most notable deficiency in leaves is the yellowing of the interveinal area of basal leaves.
- In extreme cases, red dots can appear on basal leaves.
- The dots then become more linear and line up at right angles to the secondary veins and form dark-red bars, which form into large blotches between green veins.
- Some of these symptoms can be confused with leafroll virus, but phosphorous symptoms occur earlier in the growing season (blooming).
- It can produce a change in root growth pattern, increasing the root-shoot ratio.

Excessive Symptoms

- The excess of phosphorous can limit the uptake of other elements, for example, Zinc.

Figure 5. Phosphorous deficiency case

III. Potassium (K)

Why is Potassium important?

- Vines remove a large amount of potassium from the soil.
- Most of the potassium is removed through the fruit.
- Potassium is crucial between blooming and véraison.
- It is an important and relevant component of grape juice (must) and wine.
- To help with a successful overwintering of grapevines, potassium acts as an antifreeze when applied at the proper rates.
- Potassium has low-medium mobility in the soil and high mobility in the plant.

Deficiency Symptoms

- Begins as yellowing (white grape varieties) or reddening (red grape varieties) of older leaf margins.
- As the deficiency worsens, leaf margins become necrotic and curl upwards, and inter-vein chlorosis develops.
- Other symptoms are reduced bunch weight, uneven berry ripening and even blackening of leaves.

Excess Symptoms

- Excessive K in the soil can cause high potassium levels in the berry juice, resulting in an increase of the must pH, which may cause trouble with colour and stability of the wine.
- Increasing the K concentration can cause a reduction in the concentration of nitrogen and magnesium levels.
- An excess of K can cause a reduction of uptake of calcium and magnesium.

Figure 6. Potassium deficiencies in a white variety (courtesy of Yarra)

IV. Magnesium (Mg)

Why is Magnesium important?

- Combats chlorosis giving healthier green foliage.
- Increases sugar levels in berries.
- Prevents and controls grape stem necrosis.
- A high level of magnesium may limit the uptake of potassium.
- Magnesium has low mobility in the soil and high mobility in the plant.

Deficiency Symptoms

- The symptoms are similar to potassium deficiencies, but the symptoms appear at véraison in the basal leaves.
- Plants with deficiencies are particularly light-sensitive, which can be clearer in leaves with sun exposure.
- White varieties – bright yellow wedge-shaped areas extend inward between the veins on older leaves.
- Red varieties – red wedge-shaped areas extend inward between the veins on older leaves.
- It can interrupt the root growth.
- Fruit cluster stem necrosis and berry withering.

Figure 7. Magnesium deficiencies in the lef white variety in the right a red variety (courtesy of OMFRA the left photo and the right Viticultura: Fundamentos para optimizar produccion y calidad)

V. Calcium (Ca)

Why is Calcium important?

- Improved berry quality.
- Reduction of grape stalk necrosis.
- Improved berry firmness and storage potential.
- Calcium has low mobility in the soil and the plant.

Deficiency Symptoms

- Grapes turn brown and dry out.
- It can diminish the elasticity of the grape berry skin and potentially produce issues once the fruit beings to ripen, causing even an increase of botrytis damage.
- Reduction in the root size and consistency.
- Calcium deficiency gets worse in acidic soils, sandy soils (leaching), soils rich in Na and Al, drought conditions, large fruit.

Figure 8. Calcium deficiency in grape berries (courtesy of **Polysulphate.com**)

VI. Sulfur (S)

Why is Sulphur important?

- Sulphur is present in proteins and chlorophyll.
- Plays a role in energy metabolism.
- Sulphur plays a significant role in the control of plant pathogens and mites, and it is usually sprayed regularly in vineyards.
- Sulphur has moderate mobility in the soil and low-medium mobility in plants.

Deficiency Symptoms

- Typically they are fairly rare, but they are similar to the symptoms of nitrogen deficiency.

4.2.4.b Micro-nutrients

The micro-nutrients, Boron, Copper, Iron, Manganese and Zinc, will be explained in this chapter with their importance to the vine and their symptoms in case of excess or deficiency.

I. Boron (B)

Why is Boron important?

- Improves flowering.
- Improved fruit set.
- Gives more of an even ripening.
- Boron has high mobility in the soil and low-medium mobility in the plants.

Deficiency Symptoms

- It can produce a shortened internode with a zig-zag pattern, plus the death of shoot tips and interveinal chlorosis of older leaves.
- Only has a few seeded berries set. Most berries remain small and seedless. This is commonly referred to as 'hen and chicken.'
- Deficiency first appears as chlorosis on leaf margins and extends between the veins. Later, leaf margins show red-brown colour and die off.
- Boron deficiency is one of the most serious nonparasitic grapevine diseases. It is the most common on highly acidic soils.

Figure 9. Boron deficiency in grape bunch (courtesy of Grape – Extension Foundation)

II. Copper (Cu)

Why is Copper important?

- Copper is used as a fungicide treatment on grapevines.
- Levels must be monitored as not to cause contamination in the must.
- Copper has low mobility in the soil and plants.

Deficiency Symptoms

- Deficiencies are very rare. It is more likely to have toxicity for the accumulation of Cu in the topsoil due to fungicide use.
- Poor vine growth and yield.
- Small pale-coloured leaves with small indentations.
- Deficiencies are more common in young vineyards which haven't been exposed to fungicide sprays.

Figure 10. Copper deficiency (courtesy of The Australian Wine Research Institute)

III. Iron (Fe)

Why is Iron important?

- Combats chlorosis, creating green foliage.
- Iron has low mobility in the soil and the plant.

Deficiency Symptoms

- Symptoms always begin on the youngest leaves with yellow-green, later pale yellow interveinal chlorosis,while the main veins remain green.
- Severe deficiency produces symptoms on older leaves and entire shoots too.
- Iron deficiency is usually uncommon because most soils contain enough iron to meet the growing requirement.

Excess Symptoms

- To date, iron deficiencies are not known to occur in vineyards.

Figure 11. Iron deficiency (courtesy of Yarra)

IV. Manganese (Mn)

Why is Manganese important?

- Combats chlorosis giving healthier green foliage.
- Increases potential alcohol content in berries.
- Increases sugar level in berries.
- Manganese has low mobility in soil and plants.

Deficiency Symptoms

- Symptoms start on young, fully developed and on medium leaves.
- The leaves eventually look like a mosaic. The fine veins will stay green.
- Spots and blotches appear. Leaves are smaller than healthy leaves.
- Early-stage of deficiency shows symptoms on whole leaf blades.

Figure 12. Manganese deficiency (courtesy of Yarra)

V. Zinc (Zn)

Why is Zinc important?

- Promotes healthy green foliage.
- Improved fruit set and development of berries
- Zinc has low mobility in the soil and plants.

Deficiency Symptoms

- Appear on young leaves first. A light green mosaic-like chlorosis appears in the interveinal areas and continues to pale over time.
- Along the veins, a dark green border remains.
- The leaf blades are small and asymmetrical. One half of the leaf is always larger than the other.
- The main vein runs in a slight curve, with the tip leading towards the small half.

Figure 13. Zinc deficiency (courtesy of Yarra)

4.3 CANOPY MANAGEMENT

In our vineyards, one of the key goals is to achieve a healthy crop and plant, and this can be accomplished through the management of the canopy and fruit zone. These two areas in the vine can have the most effect on the grapes' quality and quantity. Let's briefly define each concept:

Canopy: It's all the aerial part of the vine, which are shoots, stems, leaves and grape clusters. Some parameters to consider are length, height, width, leaf area, number of leaf layers and shoot density.

Fruit zone: As the name suggests, it's the area in the vine where the grape clusters will be positioned through the growing season.

The objective in the vineyard is trying to balance plant size and fruit production. This goal can be achieved by managing the canopy and the fruit zone. The first step to have a balanced plant is selecting the proper site and the correct cultivar or cultivar with the rootstock. Sites with high fertility and high-water holding capacity will produce vines with too much foliage and fruit, making it difficult to manage towards a balanced vine and ripe fruit. The main goal of wine grape production is to produce a moderate size vine. Therefore the energy will be used less on growing the leaves and more on ripening the fruit.

Canopy management considers the microclimate inside the main canopy and fruit zone, as previously mentioned, with the main goal to have a balanced vine and the correct fruit ripeness depending on the wine desired to be produced.

Let's see some benefits of canopy management:

- **Air movement:** removing leaf layers will increase the airflow, accelerate drying the leaves and fruit from rain and dew, and therefore diminish the impact of fungal diseases.
- **Spray penetration:** with fewer leaf layers, the sprayer applications will be more efficient, and the disease control can be improved.
- **Fruit quality:** a vineyard with dense canopies can have higher pH and unripe flavours in the grapes. Exposing the fruit zone can result in higher sugars, colour, and desirable aromas and flavours.
- **Bud development:** buds for the following season are initiated in late spring and early summer on shoots grown in the current season. These news buds develop the initial components of flower clusters. An adequate sunlight exposure of the shoots is critical to obtain sufficient floral initiation and fruitfulness.
- **Canopy efficiency:** the outside leaves of the vines absorb or reflect more than 94% of the sunlight, and less than 6% of the light is available to the leaves in the interior. Leaves within the second to third layers will be users of nutrients rather than producers to support the plant.

An **important reminder** that having too little canopy with over-exposed fruits can negatively impact vine health, productivity and fruit quality.

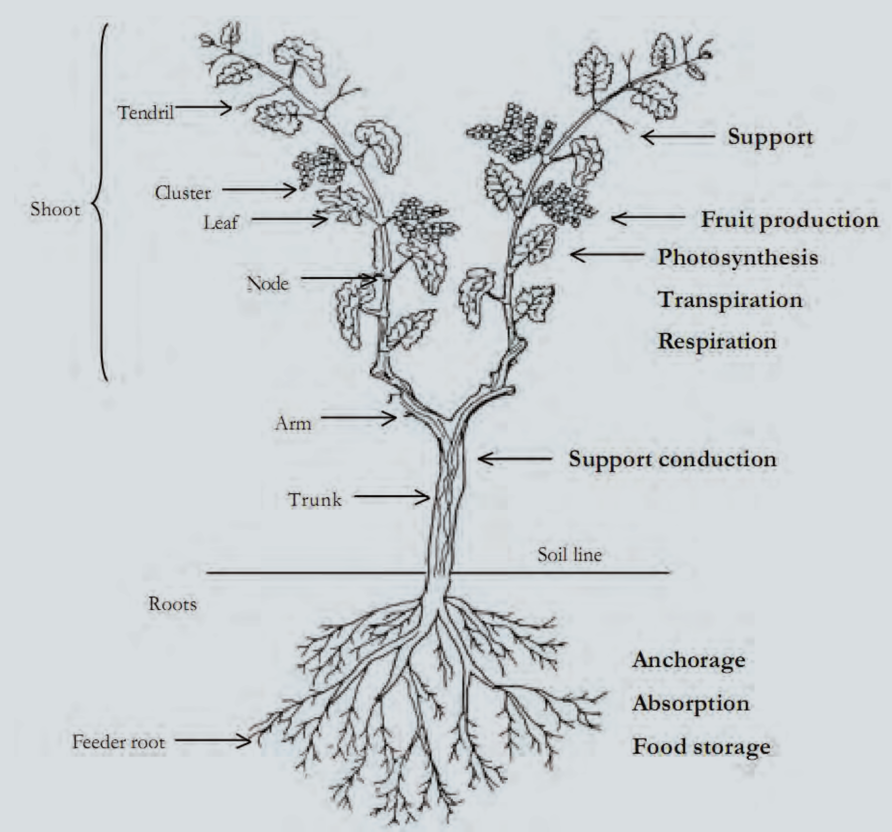


Figure 1. Grapevine structure (courtesy of Penn State University)

4.3 CANOPY MANAGEMENT

4.3.1 DIRECT CANOPY MANAGEMENT

The application of canopy management practices will happen throughout the growing season by eliminating shoots or fruit thinning. Even with all these practices, the vine will continue growing depending on the water and nutrient availability. Therefore, it's possible to see the growth of leaves, lateral shoots and even secondary fruit, which will be more notorious in more vigorous vines. In this section, you will find five canopy management practices: shoot thinning, shoot positioning, hedging, leaf removal and crop thinning.

4.3.1.a Shoot thinning

This process is called 'suckering' depending on the shoot being eliminated. It consists of eliminating all the undesired and wrongly positioned shoots on the trunk, cordon and cane or spurs. With the trunk, one or two suckers can be left if a new trunk needs to be replaced or if a trunk replacement is necessary due to cold injury.

The adjustment of the number of shoots per vine is needed to optimize canopy density and fruit production. Shoot thinning reduces the competition of energy and nutrients at the early stages of the growing season when the leaves are unable to conduct proper photosynthesis to produce their own energy. For weak plants, fewer shoots will help to have proper development. On the other hand, when the plants are vigorous, fewer shoots can increase the rest of the plant growth and decrease the fruit production, increasingthe unbalance within the grapevine even more.

When: the proper time to apply this technique is early in the season when the shoots are one to three inches long in the trunk or six to 12 inches long in the cordon. This process has to be performed after the last expected frost, that way, the grapevine has options in casea late frost event happens in spring. Depending on the plant vigour, suckering can require more than one pass.

Some considerations to keep in mind:

- Avoid thinning before the flowers (know as) inflorescences of grapes are visible (0.8 to 4 inches).
- In the case of late shoot thinning, more than 12 inches, the shoots can lignify on the base, making shear usage necessary. This will take longer and be more expensive.
- Remove the weak and unfruitful shoots from crowded areas.
- If the primary shoot has good health conditions, secondary and tertiary shoots can be removed.

Figure 2. Before shoot thinning: spur pruned (left) and cane pruned (right) in Gruner Veltliner (courtesy of Penn State University)

4.3.1.b Shoot positioning

This process consists of facilitating the shoot growth vertically and parallel to the trunk of the vines, and the shoot growth can be upwards or downwards depending on the training system designed. Grapevines have atendency to growsideways; they use their tendrils at the top of the shoot to attach to the cordon wire or even to other plants. As in the case of shoot thinning, shoot positioning seeks a better canopy configuration and diminishes or avoids the overlapping of the shoots.

An important factor to consider is the wire moving. The wires can be moved when shoots have active growth. Therefore, the timing is crucial to move the wires. If it's done too early, the shoots will grow and not keep their position, while if it's too late, the shoot will have to be bent, which usually leads to breakage and loss for the rest of the season. Many vineyards have catch wires, allowing growers to pull them away from the canopy and sweep the shoots inside.

Depending on the variety, this process can be more or less labour intensiv. For example, L'Acadie blanc tends to grow upwards, which can facilitate the process of shoot positioning through the season. On the other hand, Chardonnay requires more attention to avoid laying down through the wires, and some extra time is needed to position the shoots upwards.

There are two terms to consider depending on the shoot positioning:

- **Tucking:** the shoots will be positioned upwards, and it's commonly used in Vertical Shoot Positionig (VSP). The conduction of shoots will be facilitated using two to four permanent or moveable catch wires spaced between 10 to 12 inches. Shoots will require several passes through the season and will continue until they overpass the last set of wires.
- **Combing:** in this case, the shoots are organized in a downward position. This system will diminish the vigour and help with the proper canopy density. Grapevines tend to have shoot breakage. Therefore, if this system is applied, it would be convenient to start with the varieties that are less prone to breakage.

When: timing will be crucial to diminish shoot breakage and facilitate the positioning. One aspect to highlight is to reduce shading to increase sunlight exposure, which is fundamental for bud fruitfulness.

4.3.1.c Crop thinning

This labour is sometimes avoided to obtain a faster vineyard production. However, for the long-term vineyard lifespan, eliminating the crop in the first years after the plantation is crucial. In the following years, this activity will be applied to adjust fruit yields to balance canopy and fruit and achieve the best fruit quality. Even though fruit production is controlled at pruning, leaving a specific number of buds to reduce the potential yield and assisted by shoot thinning at the beginning of the season, crop thinning will be required depending on the vineyard goals.

Some cultivars are characterized to have extremely fruitful primary shoots with three or more clusters per shoot, which obliges the use of crop thinning. Some cultivars can even have fruitful secondary and base buds. Two very good examples are Seyval blanc and Vidal blanc. Due to their overproduction, eliminating clusters will be necessary to seek a balance in these plants.

When: crop thinning can be done starting from pre-bloom until before harvest. Timing of crop thinning will be important because the shoots and the flowers (also called inflorescences) or grape cluster are competing for resources in the plant. Therefore, the results can be different for the canopy and the fruit. It's possible to perform crop thinning pre-bloom or post-fruit set.

I. Pre-bloom: this consists of removing flowers, which can be done at the same time as shoot thinning. Eliminating the flowers at this stage can be faster as they are easy to see. According to the research results, performing this pre-bloom thinning can produce a higher fruit set (more berries) on the remaining clusters and potentially increase the vegetive growth. Moreover, the berries will be bigger at harvest, which can be negative in some cases since the cluster will be tighter and potentially increasing the risk of bunch rot. This practice is not recommended to be performed in the varieties with tight clusters, for example, in Seyval blanc.

The literature characterizes crop thinning at or close to fruit set with an increased concentration on the berries of phenolics (mouthfeel characteristics) and anthocyanins (colour) at harvest. Fewer clusters per plant allow the remaining ones to develop with less competition, and this would be helpful in small or weak plants.

II. Post fruit set: this strategy is more commonly recommended for cultivars with tighter clusters which are susceptible to bunch rot. At this stage, thinning may take longer due to the difficulty of seeing the fruit through the foliage. The advantage of this stage between fruit set and bunch closure would be the estimation by the growers on how much crop must be thinned to accomplish their goals. When thinned at veraison, all the fruit lagging ripeness will be removed based on the colour changed in red varieties.

4.3.1.d Leaf removal

Also called leaf thinning, leaf pulling or defoliation, this process consists of removing leaves around the cluster (fruit zone) to increase the sunlight and airflow exposure. This will reduce disease pressure, increase spray coverage and improve fruit ripeness. Another option is removing the laterals and retaining the basal leaves. It can be performed early, mid-season or at both times of the season depending on the plant characteristics.

Leaf removal is performed on the shade side of the canopy, depending on the vineyard's row orientation. Avoid removing leaves late in the season, as the result can be sun or heat-burned fruit. Exposing the cluster earlier to the sun will benefit the berries as they will produce more photo-protective flavonoids (like a sunscreen), which will provide the sun's protection. In the case of exposing the clusters later, at or around veraison, the increase of sunlight and heat may produce burn because these berries will have low levels of these photo-protective compounds.

In cool climates, leaf removal is a practical technique, especially early in the season for disease control and later to improve fruit ripeness. In areas like Willamette Valley in Oregon, removing leaves from the cluster zone from bloom to bunch closure reduces the disease incidence and increases fruit quality without sunburn. Moreover, the ripening period can be extended through October when the sun will be less intense. In this case, the leaves at the fruit zone will be completely removed, increasing berry temperature, which will help grape ripeness. Studies in Willamette Valley showed that fruit zone leaf removal reduces the incidence of Powdery Mildew and Botrytis bunch rot compared to vines without leaf removal. Fewer diseases result in more efficient canopies, more marketable crops and better grape quality.

The percentage of leaf removal can be from 40% to 100% of the fruit zone, requiring pulling out three to five leaves from the area. Usually, the intensity in red grape varieties will be higher than whites, but this can depend on the canopy density and the climate of the growing area. Also, it's possible to have a partial defoliation, which is the elimination of foliage from only one side of the vine. This will diminish the risk of sunburn depending on the climate. For example, in cool and sunny areas, the partial thinning on the cold side (the morning side of a north-south oriented row) would be beneficial.

How: it's possible to perform leaf thinning in two ways, by hand or machinery.

- **Hand thinning:** this type of removal can be more costly, but the fruit zone will be cleaner, and it's gentle on the fruit.
- **Mechanical thinning:** this equipment works by pulsed air or suction when cutting the leaves. They can be adjusted to different intensities, but the growers need to choose the proper equipment depending on their necessities.

4.3 CANOPY MANAGEMENT

It's important to highlight that the cost of leaf removal may not be fully recovered from the sales of the grape. Therefore, it's important to maintain a low cost and evaluate which varieties will benefit from this technique.

When: there are two distinct periods, one is called traditional (between fruit set and veraison), and the other is called early leaf removal (between pre-bloom and fruit set).

I. Traditional: this strategy is used to improve microclimate within the canopy, especially in the fruit zone. Increasing the light and temperature exposure of the berries will influence the ripeness process.

II. Early leaf removal: consists of removing the basal leaves, reducing photosynthesis, reducing fruit set and decreasing the number of berries per cluster. Additionally, the remaining berries will decrease berry size, reducing cluster compactness and yield effects. On the other hand, this will increase berry skin thickness and improve berry composition. This strategy would be beneficial for over-cropping varieties or susceptible ones to bunch rot due to tight clusters. However, this strategy wouldn't be recommended for varieties that produce low yields.

Whether traditional or early leaf removal, positive results can be achieved with this strategy. Here are some things to consider:

- Consider which varieties and which locations in the property.
- Timing and intensity are fundamental when considering the variety.
- For either strategy, traditional or early, start in small areas to evaluate.
- Keep records of crop yields, fruit composition, and quality to compare treated and untreated areas.

4.3.1.e Hedging

This practice consists of removing the excessive amount of primary and lateral shoots from the top and the sides of the canopy. If the thinning is done at the top of the canopy, it's called hedging, and for downward shoots, it's called skirting. The goal is to avoid shading and tangling of shoots, allowing people and machinery traffic through the rows. Even though the shoot length will diminish, this will not affect the plant's vigour and can induce lateral shoot growth.

When: it can be done once the shoots grow beyond the trellis space and they achieve the desired length. Depending on the local conditions, the number of hedging will vary from one to three passes. Don't hedge after veraison. This may delay fruit ripeness, reduce wood maturity and thus diminish winter hardiness.

4.3.2 FIRST HARVEST AFTER THE PLANTATION

After planning and planting the vineyard, the waiting period for the first harvest starts. The first two years after plantation, no crops can be harvested. These first years of the young grapevines are very important for establishing their root system to support them during their lifespan. Although plants can produce some fruits during the first two years, it's necessary to eliminate them to promote the proper plant development.

The plants gradually increase the yield through the first five years of plantation. It's possible to crop the first harvest in the third year after the plantation. However, keep in mind that the vine will still be undersized. Therefore, full production is generally expected to be reached in the fifth year.

Figure 3. Chardonnay with leaf thinning and nets

Figure 4. Vine before and after hedging (courtesy of Oregon State University)

5.0 PEST AND DISEASES

5.1 BACTERIAL AND FUNGAL DISEASES

5.1.1 ANTHRACNOSE

Anthracnose is also known as black spot, bird's-eye rot and bird's-eye spot. It is caused by a fungal pathogen (*Elsinoe ampelina*). Under warm and humid growing conditions of eastern North America, anthracnose can cause significant damage to grapevines by destroying new shoots and leaves and reducing fruit quality and yield. It can affect all aerial succulent parts of the vine, including young shoots, leaves petioles, tendrils and berries.

5.1.1.a Symptoms

Leaves

Initially, small, circular brown spots (1-5 mm in diameter) appear, which later turn gray in their centers and develop dark brown to black margins (Figure 1A). Older lesions may have circular or angular margins, and the necrotic centers usually drop out, creating a "shot-hole appearance" (Figure 1B). These lesions may coalesce and cover the entire leaf blade, followed by the death of the infected leaf. Young infected leaves at the shoot tips are malformed and appear burned as the lesions prevent their normal development (Figure 1C).

Shoots

The infection on young shoots start as small, reddish-brown, circular spots. Later, these lesions appear sunken with gray centers and dark brown round or angular margins (Figure 2A). The margins of the lesions may appear raised, and their centers may extend to the pith of the shoots. Later these individual lesions coalesce, and the blighted shoot may crack (Figure 2B and 2C).

Berries

The rachis and pedicels (these are the stems holding the berries to the bunch) develop lesions like on petioles and shoots as described above. If rachis is girdled, the cluster shrivels and dries. On berries, small, reddish-brown, circular sunken spots (5-7 mm) develop. Later, the centers of the spots turn whitish gray with reddish-brown to black margins, which resemble a bird's eye (Figure 3A). These lesions may ingress into the pulp, followed by cracking and invasion of secondary micro-organisms resulting in sour rot and poor juice quality. Severely infected berries look mummified due to shrivelling and drying (Figure 3B & 3C).

5.1.1.b Scouting

Vineyards should be monitored from mid-June to mid-September, with more frequent scouting between June to August.

- **When:** from phenological stage three (the first leaf unfolded to 4-6 leaves unfolded) to stage 12 (inflorescence visible). Monitor till harvest, particularly after rainfall and storm events, when the vines are wet for more than 12-hours.
- **Where:** throughout the vineyard.
- **How:** monitor young leaves for the appearance of small brown spots (1-5 mm in diameter), which later turn gray in their centers and develop dark brown to black margins.

5.1.1.c Confused with

Anthracnose lesions on the shoots may be confused with hail injury. However, unlike hail damage, anthracnose lesions have raised, dark-brown edges. In addition, hail damage occurs on only one side of the shoot, whereas anthracnose lesions are more distributed.

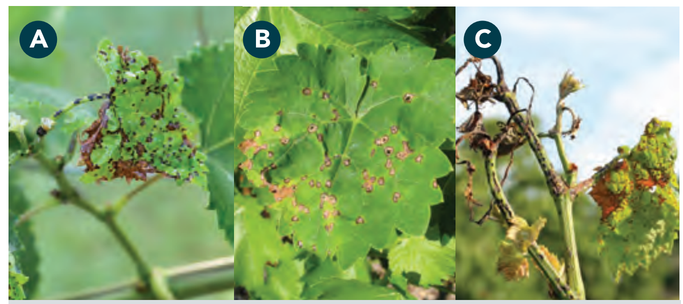


Figure 1. (**A, B**) Circular brown spots of anthracnose lesions with black margins on grape leaves, and (**C**) young shoots (Courtesy Texas A&M Agriculture and Life Sciences).

Figure 2. Anthracnose infections on shoots. (**A**) Small, reddish-brown and circular lesions (Courtesy Texas A&M Agriculture and Life Sciences, (**B**) older lesions with a flaky appearance, (**C**) crack on a blighted shoot (Courtesy Agriculture and Food, Western Australia).

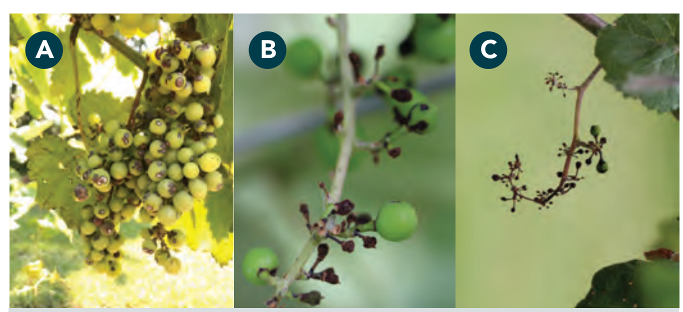


Figure 3. (**A**) Bird's eye spot on developing berries, (**B**) mummified berries with girdled pedicel and (**C**) rachis (Courtesy Texas A&M Agriculture and Life Sciences).

5.1.2 BLACK ROT

Black rot is caused by the fungal pathogen *Guignardia bidwelli* (also known as *Phyllosticta ampelicida*). Although it is an economically important disease in warm and humid regions, it poses a serious threat if moderate temperatures accompany rainfall in the late spring and summer. Unlike any other disease, Black rot can cause complete crop failure within a few days if not managed properly by fungicides. To date, it is the most challenging disease in organic vineyards. This disease affects all green tissues of the grapevine, including leaves, petioles, shoots, and young berries.

5.1.2.a Symptoms

Leaves

Circular to irregularly shaped lesions of 2-10 mm in diameter appear on the upper leaf surface. These lesions initially are cream-coloured (Figure 1A), becoming tan to reddish-brown and are delineated by a narrow dark-brown band (Figure 1B). The small black pimples of fruiting bodies (pycnidia) can be observed with a handheld magnifying glass (Figure 1C).

Stem

On petioles, small dark depressions appear, which may girdle and kill the entire leaf (Figure 2A). The symptoms on shoots appear as elongated black cankers ranging in length from 1 mm to 2 cm (Figure 2B).

Berries

The first symptom on the berries is observed as a cream-coloured dot, which is very quickly surrounded by a zone of chocolate-brown necrotic tissue (Figure 3A). This necrosis covers the entire berry until it turns dark. Eventually, the berry begins to shrivel into a hard, blue-black mummy that remains firmly attached to the pedicel. The black pimple-like fungal fruiting bodies cover the rotted berry's entire surface in a short period of time (Figure 3B and C).

5.1.2.b Scouting

- **When:** vineyards should be monitored from mid-June to mid-August at 2-3 or 4-5 fully expanded leaf stage (stages 9-12). Scouting should be more intense during rainy periods combined with temperatures above 9°C. The critical period for berry infection is from the end of flowering to the beginning of veraison.
- **Where:** throughout the vineyard.
- **How:** walk along rows and pick a sample every 20-30 paces and monitor for the presence of small brown lesions on leaves and fruit rot.

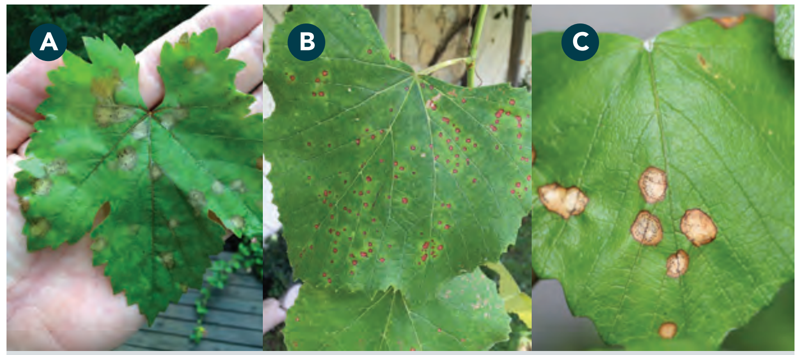


Figure 1. Black rot symptoms on grape leaves. (**A**) Creamy coloured lesions, (**B**) tan to reddish-brown lesions with dark brown band, (**C**) black pimple-like fruiting bodies of black rot fungus in the older lesions (Courtesy Texas A&M Agriculture and Life Sciences).

Figure 2. (**A**) Small dark depressions on the petioles, (**B**) elongated black cankers on the shoot (Courtesy Texas A&M Agriculture and Life Sciences).

Figure 3. Black rot symptoms on berries. (**A**) Cream-coloured lesions surrounded by necrotic tissue, (**B**) advance symptoms on the berry with black fruiting bodies evident, (**C**) mummified berries with black fruiting bodies (Courtesy Texas A&M Agriculture and Life Sciences).

5.1.3 BOTRYTIS BUNCH ROT AND BLIGHT

Botrytis bunch or gray mould is caused by a fungal pathogen (*Botrytis cinerea*). This disease is prevalent in all the world's vineyards but more severe in regions with moderate temperatures and high relative humidity between veraison and harvest. Serious economic losses in yield and quality are associated with pre-and/or post-harvest berry rot. Botrytis affects the wine quality by hindering clarification of wines due to the altered chemical composition of the diseased berries. Furthermore, the chemical action of its secreted enzyme (laccase) results in the browning of white wines and colour instability of red wines. For table grapes, the affected clusters are hard to market due to their poor quality. In addition, Botrytis infection remains undetected within clusters during transit as this pathogen can grow at near-freezing temperatures.

5.1.3.a Symptoms

Leaves

After prolonged periods of rain and fog, large irregular necrotic patches appear at the base of the leaves or at the edge of the leaf (known as lamina), where water droplets tend to accumulate.

Shoots

Early in the season, the infected buds and young shoots may turn brown and desiccate. Later in the season, patches of bleached bark develop, mostly surrounding a node where black resting structures of fungi (sclerotia) and grayish mycelium can be noticed. This pathogen can destroy the newly grafted grapevines due to its rapid colonization of the union between rootstock and scion.

Berries

An infection of young clusters appears as brown to black spots on rachis, calyptra and pedicels of the inflorescence. Under humid conditions, the entire cluster is blighted, and the grey cottony mycelium, along with long dark brown appendages, can be seen on the surface of the necrotic tissue. Depending upon the weather conditions, the early infection of Botrytis at flowering time remains inactive, and symptoms develop from veraison onwards. Typical symptoms of "slip skin" can be observed on the infected berries due to water-soaked lesions and shiny skin of the berries. Dead or aborted florets and fruitlets are mostly trapped within the cluster as bunches close. That's where fungus survive as a saprophyte and attack on healthy ripe berries which have become susceptible. This is one reason for bunch rot during storage conditions which is mostly accompanied by profuse gray mycelial growth and characteristic sporulation of this fungal pathogen on the rotting berries. These rotten berries are invaded by other secondary micro-organisms, which leads to "Sour Rot."

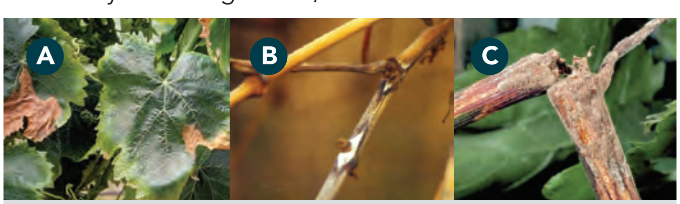


Figure 1. (**A**) Botrytis infection on leaves (Courtesy L. J. Bettiga), (**B**) infected young bud with bleached bark (Courtesy W. D. Gubler), (**C**) rotting of young tissue with sporulation (Courtesy J. K. Clark).

5.1.3.b Scouting

Vineyards should be monitored from mid-June to mid-July and from mid-August till the end of September.

- **When:** at phenological stages 19-21 (onset of bloom), and 35 onwards (during veraison). Monitor till harvest, particularly after rainfall and storm events, when the vines are wet for more than 12 hours.
- **Where:** throughout the vineyard.
- **How:** monitor drying out of the inflorescence, and the presence of rotten berries with or without grey mycelium, and sporulation during veraison.

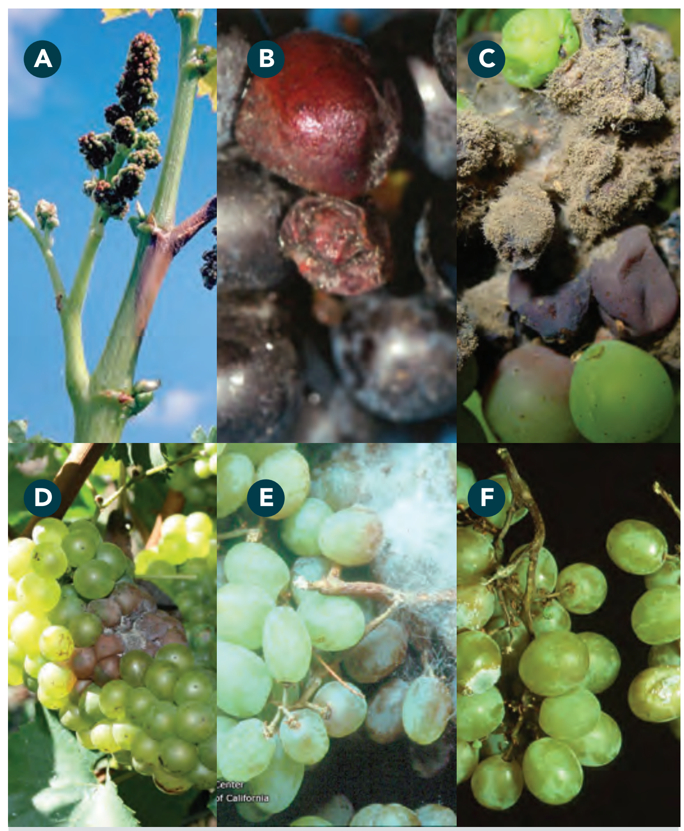


Figure 2. (**A**) Botrytis-blighted flower cluster (Courtesy W. J. Moller), (**B**) slip skin symptom due to water-soaked, shiny skin (Courtesy W. Mahaffee), (**C**) grey fungal growth with profuse sporulation (Courtesy Agriculture and Food, WA), (**D**) botrytis infection in the middle of the cluster (Courtesy Patty Skinkis), (**E**) mycelial growth of Botrytis, (**F**) secondary infection of Blue mould on Botrytis infected berries (Courtesy Carlos Crisosto, UC Davis).

5.1.4 CROWN GALL

Crown gall is caused by the bacterial pathogen *Agrobacterium vitis*. Grapevines grown everywhere are affected by crown gall, but it is a serious problem in areas with low winter temperatures. Its infection results in the development of fleshy tumours, which compromises plant vigour. Infected vines grow poorly or may die in case of heavy infection. The appearance of crown gall in grapevine nursery results in significant economic losses as the entire diseased plant is discarded.

5.1.4.a Symptoms

Stem

Fleshy galls are produced in response to infection by the bacterium and are composed of disorganized phloem tissue, parenchyma cells and vascular bundle. As the gall formation begins in the cambium (internal trunk tissue beneath the bark), it disrupts the normal flow of nutrients and may result in wilting of leaves and shoots, especially during water stress. Galls are mostly spherical and are observed on the lower trunk, often at graft unions near the soil line (Figure 1A - C). The portion of the vine above the galls may decline and die (Figure 1D-E). A higher incidence of gall formation has been observed in nurseries at the graft unions and above. Large galls can completely restrict young vines in just one season.

5.1.4.b Scouting

- **When:** at the time of planting and early in the summer for vines older than one year. It is important to scout during summers that follow a very cold winter and/or a winter with little snow cover. Vineyards should be monitored from mid-May to mid-June.
- **Where:** the lowest areas of the vineyard, where frost pockets and poor soil drainage may occur.
- **How:** note the presence of wilting, particularly during periods of drought. A large number of sucker growth or aerial roots is also indicative of crown gall. Inspect the base of the plants for the presence of galls.

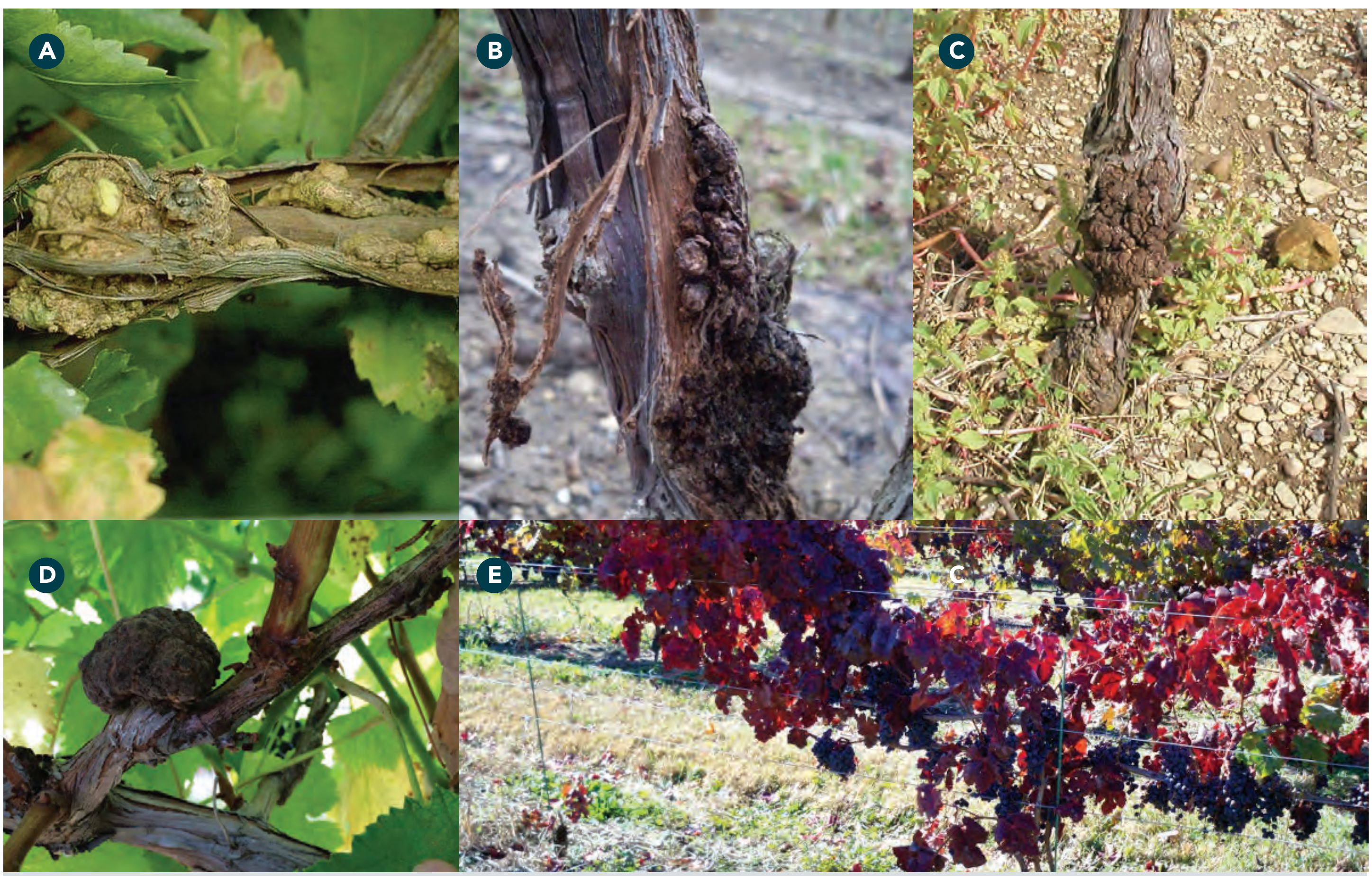


Figure 1. Gall development on the trunk at an early (**A**) and at late (**B**, **D**) stage (Courtesy Texas A&M Agriculture and Life Sciences), (C) crown gall development at graft union near the soil line (Courtesy Penn State Extension Wine & Grapes U.), (**E**) decline of vine due to gall formation at the trunk near soil line (Courtesy Texas A&M Agriculture and Life Sciences).

5.1.5 DOWNY MILDEW

Downy mildew is caused by the fungal pathogen (*Plasmopara viticola*), and it is the most serious grapevine disease in warm, humid summer climates. This disease affects leaves, inflorescences and young berries. The primary infection starts in spring (June) under moist conditions at temperatures >10 ˚C. The secondary spread of the disease is through asexual structures (sporangia). These sporangia produce motile zoospores, which swim in thin layers of water to cause new infections. Disease symptoms may appear within 4-6 days in favourable conditions (optimum temperature 18-25 ˚C).

5.1.5.a Symptoms

Leaves

The infection on the upper surface of young leaves starts as slightly darker and shiny circular lesions, which eventually turn to light green or yellowish and is referred to as “oil spot” (Figure 1A). Soon tiny necrotic specks can be observed within these lesions that turn reddish-brown (Figure 1B). The lesions are delimited by the leaf veins and appear angular in shape. Under humid weather, a white cottony mass of sporulating fungus can be easily observed beneath the necrotic lesions (Figure 1C). With repeated sporulation cycles, this cottony white mass turns light brown, and the entire lesion turns necrotic with age. Leaves bearing multiple necrotic lesions may droop and drop from the plant.

Stem

Infected shoot tips curl (“shepherd’s crook”), and a whitish mass of sporulating fungus can be observed on the stem.

Inflorescence

The inflorescence is highly susceptible to downy mildew. The rachis and pedicel turn greyish (gray rot) and droops (Figure 2A). Under humid weather, whitish sporulation of the fungus will be evident (Figure 2B).

Berries

The berries become less susceptible as they mature, but the pedicel remains susceptible to downy mildew infection. Infected berries of white cultivars turn dull gray-green (Figure 2C), whereas the infected berries of black cultivars turn pinkish-red prematurely. The infected berries remain firm compared to uninfected berries, which soften as they mature. Under humid conditions, whitish sporulation (or spore formation) can be easily observed on the infected berries.

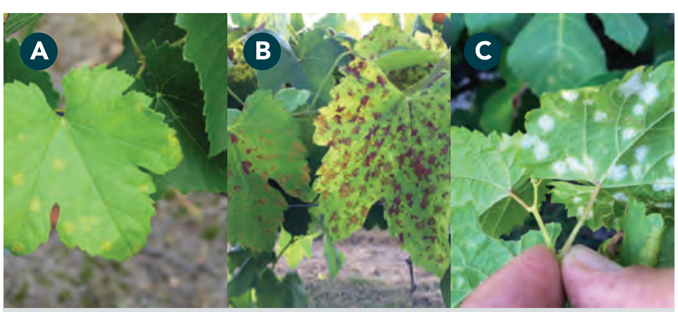


Figure 1. (**A**) Oil spot lesions of downy mildew on a young leaf, (**B**) reddish-brown lesions on an older leaf, (**C**) white cottony mass of sporulation of downy mildew on the underside of a leaf (Courtesy Texas A&M Agriculture and Life Sciences).

5.1.5.b Scouting

Vineyards should be monitored from early June to mid-September, with more frequent scouting between June to August.

- **When:** from first leaves unfolded (stages 5-7), particularly during periods of rain, heavy dew, and persistent fog at a temperature above 11°C.
- **Where:** downy mildew develops in shaded parts of the canopy. Special attention should be given to wet areas with heavy soils, poor drainage, depressions and abundant foliage.
- **How:** The appearance of characteristic “oil spots” on the upper leaf surface should be monitored (Figure 1A). Check the lower surface of necrotic lesions for the presence of cottony white sporulation of the fungus (Figure 1C).

5.1.5.c Confused with

Downy mildew can be confused with powdery mildew, which is caused by another fungal pathogen. The cottony white sporulation in the case of downy mildew is on the lower surface of the leaves, whereas powdery mildew’s sporulation is on the upper leaf surface. In addition, powdery mildew does not produce angular necrotic lesions on the infected leaves.

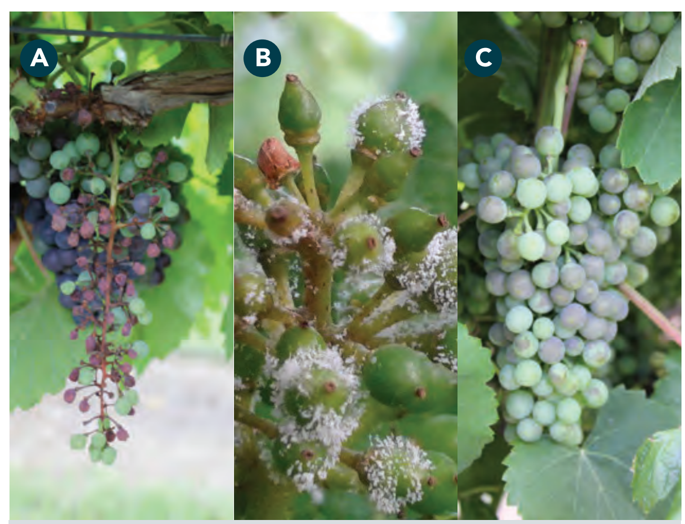


Figure 2. (**A**) Gray rot of pedicel and rachis (Courtesy Texas A&M Agriculture and Life Sciences), (**B**) whitish sporulation of downy mildew on young grapes (Courtesy Stocemgen), (**C**) dull-gray-green colour of downy mildew infected berries of the white cultivar (Courtesy Texas A&M Agriculture and Life Sciences).

5.1.6 POWDERY MILDEW

Powdery mildew is caused by the fungal pathogen *Erysiphe necator* (formerly *Uncinula necator*). It is the most consistently occurring disease of grapevines worldwide. This pathogen grows exclusively on the surface of the plant and appears as a conspicuous whitish powdery growth. This disease affects all green tissues of the grapevine, leaves, inflorescences and young berries.

5.1.6.a Symptoms

Leaves

Infection begins on newly emerged leaves close to the vine's trunk or arms, where fungal resting structures overwintered to initiate primary infection in early spring. Initial lesions appear as whitish, silver-grey, or light brown spots on the lower leaf surface but often go unnoticed. On rapidly growing young leaves, numerous lesions may cause the leaves to become puckered and distorted as they expand. On the upper leaf surface, somewhat circular white colonies of varying diameters appear as a sign of secondary disease spread. The conspicuous white powdery appearance of colonies is due to the mass of fungal threads and chains of spores forming on the leaf surface (Figure 1B). Colonies may also appear chlorotic (yellowish), which can be confused with "oil spot" symptoms produced by downy mildew (Figure 1A). Older colonies turn grayish and produce large numbers of yellowish to black sexual fruiting bodies called chasmothecia (formerly cleistothecia) that also act as overwintering resting structures (Figure 1C). Necrotic patches may be observed on the leaves either due to natural colony mortality, host response of resistant varieties, or the killing action of fungicide treatment. Severely infected leaves senescence, develop necrotic blotches and fall prematurely.

Stem

The initial infection on stems produces symptoms as those observed on leaves, but the affected areas turn black as the disease progresses. With cane maturity, powdery mildew colonies die, leaving dark, weblike scarring of the affected area (Figure 2A). Bud break of overwintered infected buds is often delayed, and leaves on severely infected shoots (flag shoots) may appear cup-shaped, dwarfed, or distorted even without conspicuous powdery mildew symptoms. The entire flag shoot may become heavily coated with white fungal growth (two weeks after shoot growth begins).

Berries

Pre-bloom and early infection of berries can severely affect their quality. The berry surface may become completely coated with the whitish powdery growth, and cease to expand (Figure 2B), causing the skin to split (Figure 2C). Other opportunistic fungal and bacterial organisms may cause rotting of the split berries, which shrivel and eventually drop from the cluster. The period of highest susceptibility to infection occurs between two weeks before flowering as the inflorescences expand to 3-4 weeks after flowering when the green berries develop. After that berries gradually become more resistant.

5.1.6.b Scouting

- **When:** vineyards should be monitored from late May-early June to mid-September with more frequent scouting between two weeks before and 3-4 weeks after flowering when berry infection is most likely to occur
- **Where:** throughout the canopy with special attention to the shaded parts where disease is favoured to develop.
- **How:** walk along rows and pick a sample every 20-30 paces from the interior of the canopy and look for discoloured spots and/or whitish growth on the upper and lower leaf surfaces. Disease is easiest to detect on leaves and can be used to indicate potential disease development on other plant parts.

5.1.6.c Confused with

Powdery mildew can be confused with downy mildew, which is caused by another fungal pathogen. The cottony white sporulation of downy mildew occurs only on the lower surface of leaves. In contrast, powdery mildew sporulation occurs on both upper and lower surfaces, but mostly the upper surface. In addition, powdery mildew does not produce angular necrotic lesions on diseased leaves.

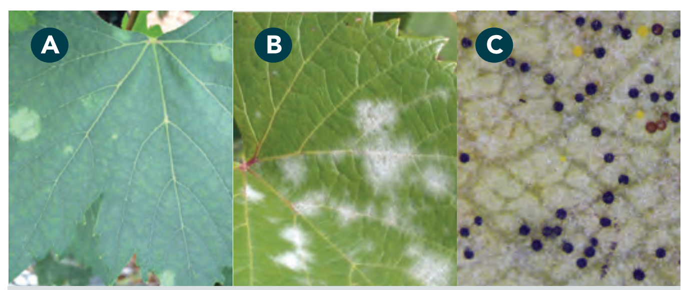


Figure 1. (**A**) Oil spot lesions during early stages of infection (Courtesy Texas A&M Agriculture and Life Sciences), (**B**) patchy white growth of powdery mildew on the leaf surface (Courtesy University Wisconsin Fruit Program), (**C**) yellowish to black fruiting bodies (Chasmothecia) of powdery mildew pathogen (Courtesy Agriculture and Food, Western Australia).

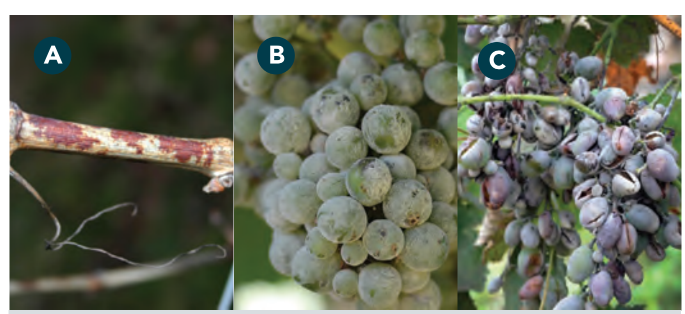


Figure 2. (**A**) Web-like scarring of cane by powdery mildew (Courtesy Texas A&M Agriculture and Life Sciences), (**B**) whitish powder of powdery mildew on developing berries (Courtesy University of California, Davis), (**C**) split-skin and mummification of ripe berries (Courtesy Becky Garrison).

5.2 INSECTS

5.2.1 GRAPE ERINEUM MITE

Grape erineum mite (*Colomerus vitis*) is found in many grape-growing regions of the world. It infects leaves that may drop earlier in the fall compared with uninfested leaves. The females overwinter under dormant bud scales and begin feeding on the sap at bud swell. They deposit their eggs when vines have two to three leaves unfolded on the mass of felt-like hairs on the lower leaf surface and complete one generation within 15-20 days. This species can have five to seven generations per year.

5.2.1.a Symptoms

Leaves

Both adults and the young feed within dense white felt-like hairs on the lower surface of the leaf (Figure 1A and 1B), which cause patches of concave blisters or galls (erinea) measuring about 5 to 10 mm in diameter on the upper surface of leaves (Figure 1D). Later in the season, the white felt-like hairs turn yellow and then reddish-brown (Figure 1C). An infected leaf may have 50 or more erinea (galls), and heavily infested leaves may drop earlier in the fall. In severe infestations, drying of young shoots may be observed at bud break in stage when vines have two to three leaves unfolded and later on the inflorescence.

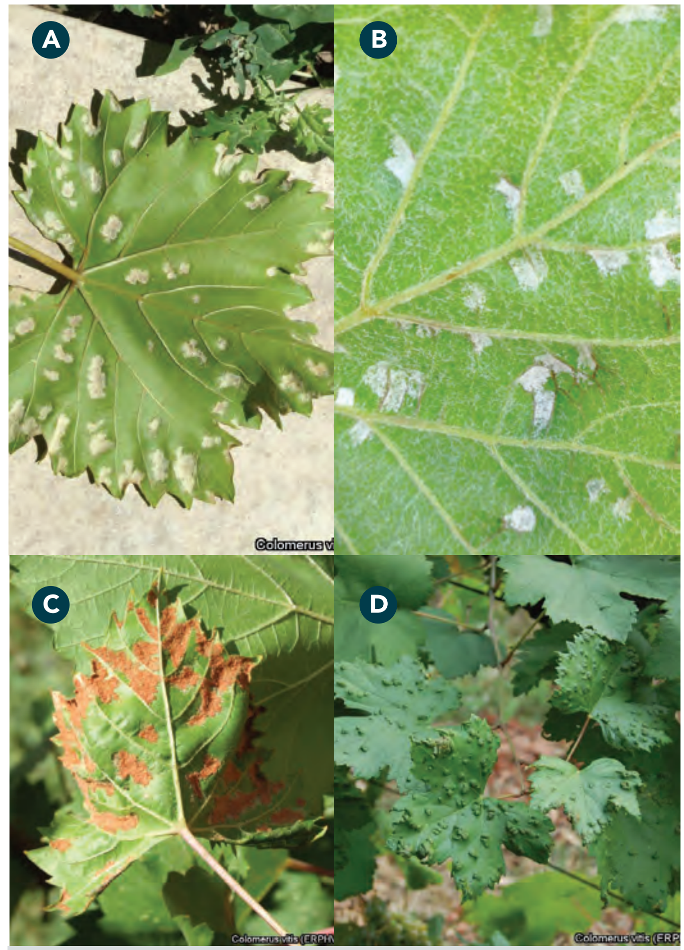


Figure 1. (**A**) Oil spot lesions during early stages of infection (Courtesy Texas A&M Agriculture and Life Sciences), (**B**) patchy white growth of powdery mildew on the leaf surface (Courtesy University Wisconsin Fruit Program), (**C**) yellowish to black fruiting bodies (Chasmothecia) of powdery mildew pathogen (Courtesy Agriculture and Food, Western Australia).

5.2.1.b Scouting

The first galls usually appear in stage of inflorescences clearly visible. Scouting in the vineyard should begin when flowers are separating. In case of a severe infestation in the last autumn, examine the foliage beginning of budburst. Look for blisters on the upper surface of leaves; they may have a reddish tinge on red varieties. The erineum mites should be present within the erinea on the undersides of the leaves.

5.2.1.c Confused with

The white stage can be confused with sporulating downy mildew, a fungal disease that does not produce blisters on the upper leaf surface.

5.2.1.d Management

- Predatory mites such as phytoseids and anystids are natural enemies of erineum mites. The establishment of flower beds or cover crops attracts natural enemies capable of reducing populations of erineum mites.
- Sulphur can be used early in the season to control powdery mildew and to reduce colonies of erineum mites.

5.2.1.e Identification

- **Egg:** the eggs are oval, smooth and whitish (Figure 2A).
- **Nymph:** there are two immature stages: the protonymph (PTN) measures about 0.05 mm long. The deutonymph (DTN) is about 0.15 mm long and resembles the adult.
- **Adults:** the adult is white to yellow, worm-like, and about 0.2 mm long and 0.05 mm wide. It has two pairs of legs and two long hairs at the tip of its body (Figure 2B).

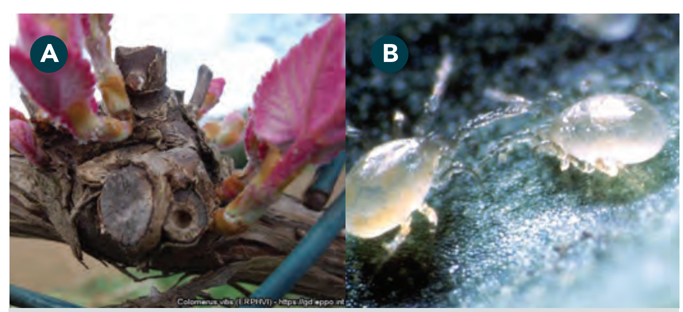


Figure 2. (**A**) Eggs of erineum mites (Courtesy Courtesy Ilay Mityushev, Russian Timiryazev State Agrarian University), (**B**) adult erineum mites on leaves of grape (Courtesy David G. James).

5.2.2 GRAPE FLEA BEETLE

Grape flea beetles (*Altica chalybea*) are native to North America and are present in Canada from the Atlantic to the Rockies (Figure 1 A, 1B). The adults feed on primary buds and cause severe economic damage. The adults' over-winter on the ground, under plant debris, and emerge in April to June to feed on young buds and shoots. The females lay their eggs near buds, and the larval development lasts for 3-4 weeks, after which it falls on the ground and pupate. The adults remain dormant till spring. Flea beetles have one generation per year.

5.2.2.a Damage

After emergence in the spring, the adults feed on the buds from wooly bud to two to three unfolded leaves, causing severe economic damage because of the destruction of primary buds and developing inflorescences (Figure 1E). No shoots are produced from the chewed buds, which leads to yield loss. After hatching, the larva feeds on the tissue between the veins of leaves (Figure 1C, 1D).

Over the summer, the adults do not cause any economic damage. Vineyard borders adjacent to woods or other protected areas are most affected. The risks of damage are heightened if the spring is cold and the bud break is delayed. The damage is occasional and varies greatly from year to year. In Quebec and the Atlantic provinces, the presence of flea beetles is due to migrations because of favourable weather conditions, namely, warm winds from the southwest before stage B 03.

5.2.2.b Scouting

Scout for adults and larvae beginning in stage of wooly bud until stage of single flowers in compact groups. Adults can be easily seen with the naked eye and jump when they are disturbed. Start monitoring as vines start to grow in the spring, especially if an area was infested by flea beetles in previous years. Vineyard edges near woods where alternate hosts for the beetle may be growing (wild grape and Virginia creeper) are prime areas for grape flea beetles. Abandoned vineyards can also be significant sources of this pest.

5.2.2.c Confused with

The early damage may be confused with damage caused by climbing cutworm. The cutworm larvae feed during the night only and are not visible during the daytime, whereas the grape flea beetle can be seen in the daytime.

5.2.2.d Management

- Remove plant debris from the outer borders of the vineyard.
- Lookout for flea beetle migrations associated with warm winds early in the spring.
- The grape flea beetle is considered a minor pest, but it can cause significant damage in some cases if enough beetles are present. A cool spring with slowly developing vines allows more time for the beetles to cause damage.

5.2.2.e Identification

- **Egg:** the eggs are pale yellow and cylindrical with rounded ends. They are 1 mm long and 0.4 mm wide and are laid under the leaves, under the loose bark of the canes and near the buds.
- **Larvae:** there are three larval stages. Newly hatched larvae (L1) are dark brown, but their colour lightens as they grow (Figure 1C, 1D). The young larva is covered with various-sized round or rectangular spots that become more pronounced as its body gradually becomes paler (L3). At maturity, the larva is 9 mm long.
- **Adults:** the grape flea beetle (*Altica chalybea*) (Figure 1A) is oval-shaped, 5 mm long and shiny black with a metallic blue colour. The lesser grape flea beetle (*Altica woodsi*) (Figure 1B) is 4 mm long and shiny black with a metallic green colour.

Figure 1. (**A**, **B**) Grape flea beetle feeding on leaves of grapes (Courtesy Oregon State University; University of California White Mountain Research Center), (**C**, **D**) feeding of flea beetle larvae on grape leaves (Courtesy Peachtree Corners), (**E**) adult flea beetle feeding on the buds (Courtesy of Tom Zabadal).

5.2.3 GRAPE PHYLLOXERA

Grape phylloxera (*Daktulosphaira vitifoliae*) is an aphid-like insect that initiates the formation of galls (swellings) by feeding on grapevine roots and leaves. This insect pest can severely damage and kill European grapevines (*V. vinifera*). The discovery that American grapevine species are resistant paved the way to develop inter-specific hybrids where American vines were used as rootstocks upon which popular European cultivars were grafted as the scion.

5.2.3.a Symptoms

Leaves

Gall formation on the lower leaf surface of the lamina is the most obvious symptom (Figure 1A, 1B). Leaf galls or swellings are produced due to the feeding and growing of nymphs and adults of phylloxera within these protrusions (Figure 1C). In severe infestation, gall formations compromise the photosynthetic potential of affected leaves, reducing shoot growth and grape yield.

Roots

Formation of nodosities and tuberosities (rounded bumps) on roots. Galls on mature roots are called tuberosities, whereas the infestation of immature feeder roots form smaller root swellings (nodosities) which can be identified by their hooked or clublike shape (Figure 2A). The most significant damage is caused by tuberosities on mature roots (> 5 cm), and their presence in large numbers on roots can lead to vine death (Figure 2B, 2C). Damaged roots impair their ability to take up water and nutrients and allow the entry of root rot micro-organisms (*Fusarium*, *Rhizoctonia*, *Alternaria*, *Macrophominia*, and *Phaeoacremonium* spp.), which can wrap the roots in a short period of time.

5.2.3.b Scouting

Nymphs and first galls can be detected through visual monitoring. Begin the visual survey at the beginning of bud burst. Walk the block and examine 100 young leaves at random. Females are present on the roots throughout the year. The first galls appear on the foliage in stage of two to three leaves unfolded. Subsequently, the formation of new galls on leaves continues until the first fall frost.

5.2.3.c Confused with

Foliar damage may be confused with the damage caused by grape erineum mite and grape tumid gallmaker.

5.2.3.d Management

- Rootstocks with pure American parentage have been resistant to phylloxera for more than a century now. Some of the interspecific hybrid rootstocks are *V. berlandieri* x *V. riparia* selections, including SO4, Teleki 5C and 420A Mgt; hybrids between *V. riparia* and *V. rupestris*, including 3309 Couderc, 101-14 Mgt, and Schwarzmann; *V. berlandieri* x *V. rupestris* hybrids, including 110 Richter and 1103 Paulsen.
- If large populations were present during the previous season, interventions should be synchronized as soon as the first eggs are observed in the galls. Later in the season, all stages of the phylloxera (eggs, larvae and adults) are within the galls and are beyond the reach of most insecticides.
- Establish beds of early blooming flowers to attract parasites (Braconidae, Ichneumonidae, Tachinidae) early in the season. These natural enemies can parasitize the grape phylloxera inside the galls throughout the season.

5.2.3.e Identification

- **Egg:** the newly deposited eggs are oval, bright yellow, and about 0.4 mm long and 0.2 mm wide. Prior to hatching, the eggs turn dark yellow and have two red eye spots at one end (Figure 1C).
- **Nymph:** emerging nymphs are similar in size to the eggs (Figure 1C). They go through four developmental stages before reaching maturity.
- **Adults:** females found in leaf galls or on roots are wingless, oval, 0.7 to 1 mm long and 0.5 mm wide. Young adults present in galls are pale yellow to orange, becoming golden brown with maturity. Radicola females are present on the roots and are pale green, light brown, or orange (Figure 2B).

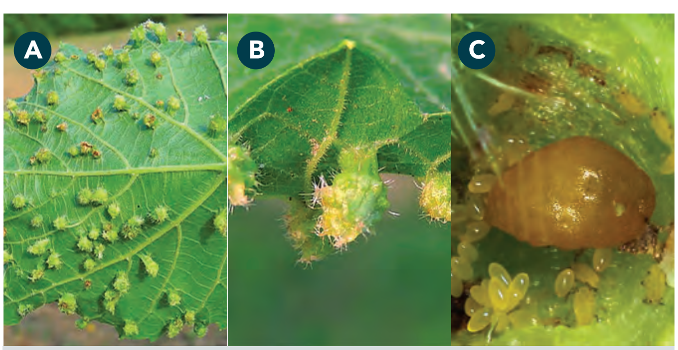


Figure 1. (**A**, **B**) Gall formation on the lower leaf surface (Courtesy Laszole Ersek Balatonfüred, 19.vii.2015), (**C**) feeding of Phylloxera nymph inside the gall (Courtesy Karl Hillig, New York, USA).

Figure 2. (**A**, **B**) Phylloxera nymph on feeder roots showing galling and root decline (Courtesy Dean Polk, New Jersey Agricultural Experiment Station; Agriculture and Food, Western Australia), (**C**) grape root with Phylloxera damage (Courtesy Michelle Moyer, Washington State University).

5.2.4 GRAPE LEAFHOPPERS

About nine species of leafhoppers have been identified in Nova Scotia. They use grapevine as a primary or alternative host. Leafhoppers can have two or three generations per year, depending on the species, and can overwinter in various forms. *Scaphoideus titanus* deposits its eggs in the bark of shoots and canes. Some *Erythroneura* species overwinter as adults under leaf debris. Some species do not overwinter in Canada and migrate every year. For example, Empoasca fabae is transported to Canada on wind currents from the northern United States in early June.

5.2.4.a Damage

Leafhoppers are piercing-sucking insects, and their damage varies depending upon the species. They feed on the sap from the leaves and young shoots (xylem, phloem, or mesophyll) of the grapevines. While feeding, the insect injects saliva containing compounds that block the plant's vascular system, reducing its vigour and growth. Major infestations cause leaves to turn brown and drop. For example, the feeding activity of *Erythroneura* spp. can cause white stippling or speckling on the upper surface of leaves as they remove green chlorophyll from the leaf cells during feeding (Figure 1). The greatest injury occurs on the basal one-third of leaves as leafhoppers prefer the inner canopy section. Early in the season, symptoms usually appear on the lower leaves of the vine in the fruiting zone and later in the season, the leaves gradually become discoloured. Potato leafhopper infected leaves appear as mottled with yellow margins and often roll or curl downwards (Figure 2).

In addition, some of these leafhoppers act as vectors of various diseases. While feeding, leafhoppers can acquire and transmit phytoplasmas present in plant vascular tissues. Phytoplasmas can cause grapevine yellows.

5.2.4.b Scouting

Leafhopper adults and nymphs can be identified and counted through visual monitoring or using a hand lens. They can be detected from stage of flowers separating to veraison. Walk in the block and examine the undersides of 100 leaves at random in the canopy. The observation of eggs can provide an idea of the size of future populations. Drought accentuates the damage caused by leafhoppers, whereas heavy rainfall reduces the incidence of damage.

5.2.4.c Confused with

Leafhoppers are sometimes confused with certain aphid species. In the case of the potato leafhopper (Empoasca fabae), the symptoms of feeding damage may be confused with those caused by lack of water, manganese deficiency, herbicide injury or leafroll virus.

5.2.4.d Management

- The diversity and relative abundance of leafhopper species depends on several factors, including grapevine variety, the history of leafhopper populations from the previous year and, for some species, the intensity of migration.
- Cool-weather with temperatures below normal and periods of heavy rain help reduce the number of leafhoppers native to vineyards.
- Flowering cover crops in the middle rows of the vineyard can encourage the presence and establishment of natural enemies. Populations of the predatory mite *Anystis* sp. and parasitoids (*Anagrus* spp.) promotes the natural suppression of leafhopper populations in the vineyard.

5.2.4.e Identification

- **Egg:** depending on the species, the eggs are about 0.5 to 1 mm long and are laid in clusters, deposited singly along the veins, or laid singly under the epidermis (Figure 2A). They vary in shape, and their colouration ranges from light green to dark brown.
- **Nymph:** newly hatched nymphs (N1) measure about 1 mm (Figure 1A, 1B, 2B). There are five nymphal stages (N1 to N5) which last 21 days on average. The cast skins (exuviae) may be visible on the underside of leaves.
- **Adults:** The adults are 2.5 to 5 mm long on average and vary in colour depending on the species (Figure 1C, 2C).

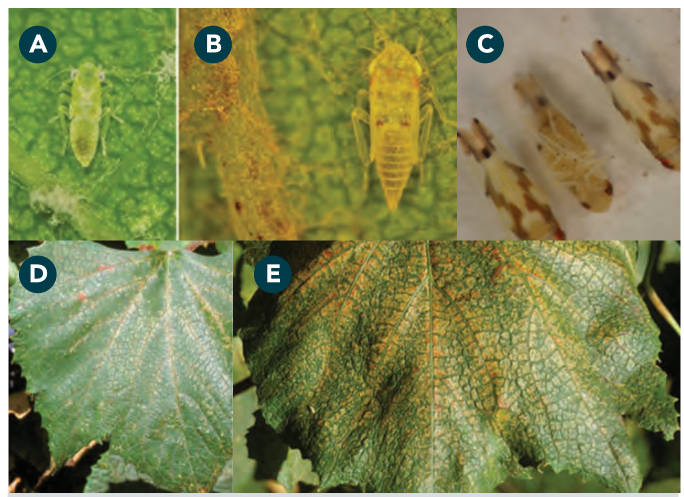


Figure 1. (**A**) Early, (**B**) ate instar, and (**C**) adult stages of eastern grape leafhopper (Courtesy Kevin Jarrel, Journal of Integrated Pest Management), (**D**) stippling along leaf veins as a sign of early damage, (**E**) necrosis on leaves and premature water stress in case of severe damage (Courtesy Tom Zabadal, Michigan State University).

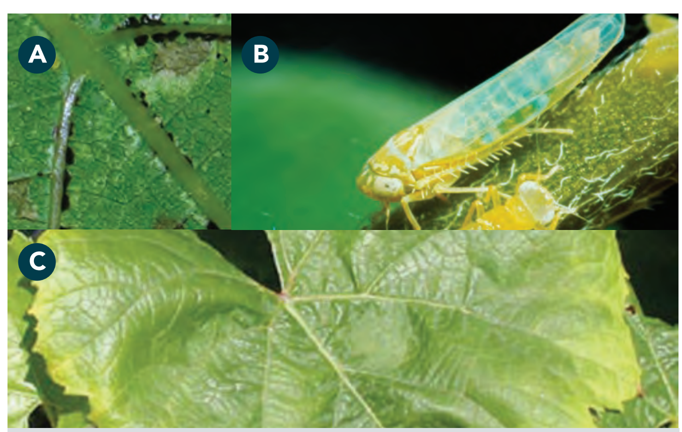


Figure 2. (**A**) Eggs of leafhopper, (Curtesy Saguez), (**B**) yellowish green adults of potato leafhopper with a long, wedge-shaped body (Courtesy Mid-Atlantic Orchard Monitoring Guide), (**C**) cupping and yellowish leaves after potato leafhopper feeding (Courtesy Rufus Isaacs).

5.2.5 SPHINX MOTH CATERPILLAR

Grape growers encounter two common species of hornworm caterpillars of sphinx moth in their vineyards: Pandora sphinx (*Eumorpha pandorus*) and Achemon sphinx (*Eumorpha achemon*). If not monitored, these caterpillars may cause severe defoliation. More than one base colour of caterpillars has been observed, which may be green, orange, rosy pink or dark brown (Figure 1). The adults are active only at night and are attracted to bright lights (Figure 2).

5.2.5.a Damage

These caterpillars feed exclusively on the leaves of the grapevines. Initially, small round holes are observed, and later the entire leaf can be consumed. Large caterpillars can eat several leaves daily. Young vines may suffer severely if the caterpillar has eaten a large proportion of their leaves. Still, large vines can tolerate their feeding injury without an impact on growth and fruit quality. A single hornworm caterpillar can defoliate entire small vines, which may lead to its death due to growth reduction. Fully grown caterpillars make tunnels in the soil and form a pupation chamber (Figure 2A) where they overwinter and emerge as adults in June or July.

5.2.5.b Scouting

Young vineyards should be monitored routinely for the presence of sphinx moth caterpillars. The first-generation of moths appear by the end of May or early June, and the second generation appears in mid-July.

5.2.5.c Management

- Caterpillars are heavily parasitized by flies and wasps, which keeps their number below the economic threshold in nature.
- The caterpillars can be removed by hand and disposed of easily or can be controlled using selective insecticide, for example, growth regulator methoxyfenozide.

5.2.5.d Identification

- **Egg:** The eggs are laid separately on grape leaves in late June or July. The caterpillars hatch two weeks later.
- **Caterpillars:** The caterpillars are bright green with a long horn on their tails. A series of black-margined whitish or light-yellow patches on their sides can be observed with the naked eye. During its development, the back-horn is replaced by a raised eyespot (Figure 1).
- **Adults:** Adult moths of Pandora sphinx are green coloured with reddish or pink markings and a wingspan of about 4-inches (Figure 2B). The Achemon sphinx has shades of light-to-dark brown and are marked with darker lines and patches. Their hind wings have patches of bright pink colour (Figure 2C).

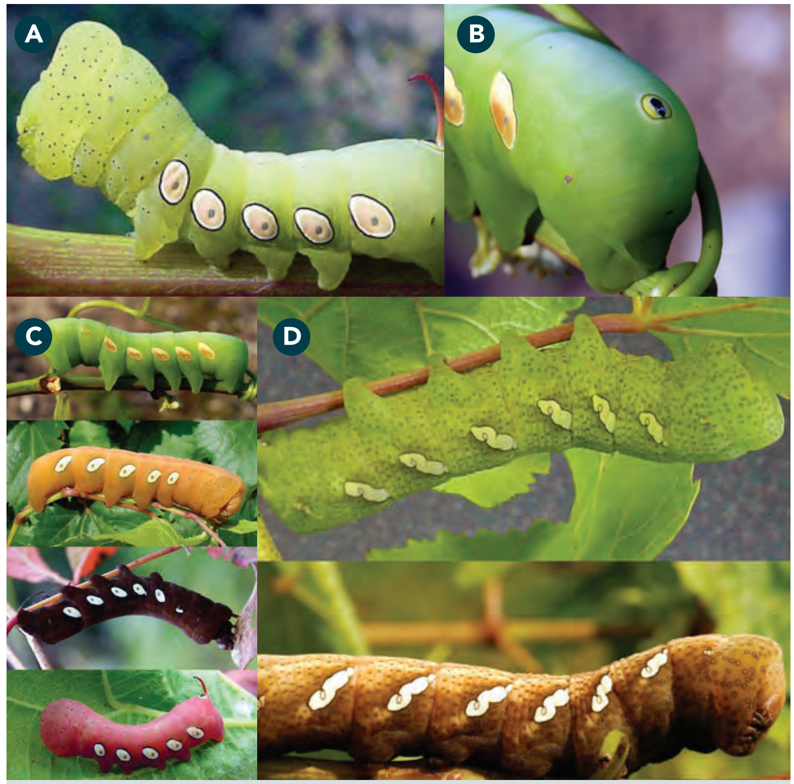


Figure 1. (**A**) Young Pandora sphinx moth caterpillar showing side patches and curled horn, (**B**) older caterpillar with eyespot marking on the tail end, (**C**) common colour forms of Pandora sphinx caterpillars, (**D**) two-colour forms of Achemon sphinx caterpillars (Courtesy Duke Elsner, Michigan State University Extension).

Figure 2. (**A**) Pupa of Pandora sphinx in soil chamber (Courtesy Duke Elsner, Michigan State University Extension), (**B**) adult Pandora sphinx moth (Courtesy Stephanie F), (**C**) adult Achemon sphinx moth (Courtesy Dider Descouens)

5.2.6 WASPS

Different species of wasps (Eastern and German yellow jackets, hornets) have been observed in eastern Canada (Figure 1). Wasps are social insects, and they live in colonies in their nests (Figure 1E). During the spring and early summer, they prey on insect pests such as caterpillars in fruit crops. But they become agricultural pests during late summer and are attracted to sugar sources like ripening grapes. Wasps can be a dangerous and disruptive pest for workers in the vineyard.

5.2.6.a Damage

Adult wasps feed on the pulp and juice of ripe grapes. They use their mouthparts to pierce the grapes' skin or exploit existing injuries (Figure 1). Prolonged feeding results in multiple wounds, and eventually, the grapes are emptied of their contents. Their activity increases considerably as the grapes ripe (late August to early September).

5.2.6.b Scouting

Monitoring is carried out when grapes are ripening on the vines when berries are ripening. Wasps and bees can be seen on the grapes.

5.2.6.c Confused with

The damage caused by wasps can be confused with the damage caused by birds and honeybees. But honeybees are slightly larger than wasps, are brown and black, and are covered with hairs.

5.2.6.d Management

- Check the ripening of the different grape varieties. Remove grapes before they become over-ripe to prevent losses due to feeding by wasps and bees.
- Overripe and damaged fruit should be removed from the grapevines.
- Perimeter trapping in early and midsummer can reduce the wasp population. Early season traps can be simple plastic containers with holes or commercial traps containing sugary bait such as apple cider or Mountain Dew or water and soap. Early season bait in the traps can include fresh meat or fish. It is recommended to put ten traps per acre around the perimeter of the vineyard.

5.2.6.e Identification

- **Egg:** The eggs are generally laid in cells within a nest and the larvae that are fed by the adults in the nest.
- **Adults:** They are yellow with black bands or black with white bands. Black, yellow, or white spots may be present. The different species are between 10 and 25 mm long. One distinguishing characteristic of wasps is the habit of folding their wings longitudinally over the body rather than the back when at rest.

Figure 1. Adult wasp feeding on grapes (**A**; Courtesy Bicanski on PIXNIO, **B**; Courtesy of Envatoelements, **C-D**; Courtesy Ontario Grape IPM, (**E**) wasp nest (Courtesy of DoMyOwn Pest control guide).

5.3 VIRUS DISEASES

5.3 VIRUS DISEASES

5.3.1 GRAPEVINE LEAFROLL DISEASE

Grapevine leafroll disease (GLD) is the viral disease of most economic concern for the wine industry and is found in vineyards worldwide. This disease is associated with a group of sequentially-named viruses called *Grapevine Leafroll associated Viruses* (GLRaVs), which are single-stranded RNA viruses belonging to the family *Closteroviridae*. Of this group, GLRaV-3 appears to be the most widespread and the main etiological agent of GLD. The effect of these viruses on grapevines varies depending on factors such as variety, scion/rootstock combination and the environment, but research from major growing regions has shown negative effects on overall vine health, production and profitability in *V. vinifera*. It is difficult to estimate the economic impact of GLD over the lifespan of a vineyard as it is influenced by factors such as vineyard age, level of disease pressure, yield losses and price penalties. Still, modelling work for *V. vinifera* 'Cabernet Sauvignon' production systems in California has estimated losses of $US 29,902 - 226,405·ha-1. While these international trends are worrying, it should be noted that to date, little research into the effects of GLD on hybrid varieties has been completed, but research is currently underway in Nova Scotia.

It is thought that GLD's ill effects are in part due to its localization in the grape's phloem tissue, where it impedes the flow of carbohydrates and other metabolites. Although GLD has been around for decades, if not centuries, the cause of this interruption has yet to be determined. The exact side effects can vary depending on the variety, but infected vines tend to have a lower yield, delayed fruit ripening and reduced berry and wine quality. Unfortunately, once a vine is infected with GLRaVs, there is no known cure, and no variety has been discovered with resistance that can be exploited using traditional breeding methods. As with other grapevine viruses, the primary source of GLD infection is through the use of contaminated budwood. Secondary infection is caused by vector transmission through phloem feeding by species of mealybugs (*Pseudococcidae*) and soft scale insects (*Coccidae*). Fortunately, it does not appear that GLRaVs are spread through regular mechanical vineyard maintenance with pruners, trimmers and harvesters.

It is surprising that a disease with such potentially negative consequences went largely undetected as the North American wine industry grew. This could in part be due to the widespread use of the vigorous AXR1 rootstock in Northern California. As growers replaced phylloxera-infected vines grafted onto AXR1 in the late 1980s with different rootstocks, GLD symptoms began to appear. It is thought that scions were infected all along, but previously GLD symptoms were masked by AXR1's vigour. Further complicating this is the expression of GLD in different *Vitis* species. Red berried *V. vinifera* can display the characteristic reddening, and downward rolling of leaves, but symptoms in white *V. vinifera* can be less pronounced. Infection can also appear latent in American *Vitis* species, interspecific hybrids, and rootstocks. For this reason, it is impossible to diagnose GLD based on symptoms alone. It is recommended that suspect vines be indexed using serological methods (i.e., ELISA) or molecular approaches (i.e., PCR).

While most GLD research to date has focused on major international growing regions, Nova Scotian growers should be alert, as Ontario has reported concerning symptoms linked to virus infections, of which GLRaV-3 is the most prevalent. Additionally, in cooler areas, viral diseases may prevent grapes from attaining quality thresholds for specific wine styles. GLD was confirmed in Nova Scotia in the mid-1990s, but to date little research has been completed on the *Vitis* hybrids that dominate our industry, nor its manifestation in cool climate regions. A study recently published by Poojari et al. (2020) indexed established Nova Scotian vineyards for a series of viruses and found GLRaV-3 to be the most prevalent, with 23% of samples testing positive. Both *V. vinifera* and hybrids were infected with infection rates in *V. vinifera* ranging from 8-12% and in hybrids 0-63%, with 'New York Muscat' having the highest incidence. It should be noted that the infection rates of specific varieties cannot be uncoupled from their propagation history. For example, 'L'Acadie Blanc' is a hybrid variety developed and propagated domestically in Canada, which may explain in part its low virus infection rate. This first study by Poojari et al. will play an important role in elucidating the impact of latent infections in hybrid varieties and will form the basis for management recommendations in Nova Scotia.

Figure 1. Grapevine leafroll disease in a red-berried ('Merlot')

5.3.1.a Symptoms

Research on GLRaVs has largely focused on red-berried *V. vinifera* varieties grown in warmer climates. Therefore the information on symptoms in white berried *V. vinifera* and other *Vitis* spp. is limited. Confounding this is the fact that symptoms can be less conspicuous or even latent in these varieties. Regardless, research to date indicates poor vine performance, significant reductions in fruit yield, and berry and wine quality.

Leaves

The most conspicuous symptoms of GLD involve leaves. In both red- and white-berried varieties, symptoms usually appear around véraison, affecting older leaves near the vine's trunk first before manifesting in younger leaves later in the season. In both berry types, leaves can also start to roll downwards as the season progresses. Leaves of some varieties roll considerably ('Pinot Noir,' 'Cabernet Franc,' 'Chardonnay'), while some do not roll as much, or at all. As the season progresses, the interveinal regions of red-berried *V. vinifera* leaves can also turn dark red/purple, with a narrow band of unaffected tissue on either side of the primary veins, leaving "green veins" (Figure. 1). In white-berried *V. vinifera* leaves can exhibit mild interveinal chlorosis or mottling (Figure. 2). That being said, GLD symptoms can vary with variety, scion/rootstock combination and growing conditions.

Stem

There are no specific visual symptoms associated with stem development, but GLRaVs target the grapevine's phloem and impede the flow of carbohydrates and metabolites.

Inflorescence

To date there are no specific visual symptoms associated with inflorescence development.

Berries

As with other symptoms, most work has focused on red-berried *V. vinifera*. It is thought that GLD negatively affects yield and berry quality by disrupting phloem flow. In red-berried *V. vinifera*, this can negatively affect fruit cluster number, yield, fruit ripening, berry sugar and anthocyanin levels and wine quality.

5.3.1.b Scouting

GLD cannot be accurately diagnosed based on symptoms alone. Serological tests such as ELISA or molecular testing by PCR are necessary to confirm the diagnosis, but scouting the field for conspicuous symptoms around véraison is a good idea. It should be noted that some varieties and interspecific hybrids can harbour latent infections, which can serve as sources of inoculum.

- **When:** late summer / early fall, or the onset of véraison. This is also a good time of year to sample older leaves for PCR testing.
- **Where:** older leaves near the trunks of vines.
- **How:** visual inspection. Keep an eye out for leaf discolouration and rolling.

5.3.1.c Note on management recommendations and insect vectors

Management recommendations continue to evolve as more research is completed in our growing region. Roguing of symptomatic vines could be one option when disease pressure is low, but more information is needed on insect vectors in Nova Scotia. Preliminary research has confirmed the presence of potential vectors (mealybugs and scale insects) in Nova Scotia, which can be monitored visually and by using sticky tape bands. To date, populations are very low and localized, and therefore chemical control has not been warranted.

5.3.1.d Confused with

LRD has been confused with grapevine red blotch disease (GRBD) and vice versa. Symptoms of LRD in red-berried *V. vinifera* can also be confused with nutrient deficiencies and mechanical damage.

Figure 2. white-berried ('Chardonnay') variety (Sudarsana Poojari, CCOVI, Brock University)

5.3.2 GRAPEVINE RED BLOTCH DISEASE

Grapevine red blotch disease (GRBD) is a newly-described grapevine disease that is quickly generating concern in the international grape and wine industry. GRBD is caused by *Grapevine Red Blotch Virus* (GRBV), a single-stranded DNA virus of the family *Geminiviridae*. Research on the effects of GRBD is just starting, but it has been found to affect berry quality through delayed ripening, reduced total soluble solids and anthocyanin content. Several studies have reported yield reductions, but further research is required to explore the interplay of variety, environment and genetic strain of GRBV. The economic impact of GRBD infection over the lifespan of a vineyard is influenced by factors such as vineyard age, disease incidence, and price penalties. However, estimates range from $US 2213/ha in eastern Washington for 'Merlot' to $US 68,548/ha in Napa County, California for 'Cabernet Sauvignon'. The estimated economic impact is lower than grapevine leafroll disease (GLD), largely due to gaps in our understanding of GRBD. While most research to date has been completed in other growing regions, and has focused on *V. vinifera* varieties, research is underway on the impacts of GRBD in Nova Scotia production systems.

Much like GLD, it is thought that the negative effects of GRBD are in part due to impeded carbohydrate translocation in the phloem of grapevine leaves, but the cause remains unknown. There are no known cures for grapevine viruses, and mitigation via management techniques will likely be challenging. Like other grapevine viruses, the primary source of infection appears to be contaminated budwood. Preliminary research has identified the three-cornered alfalfa treehopper (*Spissistilus festinus* [Say]) as a vector of GRBV, but this is largely based on greenhouse work. In New York State to date, secondary spread of GRBV has not been reported, which is consistent with the absence of *S. festinus* but could also be related to the lack of GRBV in free-living *Vitis* spp. adjacent to vineyards. It should be noted that *S. festinus* is also not believed to be present in Canada.

The disorder that would eventually be named GRBD was first reported in 2008, but since that time, testing of an herbarium sample collected in 1940 in California confirmed its presence long before. It may have proliferated unnoticed as its symptoms are similar to GLD. Symptoms can vary with variety and growing conditions, and mimic abiotic stressors such as nutrient deficiency and mechanical damage. Further complicating this is the lack of research involving non-*vinifera* grapes. For these reasons, GRBV infection cannot be confirmed based on symptoms; it is recommended that vines be tested using molecular approaches such as PCR.

To date, most grapevine virus research has focused on major international growing regions, but they are increasingly becoming a concern in Canada. Combined with the lack of research on hybrid varieties, is the concern that viral infection may negatively impact the already limited ripening window of cool climates. A recent survey of established Nova Scotian vineyards confirmed the presence of GRBD, albeit at lower rates compared to GLRaV-3. Both *V. vinifera* and hybrid vines were infected with GRBD, but 'New York Muscat' in particular had a high incidence of infection at 18% of samples. Although more research is needed to make specific management recommendations for Nova Scotia growers, their presence in our vineyards, and research completed in other regions of Canada suggest that they could be a concern.

Figure 2. Grapevine red blotch disease in a red-berried ('Cabernet Franc')

5.3.2.a Symptoms

Grapevine red blotch disease is relatively newly-described, and most research has been completed on *V. vinifera* in warmer climates. Symptoms differ by variety and growing region but can include delayed berry ripening and reduced berry quality.

Leaves

The most conspicuous symptom of GRBD is in red-berried *V. vinifera*, with the appearance of red blotches on older leaves at the base of vines in late summer that can coalesce as the season progresses. Symptoms in white-berried *V. vinifera* are not as pronounced but can include chlorotic spotting of leaves that can progress to necrosis later in the season. It is thought that symptoms may be due to higher quantities of carbohydrates found in symptomatic leaves.

Stem

To date, there are no specific visual symptoms associated with stem development. Still, it is thought that the negative effects of GRBD are in part due to impeded carbohydrate translocation in the phloem of grapevine leaves.

Inflorescence

To date there are no specific visual symptoms associated with inflorescence development.

Berries

Many of the reported negative side effects of GRBD have focused on berry development. In general, a delay in ripening and a reduction in total soluble solids and anthocyanins are observed, which can negatively affect wine quality. Some studies have also observed yield reductions and fewer clusters with larger berries, but more research is needed to clarify the effects of variety, environment and genetic strain of GRBV on these parameters.

5.3.2.b Scouting

The presence of GRBV can only be confirmed by diagnosis using molecular techniques such as PCR. That being said, keeping an eye out for proposed vectors and for symptoms is encouraged. It should be noted that some varieties and interspecific hybrids can harbour latent viral infections, which can serve as sources of inoculum.

- **When:** late summer/early fall, or the onset of véraison. This is also a good time of year to sample older leaves for PCR testing.
- **Where:** older leaves near the trunks of vines.
- **How:** visual inspection. Keep an eye out for leaf discolouration and an absence of rolling.

5.3.2.c Note on management recommendations and insect vectors

More research needs to be completed in our growing region before management recommendations can be made. Roguing of symptomatic vines could be one option when disease pressure is low, but more information is needed on insect vectors in Nova Scotia. The three-cornered alfalfa treehopper has been implicated in GRBD spread, but it is not known to be present in Canada.

5.3.2.d Confused with

It is thought that GRBD escaped notice for many years due to its similar symptomology to GLD. Although not consistently observed, differences between the two disorders include the presence of red veins and an absence of leaf rolling in red-berried *V. vinifera* with GRBD. GRBD can also be confused with biotic and abiotic stressors.

Figure 2. white-berried ('Chardonnay') variety (Sudarsana Poojari, B. CCOVI, Brock University)

6.0 PRODUCTION

In this chapter, the phonological stages of grapes, starting from budburst until harvest, will be explained. You will also find information about the techniques to protect the grapes and parameters to track berry ripeness. Finally, some important remarks about communication between grape growers and winemakers will be shared.

6.1 PHENOLOGICAL STAGES

The grapevine goes through phenological development stages during a year, known as the annual growth cycle. The main phenological stages are budburst, bloom, fruit set, cluster closure, veraison and ripening. Observing and tracking these stages in the vineyard is important for implementing efficient and accurate vineyard management practices. Moreover, it allows grape growers to make predictions based on historical data of the growth stage dates from the previous years.

6.1 PHENOLOGICAL STAGES

The annual growth cycle of the grapevine for the season can be explained as follows:

6.1.1 Budburst

The end of the winter dormancy in the vineyard is signalled with weeping, the bleeding of the xylem sap. It's followed by budburst, which is the first event of the growing season. The buds start swelling, and they eventually break. After the budburst, the leaves start to be separated, and the shoots start to elongate. During this period, buds and new shoots are susceptible to spring frost.

6.1.2 Bloom

As the shoot growth continues, inflorescences, which are the future clusters, are formed on the tips of the young shoots. The individual flowers on the inflorescence start to be separated. Afterwards, the top part of the petals, the cap, starts u to fade its colour from green to brown and eventually fall. After the cap is dropped, it's possible to see the fully exposed individual flowers.

Afterwards, the pollination takes place. Most commercial cultivars have "perfect flowers," meaning that both males and females are found in the same flower, which makes self-pollination possible. During this period, adverse weather events, such as cold, heavy rain or wind, can negatively impact pollination.

6.1.3 Fruit Set

The pollination of flowers is followed by fertilization and fruit set, which initiates the berry development.

Occasionally some of the fertilized flowers may not be able to set the fruit. In some susceptible varieties, fruit abscission can occur after fertilization. This disorder is called inflorescence necrosis or *coulure*. It causes a yield decrease due to grape bunches with missing berries. On the other hand, irregular fruit set can cause the formation of berries without the seed, and they cannot grow as much as normal berries. This causes unequal development of berries and having different sized berries within the same cluster. This situation is called hens and chicks, also known as *millerandage*.

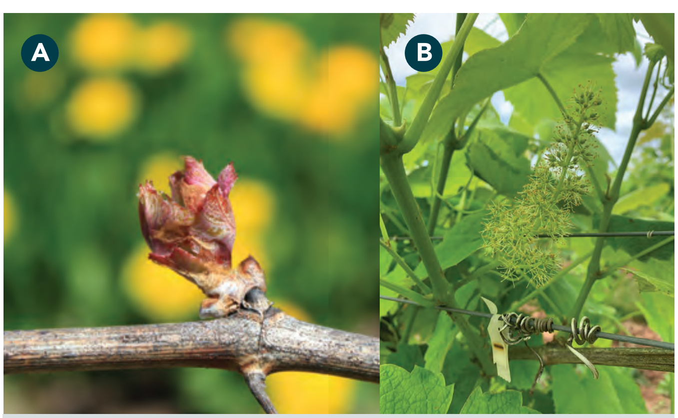


Figure 1. A. Bud burst, B. Bloom

6.1.4 Cluster Closure

After the fruit set, the formed berries start to increase their size. They grow from peppercorn size to pea size until cluster closure occurs. In this stage, berries start to touch each other in tight bunches.

6.1.5 Veraison

Following cluster closure, verasion takes place. Until veraison, both white and red grapes are hard and green. With the beginning of veraison, the berries start to soften. The white grapes start to change their colour from green to yellow and gold, while red grapes from green to red and purple.

6.1.6 Ripening and Harvest

After veraison is completed, the ripening period begins, and it continues until the grapes are harvested. The changes in the grapes and parameters to track during the ripening period are discussed in detail in the corresponding section of this guide. The grapes are harvested when the desired maturity level is reached. If any spraying takes place in the vineyard during the ripening period, it's important to take into consideration the last application date and harvest date to ensure the absence of chemical residues. Once harvested, the grapes continue their journey in the wine cellar.

After the harvest during autumn, the leaves start to fall, the shoots begin to lignify, and reserves of nutrients are stored in the roots and woody parts of the vine. This is an important part of the vines cycle since these stored nutrients will be necessary for the shoot growth early in the following season. As the growing season terminates and the weather becomes colder, the vines start their winter dormancy period.

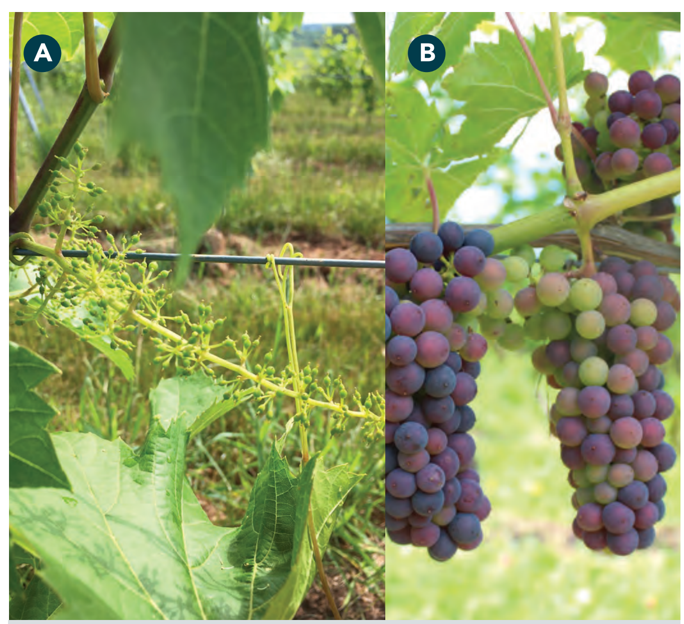


Figure 2. A. Fruitset, B. Veraison

6.2 GRAPE PROTECTION

Starting from veraison until the harvest time, one consideration in the vineyard is to protect the fruit zone from birds, raccoons and deer. If the grapes are not protected, these animals can cause large damage or loss. The most frequently used grape protection strategies in Nova Scotia are netting, fences, sonic devices, kites and a combination of these.

6.2.1 Nets

One of the most common ways to protect the bunches is netting. The nets are placed so that the fruit zone is covered from the top of the bunches until below the first wire. In some cases, nets can be placed in a way that they cover two rows completely at a time. Regardless of the coverage method selected, it's important to ensure proper coverage of the fruit zone. It's necessary to fasten the edges of the nets with staples/clips/pegs to prevent birds or raccoons from entering inside.

6.2.2 Fences

Electric fencing is used as a strategy to prevent raccoons from visiting the grapevines. For the most efficient results, protecting the entire perimeter of the property is necessary. To ensure the correct voltage along the whole fence, the area where the wires are located must be connected properly. Making some measurements before setting up the fence is recommended. Keeping the area clean from weeds will prevent short-circuiting and allow the proper functioning of the electric fence.

6.2.3 Sonic Devices

Sound repellents that are used to help with the protection of the vineyard include sonic devices and cannons. The following guidelines must be kept in mind when using sonic devices:

1. There should be a distance of at least 175 m (575 ft.) between a sonic device and any of the following if it is set to emit sound above 100 decibels.
   a. a private dwelling other than the property on which the sonic device is located
   b. public road or public pathway
2. For a sonic device that is set to emit sound of 100 decibels or less, the minimum separation distance may be reduced to125 m (410 ft.).
3. There should be a distance of at least 75 m (245 ft.) between any two sonic devices in use.
4. Directional sonic devices should not be pointed in line with a crop row, or in the direction of any of the following:
   a. private dwelling;
   b. public road or public pathway.
5. Where practical, sonic devices should be moved weekly so birds and animals do not get use to their location.
6. A sonic device should be fired only during the period between 30 minutes before sunrise and 30 minutes after sunset.
7. The maximum frequency at which a sonic device should be fired is either
   a. 1 activation every 5 minutes; or
   b. 12 activations every hour.
8. A farmer may obtain written consent from their neighbours to a shorter minimum distance than indicated above.
9. Minimum separation distances may be reduced if there are no private dwellings, public roads or public pathways adjacent to the farm property, or a large buffer exists (example trees, hill, watercourse) that will buffer the noise.

Visual devices, such as kites or scare-eye balloons, can be used as a bird management system. Finally, the combination of different strategies will help the management and protection of the crop before harvest.

Figure 1. Vineyard during the process of netting the fruit zone.

Figure 2. Grapevines with netting completely protecting the fruit zone.

Figure 3. Electric fence protecting the perimeter of the vineyard.

Figure 4. Kite combined on the left with netting and on the right with a sonic device.

6.3 GRAPE RIPENING

Grape ripening is the period that starts at the end of veraison and finishes at the harvest. There are different metabolism activities happening during this period, such as accumulation of sugar and minerals, variation in acid content, the evolution of aromatic and nitrogen compounds, production of phenolic compounds and changes in the cell wall. Although these changes are happening simultaneously, they don't happen at the same rate. The rate of the grape ripening depends on the variety and on the seasonal conditions. It's also directly affected by the vineyard management. In the following table, it's possible to see the changes in the berries from the beginning of their formation until the end of ripening.

6.3 GRAPE RIPENING

6.3.1 Grape Ripening Parameters

Ripening, as it interests growers, wine producers, and consequently to consumers, consists of increased sugar, decreased acidity, development of colour, flavour, and aroma compounds. To better understand the process and decide on the harvest date, it's necessary to measure different parameters and track the changes caused by various metabolic activities in the berries. The ripening parameters are monitored periodically for different plots and varieties and interpreted to decide optimal harvest date depending on the final objective and style of the wine to be produced. The grapes that reach an optimal chemical and physical composition depending on the grape variety, environmental conditions and wine style are considered ripe. The grapes that are harvested at the optimal time are of paramount importance for the wines' quality.

Depending on the ripening conditions of the vineyard, the grape sampling and analyzing can begin after the veraison. The frequency of the sampling and analyses is recommended to be increased getting closer to the harvest date, for example, from weekly to every other day or daily, depending on the weather and ripening conditions.

6.3.1.a Sugar parameters

Accumulation of sugar in the grape is the most important change during ripening. It can be tracked with the following parameters:

- **Brix:** it measures total soluble solids in the must (grape juice) as grams per 100 ml. It's possible to find other measurements used (specific gravity, density, Baumé, Oechsle…). However, brix is the most frequently used in North America. Since brix measures all the total soluble solids, before a certain brix level (15 – 18 brix according to different references) is reached, the other soluble solids such as organic acids may interfere with the results. Therefore, this measurement indicates berry sugar content after a certain maturity level is reached.
- **Glucose and fructose:** they are the main sugars in the must that the yeasts can use for alcoholic fermentation. Their concentration determines the sweetness in the pulp. It's measured as grams of glucose and fructose per litre.
- **Potential alcohol:** knowing the total fermentable sugar content in the must makes it possible to calculate the potential alcohol of the wine. The estimations of potential alcohol take into account the sugar/alcohol transformation ratio. As a general number, 17 grams of sugar per litre is utilized to produce 1% alcohol. Although it may vary due to different fermentation parameters, this estimation allows us to have an idea of the alcohol level of the future wine before the alcoholic fermentation process.

6.3.1.b Acidity parameters

The grape contains various organic acids from the beginning to the end of its development, and their amounts show different tendencies due to their accumulation or utilization. Acidity parameters are important to evaluate the grape maturity, along with the sugar parameters. The temperatures highly affect acidity at a given degree brix during the ripening period. The following parameters are used to track the acidity:

- **Total acidity:** it's a measure of all types of acids in the must, including organic acids such as tartaric acid, malic acid, citric acid and others, amino acids and inorganic acids such as phosphoric acid. The total acidity (also known as titratable acidity) is generally expressed as grams per litre of tartaric acid equivalents in North America. The balance between acids and sugars is one of the most critical aspects of winemaking.
- **Tartaric and malic acid:** tartaric acid is the main organic acid found in grapes, along with malic acid. They are both expressed as grams per litre. While the tartaric acid amount in the berries doesn't show a remarkable decrease during the ripening period, malic acid decreases as the grapes ripen. For this reason, malic acid tends to be higher in cool climate regions and cooler vintages, as it cannot decrease due to lack of temperature towards the end of their ripening period. Due to the specific tendency of tartaric and malic acid concentration during ripening, their ratio can be used as a maturation indicator. It varies depending on the grape variety and maturation conditions. In terms of wine, both of these acids are important for the stability and sensory characteristics of the wine.
- **pH:** it's determined by the sum of the acids and cations and defined mathematically as log subscript ten of the concentration of hydroxonium ions. Also known as "true acidity," it's one of the key parameters for winemaking for direct influence on chemical and microbiological characteristics of the wine. The pH values of must and wines range from 2.8 to 4.0.

6.3 GRAPE RIPENING

6.3.1.c Other important parameters

- **Berry weight:** as shown in Figure 1, berry weight increases until reaching a maximum weight during ripening. Periodically measuring berry weight for different grape varieties and plots helps to understand when the maximum weight has been reached. More importantly, it allows to better evaluate berry composition, acid and sugar concentration in a more precise way. Occasionally, under warm conditions, after reaching the maximum point, berries can begin to dehydrate, which is possible to observe by tracking their weight. As a common practice, 200 berries are weighted and expressed as grams.

- **Potassium:** potassium (K+) is a highly important macronutrient for various physiological and biochemical processes in vines. It's a critical cation for the uptake of other ions and sugars. During grape ripening, as sugar accumulation proceeds, K+ accumulates rapidly in the berries. The amount of K+ accumulated during ripening depends on the grape variety and environmental factors. Its concentration in the must is generally expressed as milligrams per liter. From the wine perspective, it has a strong influence on juice pH. Therefore it's important for wine acidity, colour, microbiological stability and fermentation process.

- **Yeast Assimilable Nitrogen (YAN):** total yeast assimilable nitrogen (YAN mg N/L) includes all nitrogen sources (amino acids, ammonia and peptides up to five amino acids in length) that can be assimilated and metabolized by yeasts. It's valuable to measure enological data before alcoholic fermentation to secure a healthy growth and activity of yeasts for a complete fermentation. Knowing this value before fermentation allows the winemakers to make any necessary nutrient additions in cases where it's not at sufficient levels.

- **Phenolic compounds:** phenolic compounds, mainly anthocyanins and tannins, are very important for wines, especially for red wines, since they contribute to the colour, mouth-feel and stability of wines. Therefore, there is an interest in assessing the phenolic maturity by measuring the concentration of phenolic compounds in grapes and the ease with which they are released.

- **Aromatic compounds:** there are several hundred different chemical compounds that contribute to grape aroma. Most of these aromatic compounds (with some exceptions, such as methoxypyrazines that contribute to green aromas) increase during the ripening period. The type and amount of aromatic compounds in the grapes depend on their variety, environmental conditions and vineyard management practices. The concentration of specific aromatic compounds in the grapes can be measured through lab analysis. Moreover, sensory evaluation of berries indicates the aromatic potential of the grapes.
  In terms of wine, the grapes aromatic maturity is paramount for the aromatic intensity and quality of the wine.

For unhealthy grapes, volatile acidity and gluconic acid can be measured to quantify the contamination by yeast or acetic acid bacteria and botrytis, respectively.

6.3 GRAPE RIPENING

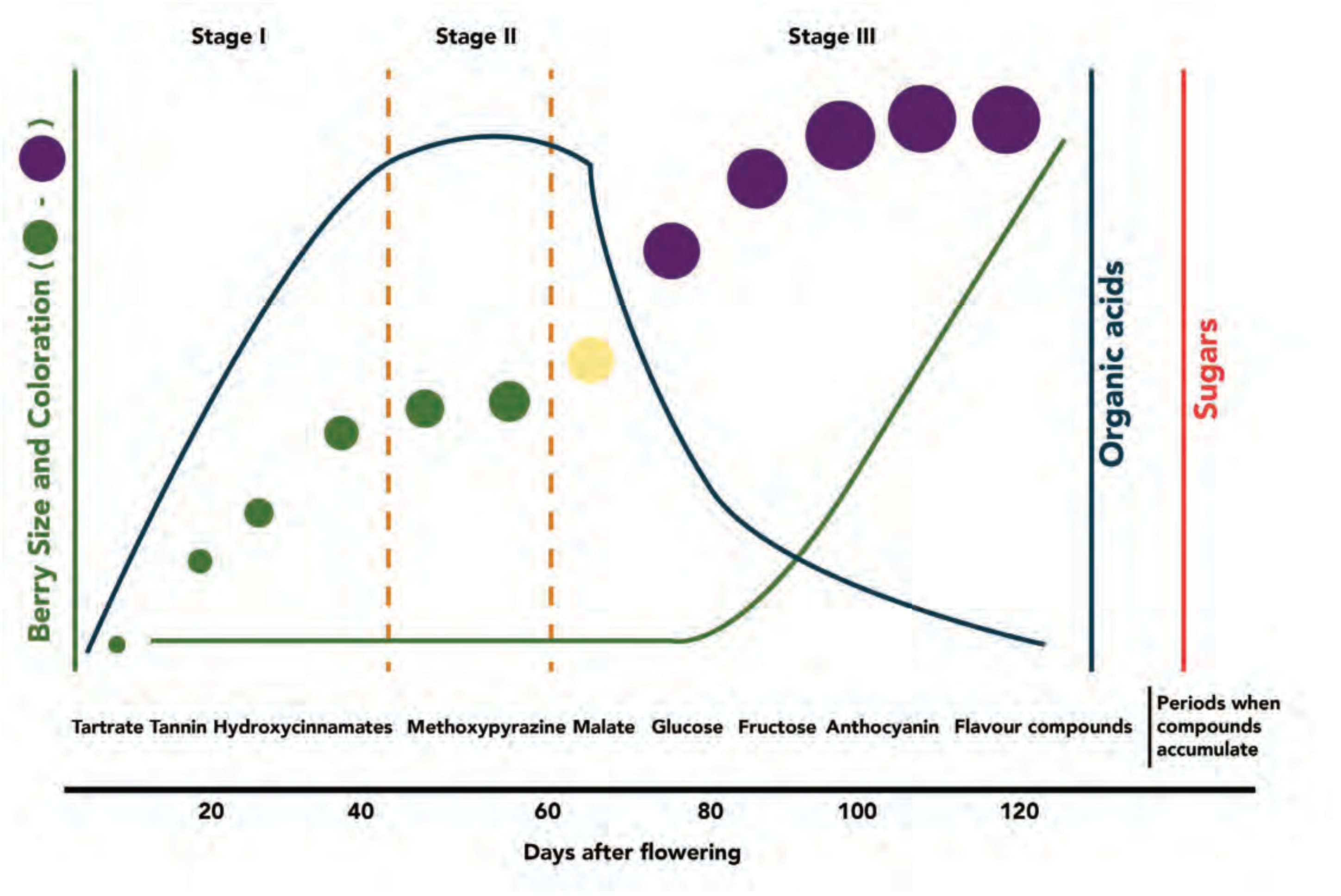


Figure 1. Grape berry development and ripening

6.4 COMMUNICATION WITH THE WINERIES

Winemaking starts in the vineyard.

Therefore, the relationship between the vineyard and the winery can not be underscored enough. Communication between grape growers and winemakers is essential during the course of winemaking for many reasons. Before harvest time, the winemakers need to have up-to-date information on the yield estimations. This will allow them to make the harvest plan in the cellar to decide which fermentation tanks they will allocate the crop. Getting closer to harvest, discussing possible dates of harvest with the winemakers will allow them to organize the grape reception.

Additionally, the ripening parameters mentioned in the corresponding section of this guide are relevant for winemaking. The winemaker will evaluate these parameters, such as acidity and potential alcohol, along with organoleptic characteristics of the grapes, such as aromas and phenolic compounds in order to decide which wine style to aim for and which method of winemaking to apply. This means a certain grape maturity level can be suitable for a specific wine style, while for another style, it might be necessary to have a different level of ripeness.

Therefore, communication of grape growers and winemakers before, during and after the harvest is of paramount importance, and allows the grape growing and winemaking processes to be successfully achieved in the most efficient manner.

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