Growing Grapes in Minnesota

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A Best Practices Manual For Cold Climate Viticulture

Growing Grapes In Minnesota

By The Minnesota Grape Growers Association

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Preface to the Tenth Edition

The continuing demand for Growing Grapes in Minnesota by growers, extension services, foreign affiliates, libraries, and others since the original publication has been encouraging to the members of the Minnesota Grape Growers Association. This is the tenth revision of the original text, and includes Best Management Practices inserted into each section.

The objective in all editions has been to provide updated information regarding cold climate viticulture and to update the text with new practical and technical developments. This edition also has been updated with current facts and figures, and introduces best management practices to enable growers to rate their current practices to the expectations of a well-managed vineyard. It is hoped that the material presented will be a useful reference and practical guide to grape growing in northern regions with severe winters.

For additional copies of this book or if interested in becoming a member of the Minnesota Grape Growers Association, please visit www.mngrapes.org.

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Introduction

Grapes are not new to Minnesota. Wild grapes (Vitis riparia), are found everywhere along our rivers and lakes extending into the Dakotas and parts of Canada. In fact, table grape production developed in this area as early as 1880-1900, growing mostly Concord and Delaware Grapes. A USDA estimate indicates that the Minnesota pioneer grape crop reached its peak in 1900, with production of 600,000 lbs. of grapes. Unfortunately, this early industry soon declined, due to the development of transcontinental rail transportation, the resulting economic competition from California vineyards, the severity of local winter temperatures, and introduction of growth regulator (phenoxy) herbicides such as 2,4-D in the mid-1940s.

It should be realized that limited grape cultivars (cultivated variety1) will grow successfully in this area without special care. European (Vitis vinifera) grapes, those widely grown in California, usually are killed at 0 to -15 degrees F. Even Concord, the standard of hardiness for American cultivars, commonly exhibits cold injury at -20 degrees F. Most French-American hybrids can only withstand -10 to -25 degrees F. With yearly winter lows of -25 to -35 F. in Minnesota, experience has shown that very few traditional cultivars can be reliably grown here. Although special cultural practices have been developed to grow marginal vines in cold climates, the cultivars released by the University of Minnesota grape breeding program, Elmer Swenson and other cold climate private breeders have the extreme cold hardiness needed to survive without winter protection. They combine excellent cold hardiness with good wine and eating quality and are a dependable choice as new plantings are established. These cultivars have become readily available to both the commercial and home grower.

Widespread interest in growing grapes is emerging in Minnesota as well as other cold climates where grape culture has not been traditional. Wineries and vineyards are developing at a rapid pace and the demand for locally grown grapes is steadily increasing. It is an exciting time to be part of grape growing and we hope this book will help you get started growing grapes in the north!

1 Variety" is a botanical term to designate a variation within a species, such as the difference between a peach and nectarine that is a fuzz less mutation of a peach. The scientific name of a peach is *Prunus persica* and the nectarine is *Prunus persica* var. *nucipersica*. The term cultivar is used to distinguish a cultivated variation within a species.

Considering Growing Grapes?

Growing grapes in a northern climate can be a rewarding experience. However, it requires a large investment and a long term commitment to establish and operate a commercial vineyard. Therefore, to be successful, it requires careful planning and preparing your site well in advance to planting your first grapevines. When determining if growing grapes is a viable opportunity, you need to consider:

1. How will the grapes be marketed?
2. Can grapes be grown successfully under your climatic conditions and can anything be done to improve the conditions?
3. Can grapes be grown successfully under your soil conditions and what can be done to improve the site?
4. How much will it cost to establish and maintain a vineyard?
5. How much labor will be required to perform the various cultural practices in the vineyard?

This section will address these issues and aid you in determining if growing grapes is an alternative for you.

Marketing

Marketing has been a topic often overlooked or relegated to the back of many grape production guides. However, if you do not have a firm marketing plan in place before planting your first grapevines, your odds of success could be greatly reduced. In developing your marketing plan, you should first identify your target market. Are you going to sell table quality grapes at a farmers market, roadside stand or grocery store; sell pick-your-own or pre-picked grapes for home juice, preserves or winemaking; sell to a local winery; or start your own winery or process grapes into juice or preserves? Each of these marketing outlets has its unique requirements.

Table grapes: The highest prices are received for table grapes, but the market is limited. Customer preference is for seedless cultivars (cultivated variety) for which there is a limited selection for northern climates. The shelf life of table grapes is limited, so selecting cultivars that mature sequentially will be important.

Juice and preserves: American type cultivars are most suitable for processing into juice and preserves. The market can be somewhat limited, but preservation extends the marketing season. State and local food processing licensing and annual inspection of the facility are required. For Minnesota, check with the Minnesota Department of Agriculture, Dairy & Food Inspections Division (Ph: 651-201-6027) or local authorities.

Selling to a winery: Visit with local wineries to determine if they will have a need for grapes when your vineyard comes into production, and if so, what cultivars and quantities would they be interested in obtaining. Would they be willing to develop a mutual relationship and work with you in producing quality grapes that meet the requirements for their wines? Explore the potential of developing a long term contract.

Start your own winery: Starting a winery is a major investment, but many home winemakers have taken the step and have been successful. In 2014, there were 71 farm wineries in Minnesota. The number of cultivars grown and the number of vines of each will be influenced by the number and size of your fermentation tanks. Keep in mind that a ton of grapes will produce about 150 gallons of finished wine but can range from 120 to 180 gallons. A ***Winery Ten Year Financial Planning Workbook*** at the Agricultural Marketing Resource Center (AgMRC) website http://www.agmrc.org/commodities__products/fruits/wine/winery_and_vineyard_feasibility_workbooks.cfm.

To become a commercial winery, you need to be licensed by the United States (US) Department of Treasury Alcohol and Tobacco Tax and Trade Bureau (TTB) (www.ttb.gov/index.shtml) and your State's alcohol beverage control board. In Minnesota, it is the Minnesota Department of Public Safety Alcohol and Gambling Enforcement (https://dps.mn.gov/divisions/age/alcohol/Pages/default.aspx). The TTB website has a link to other State and Canadian alcohol beverage control boards (www.ttb.gov/wine/state-ABC.shtml).

Site Requirements for Grapes

The first step in establishing a vineyard is the selection of the site. This should be done carefully, as grapevines have special needs and future problems can be avoided by choosing a favorable site. When determining if your site is suitable for growing grapes, you need to consider your climatic conditions, the topography of the site relative to the surrounding area, and its soil characteristics. These factors interrelate in determining if grapes can be successfully grown on the site, and if so, what cultivars will do best. When assessing climatic conditions, much information is available on the "macroclimate" of a region that is gathered from various National Oceanic and Atmospheric Administration (NOAA) recording sites spread over the state. Within a region, the topography of the site affects the local climate or "mesoclimate", and site specific soil conditions can influence how grapevines respond to the various climatic conditions.

Minnesota's Macroclimate

Climatic factors that influence grape production include winter and growing season temperatures, frequency of spring frosts, length of the growing season, and precipitation. Of these factors, winter temperatures have the greatest influence on whether grapes can be grown and which cultivars to plant. The state of Minnesota stretches from latitude of 43^o in the south to 49^o in the north, almost the same latitudes as France. The major advantage that France and the rest of Western Europe enjoy over Minnesota as a site for growing grapevines is the presence of the Atlantic Ocean and Mediterranean Sea which moderate the climate substantially. In contrast, Minnesota and the rest of the upper Midwest have a continental climate where winters are colder with rapid temperature changes, and summers are warmer. As northern grape growers, our challenge is to grow early-maturing grape cultivars, for which there is a long enough growing season with sufficient heat and sunlight to allow complete ripening and to lessen the dangers of extreme winter cold by either choosing vines that are cold-hardy, selecting sites that are less prone to extreme cold, and using cultural techniques to protect tender vines.

Winter temperatures: There are three basic types of grapes grown in North America – American (*Vitis labrusca*, *V. aestivalis*), European (*V. vinifera*) and Interspecific French-American hybrids (often referred to as "French hybrids"). A more recent group of cold hardy hybrids based upon *V. riparia* are referred to as "Northern hybrids". Grape cultivars have been classified based on the maximum cold hardiness in mid-winter (Table 1):

Table 1. Grapevine cold hardiness classification based upon the temperature range that bud injury begins to occur. *Adapted from: Midwest Grape Production Guide. OSU Ext. Bul. 919*.

Cold hardiness class	Temperature range	Suitable grape types
Tender	0^o to -10^o F	Warm climate European cultivars
Slightly hardy	-5^o to -15^o F	Most northern European cultivars
Moderately hardy	-10^o to -20^o F	Hardy European, & moderately hardy French hybrid cultivars
Hardy	-15^o to -25^o F	Most American, hardy French hybrid, & some Northern hybrid cultivars
Very hardy	-20^o to -30^o F	Some hardy American, & most Northern hybrid cultivars
Extremely hardy	-25 to -35^o F	Very hardy Northern hybrids

Within these classes, injury can occur at much warmer temperatures in the fall and early winter during the period of acclimation, and in late winter and early spring during the period of de-acclimation.

The 2012 US Department of Agriculture (USDA) Plant Zone Hardiness Map divides Minnesota into five climatic zones based on the average annual extreme minimum temperature recorded from 1976 through 2005 (Figure 1). Based on this map, some very hardy cultivars could be grown in zone 4a, while most very hardy and some hardy cultivars could be grown in Zones 4b and 5a. An interactive version and maps for other states are available at http://planthardiness.ars.usda.gov/PHZMWeb/. For Canada, a zone hardiness map is available at http://www.planthardiness.gc.ca/.

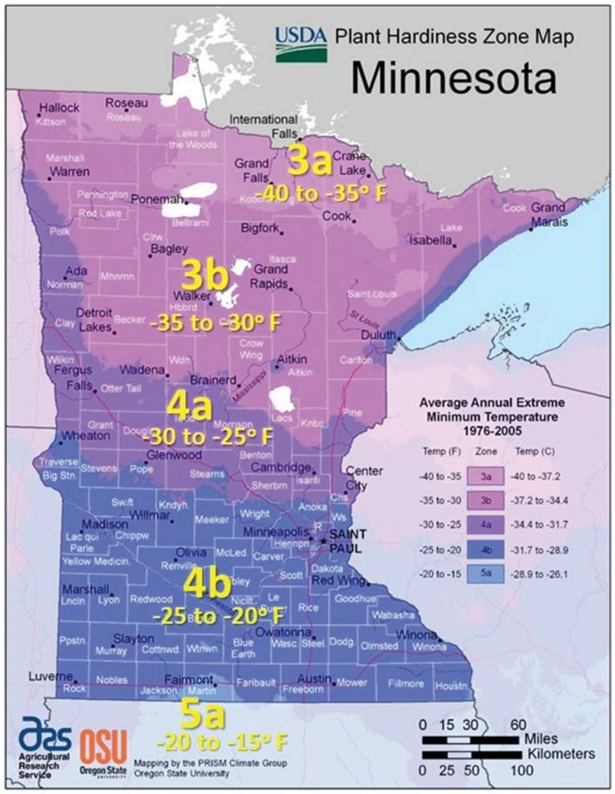


Figure 1. 2012 USDA Plant Zone Hardiness Map for Minnesota.

Length of the Growing Season determines what cultivars can be grown. The growing season needs to be long enough to properly mature the grapes and provide sufficient time after harvest for the grapevines to harden off and store carbohydrates for the next season in the roots, shoots and trunks before the first killing fall frost. The general rule for cultivars selection based on the number of frost-free days (Table 2).

Table 2. Recommended seasonal ripening grape cultivars to plant based on the number of frost-free days.

Number of Frost-free Days	Recommendation
Less than 150	Do not consider planting grapes. *However some very-early maturing cultivars are being developed.*
150 to 160	Only plant early season maturing cultivars.
160 to 170	Plant early and mid-season maturing cultivars.
170 to 180	Plant early, mid-season and some early late-season maturing cultivars.

Figure 2 shows the median number (50% probability) of frost-free days at 32° F (blue) and 28° F (red) derived from Minnesota NOAA weather reporting stations from1981 to 2010. Frost-free days is normally reported as the number of days between the last date 32° F was recorded in the spring to the first date it was recorded in the fall. However, temperatures need to drop below 28° to kill emerging shoots in the spring and leaves of some cultivars in the fall. Specific site topography characteristics relative to the surrounding area (mesoclimate) can greatly affect the number of frost-free days. Additional information on estimated date of events and probabilities is available on the Minnesota DNR interactive "Final Spring/First Fall Freeze & Frost Date Probabilities" web site http://www.dnr.state.mn.us/climate/summaries_and_publications/freeze_date.html.

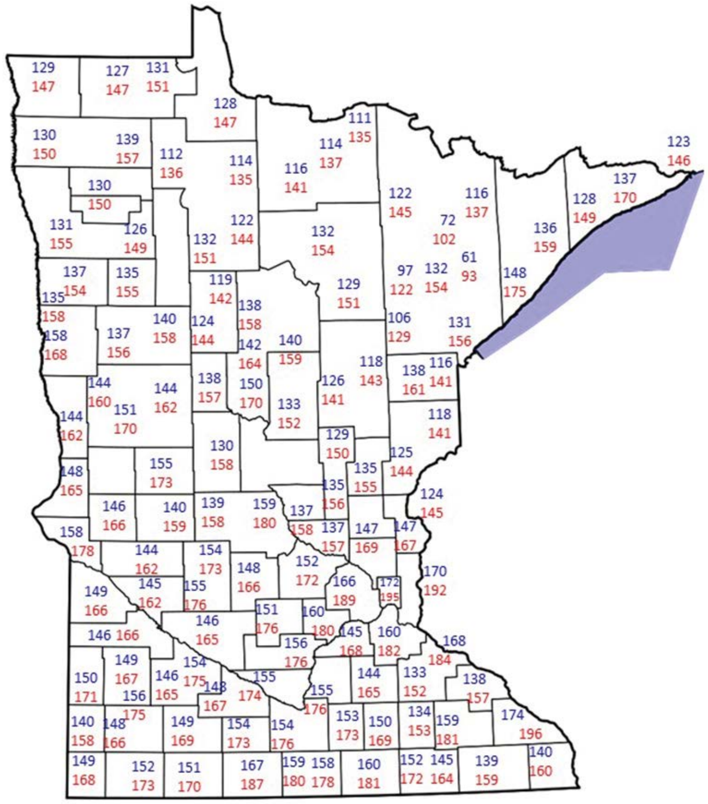


Figure 2. Median (50% probability) number of frost-free days at 32° F (blue) and 28° F (red) at various NOAA recording sites in Minnesota.

Growing season temperatures affect the rate of plant photosynthesis and subsequent vine development. Heat summation expressed as growing degree days (GDD) has been used to quantify the influence of growing season temperatures on plant development. Typically plant growth does not occur at temperatures below 50° F which serves as the base temperature (base 50F) when computing GDD. The daily GDD is calculated by averaging the daily high and low temperature and subtracting 50°. For example, if the daily high was 80° and the low was 60° F: 80° + 60° = 140; 140 / 2 = 70 average; 70 – base 50= 20 GDD. When night temperatures are below 50° F, 50° is substituted for the daily low temperature. Amerine and Winkler at UC Davis used a similar system based on average monthly high and low temperatures to characterize California into five wine growing regions. It has since been found that plant photosynthesis slows then temperatures rise above 86° F, thus the 86° F cutoff (if the daily high is above 86° F, 86° is substituted for the daily high), and night temperatures above 64° F tend to increase the rate of respiration to negate more of the plant carbohydrate accumulated during the day. The Amerine and Winkler regions are not directly applicable to the Midwest and Eastern winegrape growing regions because, with our high humidity, we experience high night temperatures, but GDD still serves quantify growing season conditions and whether early season, mid-season or late season cultivars can be grown.

Based on GDD map in **Figure 3**, about the southern two-thirds of Minnesota has a growing season that is warm enough for the successful ripen grapes in the majority of years. Regions accumulating from 2100 to 2500 GDD are probably warm enough to adequately mature very-early, early season and maybe some early mid-season cultivars; and areas accumulating more than 2500 GDD are probably suitable for early and mid-season maturing cultivars. Areas accumulating 2000 GDD or less have growing seasons that are probably too short and too cool to insure proper ripening of most commercially grown cultivars although new cultivars are being developed that will likely extend this range significantly northward. Moreover good site selection and adapted cultivars will increase success in any area selected.

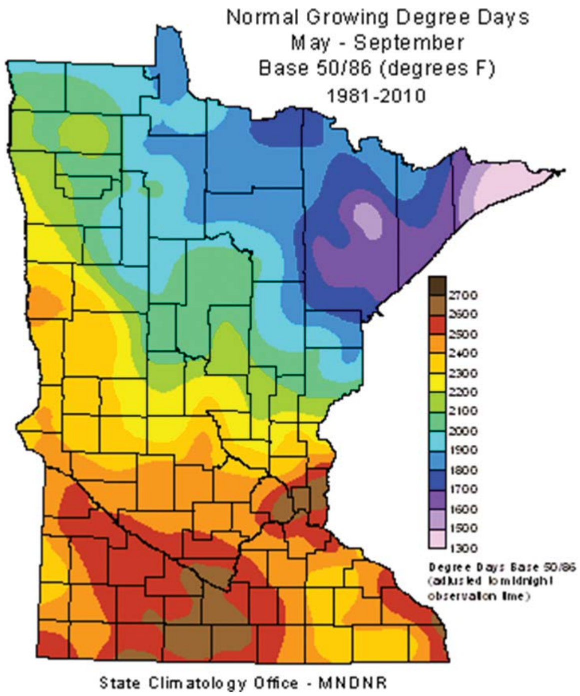


Figure 3. Growing Degree days, Base 50 Degrees F

Precipitation: Minnesota's average annual precipitation ranges from about 36 inches in the far southeast corner to 21 inches in the far northwest (**Figure 4**). As a general rule, most crops require about an inch of rainfall per week during the growing season for normal development. However, for grapes it will be less during the early stages of canopy development, and may be up to 1.2 inches per week at full canopy development when there are more leaves and temperatures are also higher. For the period from May 1 to October 1, 22 inches of rainfall would provide one-inch per week. Frequency of droughts and the available moisture holding capacity of the soil will determine if supplemental irrigation will be required.

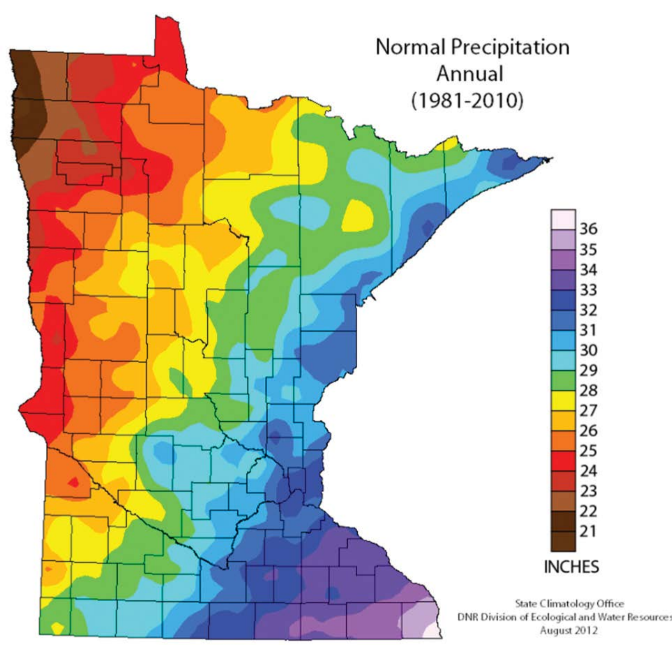


Figure 4. Average annual precipitation 1981-2010.

Vineyard Best Management Practices – Site Selection and the Macroclimate

Rate your site based on macroclimatic factors:

Management Area: **Climate of Proposed Vineyard Site**	**Best Practice**	**Minor Adjustments Needed**	**Concern Exist: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Average minimum winter temperature	-15 to -20º F (Zone 5a) Can grow hardy & very hardy cultivars with little difficulty. May be able to grow some moderately hardy cultivars.	-20 to -25º F (Zone 4b) Restricted to growing very hardy cultivars. Will need winter protection for less hardy cultivars.	-25 to -30º F (Zone 4a) Restricted to growing extremely hardy & the hardiest of the very hardy cultivars or provide winter protection.	-30 to -40º F (Zone 3b & 3a) Very limited in cultivar selection. Winter protection will be needed.
Frost Free Days in a normal year	160 to 179 days Can plant early, mid-season & maybe early late season cultivars in best locations.	150 to 159 days Restricted to planting early & maybe early mid-season cultivars in the best locations.	140 to 149 days Restricted to planting very-early & maybe early season cultivars in the best locations.	< 140 days May be able to plant very early season cultivars in the best locations.
Growing Degree Days (GDD, base 50ºF) accumulated in a normal year)	> 2,500 GDD Suitable for growing early & mid-season cultivars.	2,300-2,400 GDD Suitable for growing early & some early mid-season cultivars.	2,000-2,200 GDD Suitable for growing very-early & some early-season cultivars.	< 2,000 GDD Try some very-early season cultivars on a trial basis.
Average annual precipitation	>34 inches adequate unless on a sandy textured soil	30 to 34 inches adequate in most years; supplemental irrigation may be required on sandy textured soils	26 to 30 inches supplemental irrigation may be required.	< 25 inches supplemental irrigation should be considered.

Site Selection and the Mesoclimate

Macroclimate maps provide information on regional characteristics, but are too general for pinpointing the best sites for a vineyard. The mesoclimate is the site specific characteristic and is influenced by the topography and elevation of the site relative to the surrounding area, slope of the land, direction of the slope (aspect) and flora around the area. These characteristics affect exposure to low and high temperatures, frequency of spring frosts, length of the growing season, GDD, and exposure to sunlight.

Topography: A proper vineyard site is one that is elevated above low-lying areas such as river or creek bottoms. Selecting such sites is often the best protection against spring frosts and exposure to the lowest winter temperatures. The coldest temperatures occur under radiation freeze conditions. This occurs when a dry cold air mass settles in over an area, and at night there is an absence of cloud cover and winds are calm. Under such conditions, the earth releases heat as radiant energy to the atmosphere, the air near the ground cools, and the air stratifies forming an inversion layer of warmer air about 30 to 50 feet above the ground. Cooler dense air is trapped beneath the warm air continues to cool and because it is heavier than warm air, it drains into low-lying areas forming frost pockets (**Figure 5**).

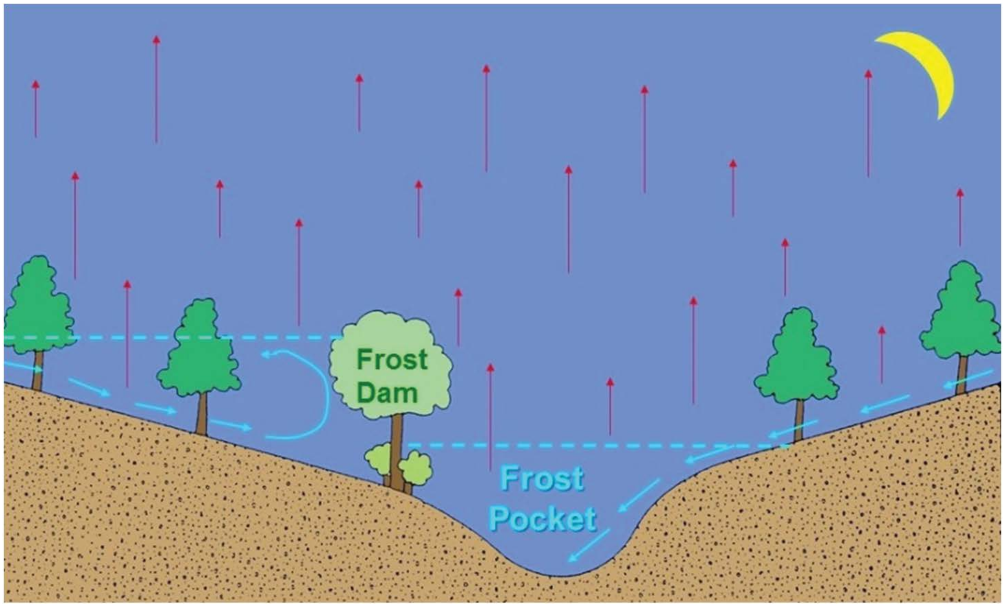


Figure 5. Effect of topography and an obstruction during a radiation freeze event
(P. Domoto, ISU)

Obstructions below a vineyard that impede the cold air drainage to lower areas such as woodland with thick under-story vegetation along the perimeter can form frost dams.

Ideally, it is best to plant the vineyard on hillsides and the tops of bluffs or knolls least 30 to 50 feet above a valley floor. If woodland exists below the proposed vineyard site, take measures to improve the air drainage such as clearing out the understory vegetation on the perimeter and/or cut paths through the woods to allow the cold air to drain out of the vineyard. Taking these measures will reduce the risk of a late spring and early fall frost to significantly extend the length of the growing season. In addition, this will also moderate the vineyard's exposure to extreme low winter temperatures.

A good practice is to monitor the temperature with maximum-minimum thermometers placed at different elevations and locations in the field being considered for a vineyard. The thermometers should be placed 4 to 5 feet above the ground and sheltered from direct sunlight. They need to be re-set before each freezing event. An alternative method would be to walk the field during a radiation freeze event with a sensitive handheld thermometer and a GPS device that measures elevation.

Slope: The slope of a field is measured as the vertical fall or rise per 100 feet horizontal distance and is reported as a percentage. Vineyards do best on land that is moderately sloping in the 3 to 14 % range. On land that is flat, cold air does not drain away well from the site during a radiation freeze. In addition, any excess precipitation does not runoff well and the soil is more prone to waterlogging. On slopes steeper than 15%, operating equipment becomes hazardous and such soils are much more prone to erosion. County Soil Surveys and the online Web Soil Survey (See section on soils) provide information on the percent slope of the land.

Aspect (direction of the slope): Aspect is the approximate compass direction a slope faces. It affects the angle at which sunlight hits the vineyard and influences the growing conditions. A south-facing slope has the highest angle of sunlight intercept, therefore it warms up sooner and accumulates the greatest GDD which is beneficial in a northern climate such as Minnesota. However, grapevines on a south-facing slope will be more prone to spring frosts because it warms up sooner, and will have the highest water requirement. A north-facing slope will have the lowest angle of sunlight intercept, and warm up the slowest and accumulate the lowest GDD which is less favorable in a northern climate. However, grapevines on a north-facing slope will be less prone to a spring freeze and will have the lowest water requirement. East and west-facing slopes tend to be intermediate between the south and north facing slopes, with the west-facing slope being warmer and accumulating more GDD and have a higher water requirement that the east-facing slope. However, grapevines on an east-facing slope will dry off sooner in the morning to aid in reducing the incidence of disease, and will be more photosynthesis efficient because it is cooler in the morning, particularly under moisture stress conditions when leaf stomata will close in the afternoon to conserve moisture. These differences become more prevalent as the percentage of slope increases.

The direction of the slope and elevation can have an influence on grapevine cultivars selection. Because south-facing slopes warm up sooner than other slopes, planting early bud-breaking cultivar on such sites would be more risky that planting a later bud-breaking cultivar. Planting the earliest maturing cultivars on the warmest sites is probably not the best practice because it has been found that during the final month of ripening, optimal fruit chemistry and color development are promoted by daytime temperatures in the 64° to 77°F range with night temperatures of 59° to 68°F. Therefore the best management practices would be to plant the earliest bud-breaking cultivars on the least frost-prone sites, and reserved the warmest slopes for the cultivars the may be marginal for the area because of length of the growing season.

Sunlight: Vine performance is dependent upon a need for full sunlight. Care should be taken so that the vines will receive full sun during the day or nearly all day. Neighboring trees that could cast shade on the vineyard should be avoided or removed.

Vineyard Best Management Practices – Site Selection and the Mesoclimate

Rate your site based on mesoclimatic factors.

Management area: **Site topography, elevation, slope**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exist: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Topography	Site sits at least 30 ft above the bottom of a hill or on top of hill with no obstacles below to impede air drainage	Site sits at least 30 ft above the bottom of a hill or on top of hill with obstacles below that can impede air drainage	Site sits less than 30 ft above the bottom of a hill.	Site sits at the bottom of hill or on low land.
Slope	Site sits on 3%-9% slope that allows for good air and excess surface water drainage.	Site sits on 9%-14% slope. Erosion may become a problem.	Slope greater than 14% will require extensive erosion protection and specialty equipment.	Site sits on flat land with 0-2% slope. Lack sufficient air and excess surface water drainage.
Aspect (direction of the slope)	Site sits on a South, South East or South West facing slope	Site sits on East or West facing slope	Site sits on a mostly flat surface.	Site sits on a North facing slope.
Exposure to sunlight	The perimeter of the site receives good sunlight exposure throughout the day.	Woodland on the perimeter of the site shade it for a portion of the day.		Tall structures shade the site for a portion of the day.

Soil Requirements for Grapes

Soil properties are the third important consideration when determining if a site is suitable for a vineyard. Minnesota has a wide variety of soil types and grapes are being grown on many of them. In assessing if a soil is suitable, you need to examine its physical and chemical characteristics. Physical characteristics include texture, depth and profile which affect internal drainage and plant available moisture holding capacity; while chemical properties include soil pH, fertility and organic matter content.

Soil Physical Properties

The USDA Soil Conservation Service (now the Natural Resources Conservation Service, NRCS) has surveyed soils across the US and the information is published by county. These surveys are available from your county Extension Office, county USDA-NRCS office, or online at the USDA-NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/)

Texture: Soil texture classification is based on the percentages of sand, silt and clay present in the soil as illustrated by the soil triangle (**Figure 6**) where particle diameter is defined as: sand >.05 to 2.0mm; silt .002 to .05 mm; and clay <.002 mm.

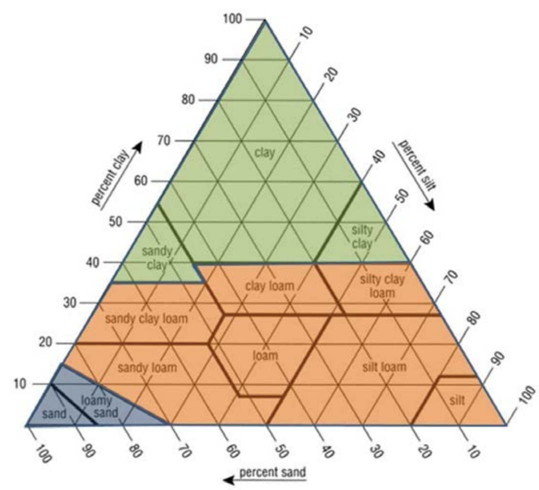


Figure 6. Classification of soil texture based on the percentages of sand, silt and clay. (UMN Extension)

Particle size directly or indirectly affects several physical as well as some chemical characteristics of the soil. The direct effects include moisture retention, permeability, and mineral nutrient retention. As particle size decreases, pore size between the particles become smaller and the accumulated surface area of the particles as well as the total pore space between particles of a given volume of soil increases.

- **Moisture retention:** Fine-textured clay soils (clay, silty clay, sandy clay) have the capacity to retain greater moisture than sandy-textured soils. However, soils with too high a percentage of clay are undesirable because their extremely small pore space between particles retains a high percentage of moisture that is unavailable to plants and such soils lack adequate aeration for good root development. Grapevines grown on these soils tend to be less vigorous because of the reduced aeration. Conversely, soils with high percentages of sand (coarse-textured) are undesirable because they lack water holding capacity.
- **Permeability:** As the pore space between particles decreased with increasing clay content, the water infiltration rate slows and the soil becomes more prone to water logging or having a perched water table.
- **Nutrient retention:** As the total surface area of a soil increases with increasing clay content, its ability to retain mineral nutrients increases. This is expressed as high cation exchange capacity (CEC) of the soil. Soil organic matter (humus) also contributes to the CEC.

Based on these characteristics, provided that the subsoil characteristics of a soil are not limiting, medium-textured soils (loam, sandy clay loam, clay loam, silty clay loam, silt loam, silt and sandy loam) are best suited for growing grapes. These soils have an adequate capacity to retain moisture yet allow for adequate aeration for good root development, and an adequate CEC to retain mineral nutrients. Although sandy-textured soils (sand, loamy sand) lack sufficient moisture holding capacity and have a low CEC, grapevines will do well on them, if irrigation is provided and nutrients are applied in split applications or in the irrigation water. Under such conditions, you can control the water and nutrient supply. Clay textured soils (Clay, silty clay, sandy clay) are not suited for growing grapes

Internal drainage: Internal drainage is important because plant roots need oxygen for good development and nutrient uptake. The USDA-NRCS Soil Survey categorizes soils by their natural drainage classification: "excessively drained", "somewhat excessively drained", "well drained", "moderately well drained", "somewhat poorly drained", "poorly drained", and "very poorly drained". Soils classified as "well drained" are best soils for a vineyard. Soils classified as "moderately well drained" are suitable for a vineyard, but may require some corrective measures to improve the internal drainage. Corrective measures will be needed on soils that are "somewhat poorly drained" while soils classified as being "poorly drained" and "very poorly drained" should be avoided. Soils classified as "somewhat excessively drained" or "excessively drained" are suitable for a vineyard when they are irrigated.

Factors that affect the internal drainage include:

- The lack of sufficient slope or a depression that limits surface runoff of excess precipitation. On finer textured soils (high clay content), such areas should be avoided because grapevine will not perform well, and such sites are more frost prone because of the lack of cold air drainage. Installing drainage tile may correct the internal drainage problem at an additional vineyard establishment cost.
- Lateral seepage on a hillside due to a textural change coming to the surface. Typically, this occurs in swales on the hillside. Such areas should be avoided and made into waterways or avenues that divide vineyard blocks.
- Impervious layer in the soil profile that slows the infiltration rate. This could be a change in soil texture or a compacted layer such as a plow pan, or glacial fragipan. If the impervious layer is near the surface and there is good soil below, subsoiling can correct the problem. This should be performed when the soil is dry and done in two directions diagonal to each other.
- A high water table. High water tables are a concern because roots will not function in a saturated environment without oxygen. They tend to be seasonal and vary with the frequency and amount of precipitation. If the minimum depth to the water table is greater than 4 feet, it should not be a problem. For shallower water tables, tiling would be needed if grapes are to be grown.

Plant available moisture holding capacity: Available moisture is the amount of moisture soil can hold between field capacity and the permanent wilting percentage. Field capacity is the amount of moisture held by the soil against the forces of gravity or 72 hours after a saturating rain, and permanent wilting percentage is the amount of moisture remaining in the soil when wilted plants will not recover are placed in a humid environment overnight. Soils textures vary in the amount of plant available moisture (**Table 3**).

Table 3. Approximate available moisture holding capacity of different textured soils.

Soil Texture (classification)	Approximate available moisture in inches / foot of soil
Coarse (sand)	0.5
Course (loamy fine sand, fine sand)	1.25
Moderately coarse (sandy loam, fine sandy loam)	1.5
Medium (silt, silt loam, loam, very fine sandy loam)	2.0
Moderately fine (clay loam, sandy clay loam, silty clay loam)	2.2
Fine (sandy clay, silty clay, clay)	2.0

The combination of soil texture and soil depth to a restrictive feature determines a soil's plant available moisture holding capacity. Soil Surveys may report this either as inches of available moisture per inch of soil, inches per foot, inches per five feet of soil, or inches in the soil profile to a restrictive layer. On medium-textured soils, grapevines do best on soils with a rooting depth of at least three feet. Additional soil depth and/or irrigation may be needed on coarser-textured soils.

The combination of soil texture, depth, annual precipitation, frequency of droughts in the area, and availability of a supplemental source of water will determine if irrigation is a wise investment. In the Midwest, trickle irrigation is often the best method for supplying supplemental water on upland sites where sufficient water for an overhead irrigation system is often limited. The *Wine Grape Production Guide for Eastern North America* (NRAES-145) contains an excellent chapter in irrigation for a vineyard. If you elect to install a trickle irrigation system, consult with a firm that specialized in trickle irrigation. They have engineers that will design a system that to fit your needs.

Soil Surveys: Information on these soil physical properties is available in your County Soil Survey or online at the USDA NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/). Both surveys contain maps to locate your site of interest and the various soils present and their descriptions. For the Web Soil Survey, all you need to do is click on the green "WSS Start" button; go to the "Quick Navigation" side bar and enter the address or other means of identifying your area of interest; click on the "AOI" (area of interest) button, then click and drag on the map to outline the specific area of interest; and when the AOI is highlighted, click on the "Soil Map" tab. For each soil in the AOI, names, texture classification and % slope will pop up. Clicking on each soil name will enable you to read the important site and soil characteristics. These characteristics include: Map unit setting (elevation, annual precipitation, frost-free days), typical soil profile, natural drainage classification, runoff classification, capacity of most limiting layer to transmit water (Ksat), depth to water table, presence of calcium carbonate, available water storage in profile, and other important information for the particular soil. In the County Soil Surveys, a more complete description is available in the soil series and soil profile classification sections, but you will need to go to the Table of Engineering Index Properties and Table of Physical and Chemical Properties to get additional information.

The soil surveys give information on the typical characteristics of the various soils. For more precise information, you should dig several test pits at various locations within each of the soil types present on the site. This will enable you to evaluate for any variations in the profile. Such pits should be at least three feet deep

Vineyard Best Management Practices – Soil Physical Properties

Rate your soil physical properties.

Management Area: **Soil physical properties**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Soil Survey	Obtain a soil survey for your site to determine the soil physical properties when selecting a site to plant a vineyard.		Obtain a soil survey for your site to determine the soil physical properties after the site has been selected to plant a vineyard.	Planted a vineyard with no knowledge of the soils physical properties.
Soil Texture	Moderately coarse to medium-textured (sandy loam, loam, silt loam, silt)	Moderately fine textured (clay loam, sandy clay loam, silty clay loam) May require drainage tile.	Coarse textured (sand, loamy sand, fine sand) Lack moisture holding capacity, irrigation should be considered.	Fine-textured (clay, sandy clay, silty clay) Poor aeration & internal drainage. Best to consider an alternative site.
Internal drainage classification	"Well drained"	"Moderately well drained" May need drainage tile	"Somewhat excessively drained", "excessively drained" Irrigation should be considered.	"Somewhat poorly drained", "poorly drained" Drainage tile is required, or consider an alternative site.
Depth to restrictive feature (clay layer, fragipan, plow pan)	>80 inches	8 to 30 inches: Preplant subsoiling	30 to 60 inches: Drainage tile may be needed.	No measures taken to correct a restrictive feature
Depth to the high water table.	>6 feet	4 to 6 feet	3 to 4 feet: May need drainage tile,	Less than 3 feet: Drainage tile is required or consider an alternative site

Soil Chemical Properties

Soil chemical properties include the organic matter content, soil pH, and mineral nutrient availability. Information on these characteristics is best obtained through pre-plant soil testing conducted at least a year before planting the vineyard. If amendments are needed, they can be applied and tilled in as deeply and uniformly as possible where they will be available to grapevines. This is very important for mineral nutrients that are practically immobile to very slowly mobile in the soil such as calcium (Ca) in lime, phosphorous (P) and potassium (K). Also, if the soil pH needs to be adjusted, it takes about a year for the benefit to occur.

Separate soil samples should be submitted for each soil type present on the site. Within each soil type separate samples should be collected if areas have different cropping histories (corn/soybean rotation being the exception) or different fertilization histories. Separate samples should be collected from the 0 to 8-inch and 8 to 16-inch depths from each sampling area. The 0 to 8-inch depth samples will provide information on the past fertilization history, while the lower depth samples will provide information on parent material. Each sample should be a composite of at least 15 to 20 cores collected over the sampling area. The cores should be thoroughly mixed, air dried and sub-sampled before submitting. Soil samples can be submitted to the University of Minnesota Soil Testing Laboratory (http://soiltest.cfans.umn.edu/) University of Minnesota Soil Testing Laboratory (Ph: 612 625-3101) e-mail: soiltest@umn.edu) or any commercial soil testing laboratory or a commercial laboratory.

Soil samples should be tested for soil pH, organic matter (OM), P, K, magnesium (Mg) and zinc (Zn). Optional mineral nutrients that can be tested include calcium (Ca), boron (B), manganese (Mn), copper (Cu), iron (Fe) and sulfur (S). On soils that are known to have a high pH (above 7.4), a test to determine the cation exchange capacity (CEC) is advised because elemental sulfur applications to lower the pH are based on the soil's CEC. Check with your Extension viticulturist or soils specialist to determine the need for these additional tests in your area. **Table 4** lists the pre-plant sufficiency ranges published in the Midwest Grape Production Guide (Ohio St. Univ. Ext. Bull. 919), Wine Grape Production Guide for Eastern North America (NARES-145), and values used by the University of Minnesota Soil Testing Laboratory and Iowa State University Horticulture Department.

Table 4. Pre-plant soil test sufficiency ranges for establishing a vineyard.

Test	OSU Bull. 919[z]	NRAES-145[y]	U of MN[x]	ISU-Hort[w]
Organic matter	2 - 3 %	2 - 5 %	--	2 - 3 (4?)%
Soil pH	5.5 - 6.5	5.5 *V. labrusca* 6.0 hybrids 6.5 *V. vinifera*	6.0 - 7.0	6.0 - 6.5
Phosphorous (P)	20 – 50 ppm	20 – 50 ppm	> 25 ppm	>30 ppm
Potassium (K)	125 – 150 ppm	75 – 100 ppm	>160 ppm	>150 ppm
Magnesium (Mg)	100 – 125 ppm	100 – 125 ppm	~100 ppm	100 – 125 ppm
Zinc (Zn)	4 – 5 ppm	2 ppm	>1 ppm	3 - 4 ppm
Calcium (Ca)	--	500 – 2000 ppm	>600 ppm	--
Boron (B)	.75 – 1.0 ppm	0.2 – 2.0 ppm	>1 ppm	--
Manganese (Mn)	--	20 ppm	>6 ppm	--
Copper (Cu)	--	0.5 ppm	>0.2 ppm	--
Iron (Fe)	--	20 ppm	--	--
Sulfur (S)	--	--	>7 ppm	>7 ppm

[z] Midwest Grape Production Guide (OSU Ext. Bull. 919).

[y] Wine Grape Production Guide for Eastern North America (NRAES-145).

[x] Univ. of Minnesota Soil Testing Laboratory.

[w] Iowa State Univ. Horticulture based on tests performed by the ISU Soil & Plant Analysis Laboratory.

(Adapted from the Northern Grapes Project ***Vine Nutrition*** Webinar, March 12, 2013.
http://www.youtube.com/watch?v=easAzwROKrc&list=PLGIR49aM1wm4SWL7XS-_oO9z8vaFttILl)

Organic Matter:

An adequate supply of organic matter (OM) or, its final product, humus, is important to the vineyard soil. Humus improves the soil's moisture holding capacity, structure, CEC, and subsequent nutrient retention. With improved soil structure properties, aeration is improved fostering the microorganisms that aid in processes of decomposition, nitrogen fixation, and nutrient uptake by plant roots. Secretions and excretions of these microorganisms serve to aggregate soil particles together into erosion resistant agglomerations. Mineral nutrients, which might otherwise leach out of the soil, become incorporated into the cells of many trillions of these microbes, to become available to plants later when the microbes die and decompose. "Good tilth" was the term used by old timers to describe a soil with these desirable traits. For grapes the optimum organic matter content should be between 2 and 3% (Dami, et al., 2005).

The OM content of a soil also serves as an indicator of soil fertility and how much nitrogen fertilizer should be applied each year. Grapevines are not high users of nitrogen (N) and require from 60 to 80 pounds of actual N per acre per year to perform well. Under upper Midwest conditions, for each one-percent increment in the organic matter content, the soil has the capacity to release up to 20 pounds of available N per acre per year. So, a soil containing 3% OM has the capacity to release 60 lbs of N per acre per year. Because grapevines have an indeterminate growth habit they will respond favorably to conditions that promote growth, such as additional N and will continue to grow until the first killing frost. Ideally, the grapevines should stop growth at veraison (when grape berries begin to turn color and soften). Rich loamy soils often contain more than adequate amounts of N and often result in overly vigorous vine growth. Such vines require additional cultural practices such as lateral shoot thinning and leaf pulling to promote good light exposure of the clusters, and the shoots are slow to lignify (turn brown) and mature. This delays the hardening off process making the vines more prone to winter injury. Ideally in the upper Midwest, the soil organic matter content should be in the 2 to 3% range, maybe up to 4% if training systems are selected and/or cultural practices adopted to accommodate vine vigor. When soil OM content approached 5% and above, alternatives to growing grapes should be considered.

If a pre-plant soil tests shows OM to be 2% or less, growing a cover crop the season before planting grapevines can be beneficial. Such a cover crop should produce a lot of biomass, and act to smother any annual weeds that germinate.

Soil pH:

The soil's pH is the measure of the acidity or alkalinity of the soil solution. It is measured on a logarithmic scale of 0 to 14 where 0 is very acidic, 14 is very alkaline, and 7.0 is neutral. The pH of the soil is important because it affects the availability of the essential mineral nutrients required by plants (**Figure 7**). Most plants, including grapevines, prefer a soil that is slightly acidic to neutral with a pH in the 5.5 to 6.5 range because the essential nutrients are most available or available in adequate amounts. However, this varies somewhat with predominate species of the cultivar. American-type cultivars with a strong *V. labrusca* parentage prefer soils in the 5.5 to 6.0 range. Traditional interspecific hybrids do well on soils in the 6.0 to 6.5 range although some Northern hybrids with will tolerate a soil pH up to 7.2, and European (*V. vinifera*) cultivars do well on soils in the 6.5 to 7.0 range.

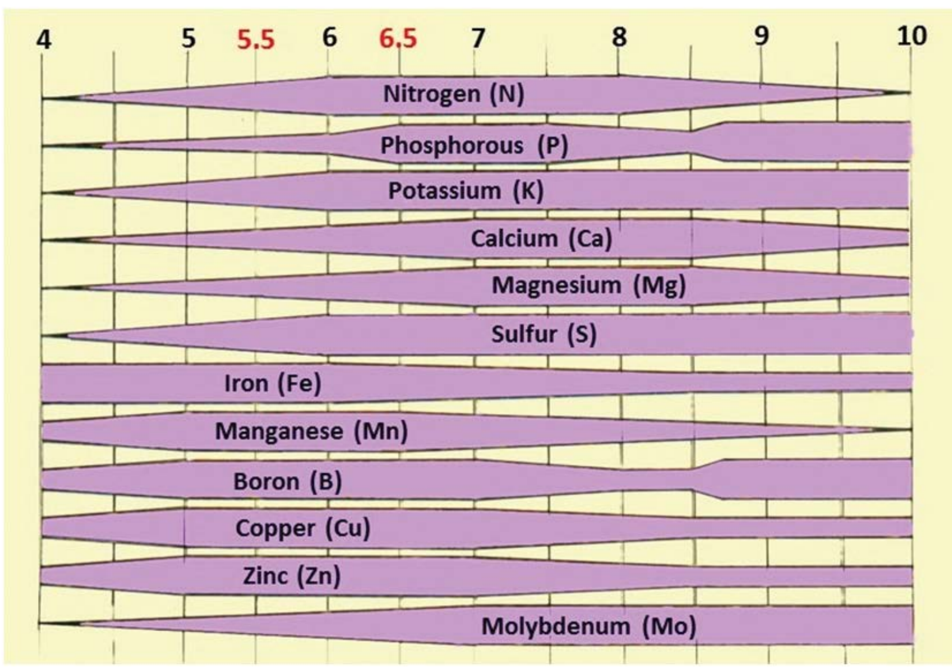


Figure 7. The effect of soil pH on the availability of the essential mineral nutrients required for plant growth. A wider line indicates greater availability of the nutrient.

Low pH soils:

Lime should be applied to raise the pH on low pH soils. The amount of lime required will depend upon the buffer pH value that testing laboratories will provide whenever the soil pH is low. For American-type cultivars, lime should be applied to raise the pH to 6.0 if the soil pH is below 5.5, and for hybrids the soil pH should be raised to 6.5 if the soil pH is below 6.0. (**Figure 8**).

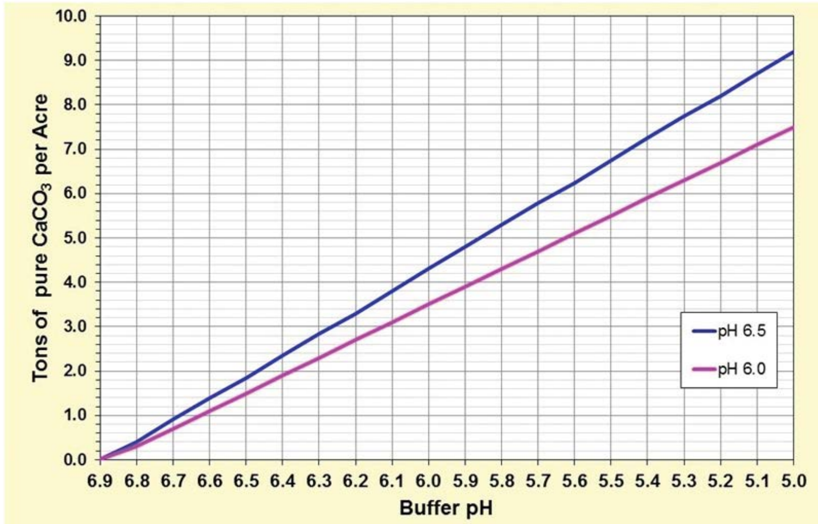


Figure 8. Lime requirement in tons of pure calcium carbonate per acre to raise the soil pH in the top 8-inches to 6.0 and 6.5.

Some laboratories base the lime requirement on the CEC of the soil. A table for the lime requirement based on the CEC is printed in the *Nutrient Management* chapter in the Wine Grape Production Guide for Eastern North America (NARES-145).

There are two forms of limestone that can be used to raise the soil pH: calcitic limestone that contains about 40% Ca and 0.2% Mg; and dolomitic limestone that contains approximately 11% Mg and 21% Ca. If soil test results show that exchangeable Mg is low, use dolomitic limestone to raise the pH. However, if soil test results show exchangeable Mg to be in the desired range or above, use calcitic limestone. Many Midwestern soils are already very high to excessively high in Mg, and additional Mg can inhibit the uptake of K.

The lime should be applied about a year before planting and tilled in as deeply and as uniformly as possible. This will allow for any "hot spots" to mellow out. In 4 to 5 years, the soil pH should be re-tested to determine if additional lime is required. If additional lime is required, it would be as a surface application, and any response to such application will take several years on loamy or clay soils because of the immobility of the lime. No more than two tons per acre should be applied per year.

High pH (alkaline) soils:

If soil test results for pH are above 6.5, measures can be taken to lower the pH to a desired level depending upon the soil pH and what type of grapevines you plan to grow. Alternative practices include:

- Doing nothing.
- Lowering the soil pH over several years with annual applications of acidifying forms of fertilizer. Examples of these fertilizers include ammonium sulfate (21-0-0), urea (46-0-0) and a one-time application of mono-ammonium phosphate (11-52-0). One pound of these materials has the capacity to neutralize 5.4, 1.8 and 5.0 pounds of lime respectively. Applications of manure or compost will also lower the soil pH, but the response is variable. For soils with higher percentages of OM, annual applications of these N sources will be less so it will take longer to lower the pH to the desired level.
- Lowering the soil pH with an application of elemental sulfur (**Figure 9**) or a similar material. Aluminum sulfate and ferrous sulfate are alternatives to elemental sulfur, but it takes six-times and eight-times as much material respectively to do the same job. Sulfur applications are based on the soil's CEC where a CEC of 5 is typically equivalent to a sandy soil with low OM, 15 a loamy soil, 25 a clay soil, and greater than 30 a clay soil with high OM.

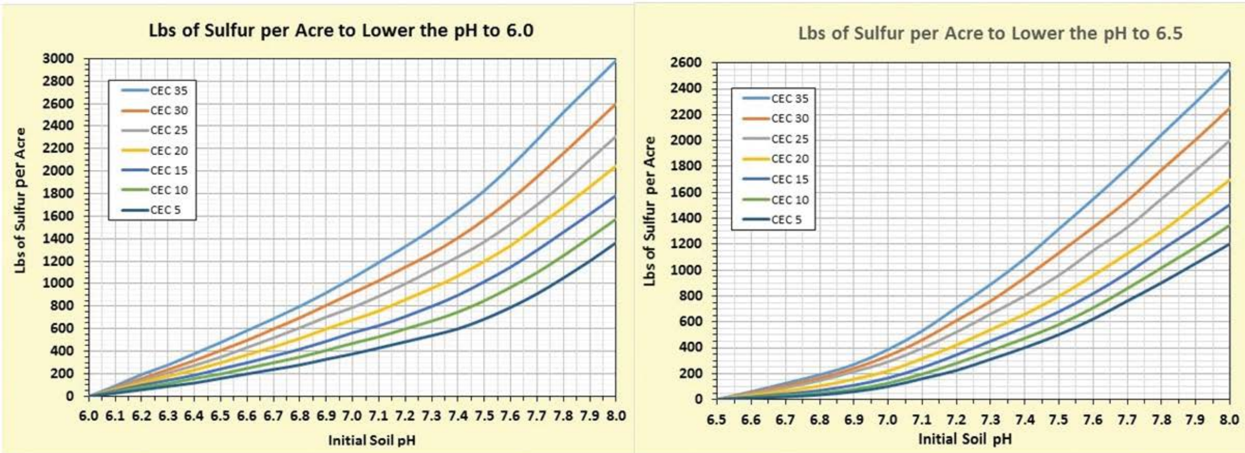


Figure 9. Elemental sulfur requirement in pounds per acre to lower the soil pH in the top 8-inches to 6.0 and 6.5 for a carbonate-free soil. Adapted from: *Soil pH Management*, **Spectrum Analytic** (www.spectrumanalytic.com/support/library/ff/Soil_ph_Management.htm)

Soil pH from 6.5 to 7.0: For American-type cultivars, the best approach is to apply elemental sulfur or an equivalent material a year before planting grapevines to lower the pH to 6.0, and use annual applications of ammonium sulfate as your N source. For French and Northern hybrid cultivars, you have the choice of doing nothing since they will tolerate a pH up to 7.0 or a little above; using annual applications of ammonium sulfate as your N source to bring down the pH over time, or applying elemental sulfur or an equivalent material year before planting grapes to lower the pH to 6.5.

Soil pH from 7.0 to 7.5: For American-type cultivars, apply elemental sulfur a year before planting grapevines to lower the pH to 6.0, and use annual applications of ammonium sulfate as your N source. For French and Northern hybrid cultivars, apply elemental sulfur a year before planting grapevines to lower the pH to 6.5, and use annual applications of ammonium sulfate as your N source.

Soil pH above 7.5: Attempting to lower the soil pH to plant grapevines becomes questionable because of the amount and cost of the material required, and the potential presence of free carbonates in the soil that require additional sulfur to neutralize before the pH begins to drop. When the results of a soil test show a pH of 7.4 or higher, a fizz test should be performed. This is done by placing a few drops of household vinegar on a soil sample, and listen and watch for bubbling (Table 5).

Table 5. Fizz test for calcareous soils.

Fizz Test Result	Estimated carbonates present %	Annual addition of elemental sulfur (tons/acre)	Duration (years)
None	0	none	none
Heard (barely audible)	0 - 1	0.5 - 1	1
Slight (few bubbles)	1 - 2	1	1 – 2
Moderate (several bubbles)	2 - 3	1	2 – 3
Vigorous (many bubbles)	>3	1	3+

From: *Acidifying Soil for Crop Production: Inland Pacific Northwest.* Oregon St. Univ. Ext. Publ. EM8917-E

When lowering the soil pH with elemental sulfur, it should be applied at least a year in advance to planting grapevines because it must convert to sulfuric acid before it begins to lower the pH. The response to aluminum sulfate and ferrous sulfate is faster. Rates of elemental sulfur given in Figure 9 are for a broadcast application. It can be applied as a 3 to 4 foot band under the vines with an adjustment for the proportion of vineyard row width covered. The elemental sulfur or alternative material should be tilled into the soil as deeply and as uniformly as possible. In about 3 to 4 years, re-test the soil pH to determine if additional sulfur is required.

Phosphorous:

Except on sandy soils, phosphorous (P) is very immobile in the soil so a pre-plant application when it can be tilled into the soil is about the only time to effectively optimize the status of P in the soil without destroying grapevine roots. Phosphorous is present in the soil as an unavailable, exchangeable and available forms. Even when soil test results indicate the status of P is below optimal, plants are often able to obtain sufficient P because of the presence of soil-borne mycorrhizal fungi that make P available to plants. Still, it is best to optimize P before planting because it can be tilled into the soil where it will be accessible to the grapevine roots. After planning, surface applications of P are of little value for grapevines and only contributes phosphate pollution of our streams and lakes. Phosphate (P2O5) fertilizers that do not contain N such as superphosphate (0-20-0) and concentrated superphosphate (0-46-0) can be applied in the planting hole.

Potassium:

Potassium (K) moves very slowly in the soil, and surface applications often require several years to move into the root zone. For this reason optimize K before planting and incorporate it as deep as possible when a pre-plant soil test shows a need. On soils that are excessively high in magnesium (Mg), the Mg can inhibit the uptake of K event when soil test show sufficient K. Therefore, it is important also test for Mg to determine if additional K is needed. After the vineyard is established, the grapevines and any ground cover will take up K and recycle on the soil surface. Over time, high concentrations of K will accumulate near the soil surface and become depleted in the root zone. Therefore, after the grapevines come into production it is important to conduct a petiole analysis to assess the status of K.

Vineyard Best Management Practices – Soil Chemical Properties

Rate your soil's chemical properties:

Management Area: **Soil physical properties**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Soil testing	Conducted soil tests of the vineyard site for each soil type present before planting.	Conducted a soil test of the vineyard site before planting.	Conducted a soil test(s) of the vineyard site after planting.	Did not conduct a soil test(s) before or after planting the vineyard.
Organic Matter (OM)	2 to 3% OM	Less than 2% OM: undertake practice to improve OM. & apply N in split applications. 3 to 4% OM: reduce N applications, consider wider spacing for vigorous & very vigorous cultivars.	4-5% OM: Select cultivars that are very hardy. Training systems to accommodate high vigor. Restrict N applications; petiole analysis when production begins.	More than 5% OM: High OM will promote overly vigorous vines. Consider an alternative site for a vineyard.
Soil pH	pH 6 to 6.5:	pH 6.6 to 7.2: Low the pH over time using ammonium form of N fertilizer, *or* acidify the soil before planting with sulfur	pH below 5.9: Lime the soil before planting to raise pH. Soil pH 7.2 to 7.4: acidify the soil before planting with sulfur.	pH above 7.4: Conduct a fizz test to determine if soil acidification is feasible.
Phosphorous & Potassium	Optimized their status based on soil test results before planting, and till into soil.	Optimized their status based on soil test results after planting.	Forgo pre-plant soil testing & use complete fertilizers (N-P-K) on an annual basis.	Forgo pre-plant soil testing with no nutrient management plans.

Other Site Considerations

Previous cropping history:

- **Alfalfa and other legumes:** Sites that have recently been in alfalfa or another legume are not recommended for grapes. Alfalfa has the potential to fix up to 300 pounds of N per acre per year. Another crop should be planted on these site to bring down the fertility before considering grapes
- **Corn/soybean rotation:** On sites where pre-emergence herbicides have been used, care must be taken to make sure that herbicides with long carry-over affects that could be harmful to young grapevines have not been used. The herbicide labels include this information in the **ROTATIONAL CROP RESTRICTIONS** section. If Grapes are not specifically listed, the restriction period for "Other Crops" would apply. Sample labels of various pesticides are posted on the CDMS Label Database (http://www.cdms.net/Label-Database).
- **CRP or Pasture land:** These sites have planted with aggressive grasses that would be very competitive for water and nutrients if not removed before planting grapevines. Such grass species should be controlled before planting and replaced with less competitive species. Such sites may also have problem perennial weeds present. These should also be controlled before planting because there are many more choices of herbicides that can be used before grapevines are planted.

Growth Regulator Herbicide Drift: Grapevines are very sensitive to growth regulator herbicides such as 2,4-D and other related herbicides. These herbicides are volatile and can drift several miles into the vineyard can be injurious to vines. Ester formulations of these herbicides are more volatile than the amine formulations. Areas often sprayed with these 2,4-D type chemicals include road and rail right-of-ways, agronomic crops, pastures and lawns. Inform neighboring land owners, local co-ops, road maintenance employees, and aerial applicators that your grapes are highly sensitive to 2,4-D. If they have to use these herbicides, encourage them use them when the grapevines are dormant, or use an amine formulation. Once a vineyard is planted, you should register your site on a sensitive crops registry. The state of Minnesota participates in DriftWatch™ Specialty Crops Site Registry (http://driftwatch.org). Other post-emergence herbicides such as glyphosate (Roundup WeatherMax® and other trade names) will also damage vines, but this is the result of particle drift, and often the grower's fault.

Vineyard Economics

To be successful, a prospective grape grower should be aware of the expenses and labor involved in establishing and operating a vineyard. Vineyard establishment costs will vary with costs associated with land preparation, cost of the grapevines, the training system and cost of the trellising materials. The cost to operate the vineyard will vary with the labor, equipment and materials required to perform the various cultural practices such as pruning, fertilizing, weed control and ground cover management, insect and disease control, canopy management, and harvesting. Basic equipment needed will be a tractor, 5-6 ft mower, fertilizer spreader, a low operating pressure herbicide sprayer, and a higher pressure sprayer (preferably an air blast) for applying insecticides and fungicides. The grapevines can be planted with the aid of either a three-point (3-pt) power take off (PTO) driven auger with a 12-inch minimum diameter (14-16-inch diameter is preferred) or with a tree planter. Both could be rented or borrowed. For installing the trellis system, post driver (may be rented or borrowed) should be used, but an auger may be needed to drill pilot holes for the longer end posts.

A single tractor could be used if it has sufficient horsepower (HP) to operate an air blast sprayer for applying insecticides and fungicides, but fuel consumption will be higher when performing the lighter tasks. Generally, a 35 HP tractor is sufficient for mowing, herbicide spraying and other light cultural practices, however, a 50 HP tractor with cab is preferred for operating an air blast spray. A larger tractor would be needed for land preparation (disking, plowing, subsoiling) and planting with a tree planter, but this work could be hired or rented to eliminate the need or purchasing the implements. If irrigation is considered it will increase the cost of the initial investment.

Iowa State University Extension developed three downloadable, interactive work books on ***Estimated Vineyard Establishment Costs*** that are posted on the Agricultural Marketing Resource Center (AgMRC) website: thtp://www.agmrc.org/commodities__products/fruits/wine/winery_and_vineyard_feasibility_workbooks.cfm. These workbooks were used to generate the information on the establishment and operation of 1, 2 and 5 acre vineyards trained to a single curtain bilateral cordon (high-wire cordon), Geneva double curtain, and a mid-wire cordon with vertical shoot positioning (VSP) under vineyard layout, production potential, labor and machinery operating expenses assumptions presented in **Table 6**. Even if you perform all the labor yourself, your time is valuable and needs to be charged to the operation. In addition, interest or lost opportunity cost was assessed at 6% for 6 months on current year expenses and for 12 months on any carryover expenses, and a land charge of $165 per acre was assessed to cover other expenses such as property tax.

Hand tools for trellis construction and for performing cultural practices are items that are purchased for the first planting of grapevines or you may already have or be able to borrow some of them. A listing of the tools and cost of these tools and options are listed in **Table 7.** For the cost of establishment and operating costs summaries for one, 2 and 5 acre vineyards presented in **Tables 12-20**, tools were purchased for the first acre. Purchase of tractors, sprayers and other machinery was not included in the production budgets because of the potential option of purchasing new or used equipment and prices vary considerably.

The largest expense in the first year are for vines and trellising materials. Cold hardy cultivars will cost from $2.80 to $4.15 per vine for Grade 1 (1-1) and Grade 1 extra (1-X) vines in quantities sufficient for planting one or more acres. The cost per acre for grapevines priced at $2.80, $3.50 and $4.15 for vineyards trained to a high-wire cordon, Geneva double curtain and mid-wire cordon with VSP are shown in **Table 8**. **Table 8** also lists the cost of bamboo stakes and grow tubes that are often used to train vines during the first year. For the estimated establishment and operating cost budgets presented in **Tables 12-20**, a price of $3.50 per vine was used, and grow tubes were included as a cultural option.

The cost of trellis materials per acre for vineyards trained to the high-wire cordon, Geneva double curtain and mid-wire cordon with VSP is presented in **Table 9** comparing the use of the H-braced end post system to the earth anchor end post system based on the vineyard layout assumptions presented in **Table 6.** For the estimated establishment and operating cost budgets presented in **Tables 12-20**, the H-brace system was used. Trellising cost were based on the use of pressure-treated pine post (4” x 8’ line post and 6” x 10’ end post) installed with a post driver leaving 6 feet extending above the ground. If an auger is used to install the line post, 9 foot post should be used at an additional expense. For shorter rows, 3.5” diameter line post and 5” diameter end post could be used to reduce costs. Alternative materials, such as native timber, metal or synthetic posts are an option. It is recommended that the trellis be built at planting time. A trellis system could be established the second year, however some cultivars can exceed eight feet the first year and grow beyond training stakes.

If everything goes well, the vineyard should come into production by the third year with a partial crop and full crop by the fifth year. When a vineyard comes into production, insect and disease control becomes more intensive to protect the fruit, and some form of protection may be need to keep birds and mammals from feeding on the berries. Bird netting is a major cultural expenditure and options for grapevines trained to a high-wire cordon, Geneva double curtain (GDC) and mid-wire cordon with VSP are presented in **Table 10**. **Table 10** also presents harvest container options that would need to be purchased beginning in the first year of production and can be spread out until the vineyard reaches full production, hopefully by the fifth year. For the estimated establishment and operating cost budgets for 2 acre (**Tables 13, 16, 19**) and 5 acre (**Tables 14, 17, 20**) vineyards, harvest containers were purchased for the first acre on the assumption that the contained would be reused for each additional acre. Full production for grapevines trained to the high-wire cordon (**Tables 6, 12-14**) was estimated at 5 tons per acre or 18.3 lbs per vine. Since grapevines trained to the GDC have the potential to produce 60% higher yields than single curtain vines, full production was set at 29.3 lbs per vine or 6.7 tons per acre (**Tables 6, 15-17**). For vines trained to the mid-wire cordon with VSP, full production of 18.3 lbs per vine was used as with the high-wire cordon vines, but with more vines per acre, full production was estimated at 5.5 tons per acre (**Tables 6, 18-20**). For each training system production in the third and fourth year was set at approximately 40% and 80% full production (**Table 6**).

It is prudent to select cultivars that are in demand by local wineries and consumers. Also check with local wineries to determine if a minimum amount of the cultivar you intend to grow will be required. Current prices for wine grapes range from $1,000 to $1,500 per ton with some high-in-demand, high quality and clean new cultivars bringing as much as $2,000 per ton. For the estimated establishment and operating cost budgets presented in **Tables 12-20**, $1,500 per ton was used. For the budgets, harvest was on a piece-work basis set at $1.50 per lug or $100 per ton or $1.63 per lug and $109 per ton with overhead (**Table 6**). **Table 11** breaks down the annual labor and machinery requirements, and materials cost per acre by cultural practice for mature vineyards trained to a high-wire cordon, GDC and mid-wire cordon with VSP. Not included in the labor expense is pest management scouting and grape cultivar maturity testing because these practices will vary for the time from bud break to maturity for a cultivar, and the number of cultivars. Pest management scouting can consume one hour per week per acre and maturity testing could take up to an hour per week per cultivar following veraison.

Based on the assumptions used to develop the estimated establishment and operating cost budget summaries, first year accumulated cost per acre was $9,272 for the high-wire cordon (**Table 12**), $9,635 for the GDC (**Table 15**), and $11,408 for the mid-wire cordon with VSP (**Table 18**). However, the pre-plant year budget was developed based on the assumption that no soil amendments were required. For each scenario, income covered the annual expenses in the fourth year (**Tables 12-20**). For one acre vineyards, return on the investment was reached in the Year 10 on the high-wire cordon (**Table 12**), Year 8 on the GDC (**Table 15**), and Year 9 on the mid-wire cordon with VSP (**Table 18**). Increasing the size of the vineyard to 2 or 5 acres shortened the time when the vineyards became profitable.

Table 6. Vineyard layout and operating assumptions used to estimate the establishment and operating expenses for 1, 2 and 5 acre vineyards trained to a single curtain bilateral cordon (high-wire cordon), Geneva double curtain, and mid-wire cordon with vertical shoot positioning (VSP).

Vineyard Layout and Production Potential

Training System:	High-wire Cordon	Geneva Double Curtain	Mid-wire Cordon w/ VSP
Vine spacing:	8 x 10 ft	8 x 12 ft	8 x 9 ft
Vines per acre:	545	454	605
Row length:	432 ft	432 ft	432 ft
Rows per acre:	10	8.5	11
Vines per row:	54	54	54

Production Potential:	Year			Year			Year		
	3	4	5 & beyond	3	4	5 & beyond	3	4	5 & beyond
Yield per vine:	7.3	14.7	18.3	12.8	25.6	29.5	7.3	14.7	18.3
Tons per Acre	2	4	5	2.9	5.8	6.7	2.2	4.4	5.5

Operating Expenses

Labor & Overhead:	Base Pay per hour	Social Security (@ 6.2%)	Medicare (@ 1.45%)	Worker Compensation (@ 1.0%)	Vacation (@ 4.0%)	Health Insurance (@ 10.0%)	Total Labor + Overhead per hour
Full-time General	$10.00	x	x	x	x	x	$12.27
Full-time Skilled	$15.00	x	x	x	x	x	$18.40
Harvest piece work	$1.50/ 30 lb lug	x	x	x			$1.63/lug

Tractor Operating Cost:[z]

Tractor horsepower	Task	Fuel use per HP (Gallons)	Rental value per horsepower	On farm Fuel cost per gallon (diesel)	Operating cost per hour
35	heavy	.06	$0.28	$2.255	$14.54
35	light	.02	$0.28	$2.255	$11.38
50	heavy	.06	$0.28	$2.255	$20.77
50	light	.02	$0.28	$2.255	$16.26

[z] Tractor operating cost/hour = (Tractor HP x rental value/HP) + (Tractor HP x fuel use/HP x fuel cost/gal)

Table 7. Trellising and cultural tools needed to establish and maintain a vineyard.

Trellising tools:	**Year of Purchase**	**Quantity**	**Cost**	**Cost used in Workbooks**	**Cost range**	**Options**
Auger: 3-pt, PTO drive, with 6-9" dia. & 12" dia. min. (14-16" dia. preferred) augers					$660 – 1,600	*Rent, borrow*
Wire jenny	1	1	$86.10	$86.10	$45.00 - 86.10	*Borrow*
Crimping tool	1	1	50.00	50.00	50.00 - 90.00	*Borrow*
Strainer handle	1	1	7.50	7.50	7.50 – 9.50	*Extra advised*
Hammer, 20-24 oz framing	1	2	24.98	49.96	20.00 – 27.00	
Fencing pliers	1	2	13.00	26.00	13.00 – 19.00	
Eye adapter (installing earth anchors)	1	1			46.00 – 83.00	*Borrow*
3-Pt pallet lift (when harvesting in bins)					180.00 – 350.00	
Total trellising tools:				**241.76**		
Cultural tools:						
Pruning shear	1	1	55.60	55.60	31.00 – 68.00	*One per person*
Holster	1	1	11.00	11.00	5.00 – 11.00	*One per person*
Shovel, long handled	1	3	24.00	72.00	20.00 – 27.00	*One per person*
MaxTapener	1	1	64.25	64.25		*One per person*
Thinning clippers	1	1	15.00	15.00	8.00 – 17.00	*One per person*
Loppers, 16-19" handles	3	1	52.00	52.00	52.00 – 93.00	*One per person*
Harvest clippers	3	4	9.50	38.00	9.00 – 17.00	*One per person*
Total cultural tools:				**$307.85**		

Table 8. Cost of vines and major training supplies per acre during the first year for vineyards trained to a single curtain bilateral cordon (high-wire cordon), Geneva double curtain, and mid-wire cordon with vertical shoot positioning (VSP).

Training System:	**High-wire Cordon**				**Geneva Double Curtain**				**Mid-wire Cordon w/ VSP**			
Grapevines	**Size/ grade**	**Cost/ item**	**Quantity**	**Cost/ acre**	**Size/ grade**	**Cost/ item**	**Quantity**	**Cost/ acre**	**Size/ grade**	**Cost/ item**	**Quantity**	**Cost/ acre**
@ $2.80 per vine	1-1	$2.80	545	$1,526.00	1-1	$2.80	454	$1,271.20	1-1	$2.80	605	$1,694.00
@ $3.50 per vine*	1-X	$ 3.50	545	$1,907.50	1-X	$ 3.50	454	$1,589.00	1-X	$ 3.50	605	$2,117.50
@ $4.15 per vine	1-X	$4.15	545	$2,261.75	1-X	$4.15	454	$1,884.10	1-X	$4.15	605	$2,510.75
First Year Training*												
Bamboo stakes	7' x 5/8"	0.55	545	299.75	6' x 5/8"	0.44	454	199.76	4' x 1/2"	0.22	605	133.10
Grow tubes	30"	0.85	545	463.25	30"	0.85	454	385.90	30"	0.85	605	514.25
T-bands (attach stakes to wires	½"	0.03	908	27.24	½"	0.03	454	13.62	½"	0.03	605	18.15
Plant tie ribbon (per roll)	4 mil	1.66	10.5	17.43	4 mil	1.66	9	14.94	4 mil	1.66	12	19.92
Total training supplies:				**807.67**				**614.22**				**685.52**
Cost of vines & training supplies per acre:												
@ $2.80 per vine				**$2,333.67**				**$1,885.42**				**$2,379.52**
@ $3.50 per vine				**$2,715.17**				**$2,203.22**				**$2,803.02**
@ $4.15 per vine				**$3,069.42**				**$2,498.32**				**$3,196.27**

* Options used in the estimated establishment and operating cost budgets presented in Tables 12-20.

Table 9. Cost of trellis materials per acre for vineyards trained to a single curtain bilateral cordon (high-wire cordon), Geneva double curtain, and mid-wire cordon with vertical shoot positioning (VSP) using the H-brace and anchored end post systems.

Training System:	**High-wire Cordon**				**Geneva Double Curtain**				**Mid-wire Cordon w/ VSP**			
H-Brace System:*	**Size/ grade**	**Cost/ item**	**Quantity**	**Cost/ acre**	**Size/ grade**	**Cost/ item**	**Quantity**	**Cost/ acre**	**Size/ grade**	**Cost/ item**	**Quantity**	**Cost/ acre**
Line posts	4" x 8'	$5.81	172	$999.32	4" x 8'	$5.81	143	$830.83	4" x 8'	$5.81	190	$1,103.90
Brace posts (4/row)	4" x 8'	$5.81	40	$232.40	4" x 8'	$5.81	34	$197.54	4" x 8'	$5.81	44	$255.64
End posts	6" x 10'	$15.75	20	$315.00	6" x 10'	$15.75	17	$267.75	6" x 10'	$15.75	22	$346.50
Brace pins (pairs)	10" & 5"	$1.02	20	$20.40	10" & 5"	$1.02	17	$17.34	10" & 5"	$1.02	22	$22.44
9 ga Soft wire	17 ft/lb	$.0.60/lb	27 lb	$16.20	17 ft/lb	$.0.60/lb	23 lb	$13.80	17 ft/lb	$.0.60/lb	30 lb	$18.00
Cross arm + brace					48"	$7.20	160	$1,152.00				
12.5 ga Hi-tensile wire (4000ft, 100 lb/roll)	2 strands	$122.00	2.3	$280.60	3 strands	$122.00	2.8	$341.60	7 strands	$122.00	8.8	$1,073.60
Strainers	1/strand	$3.25	20	$65.00	1/strand	$3.25	25.5	$82.88	1/strand	$3.25	77	$250.25
Crimping sleeves (2/splice)	small	$0.24	126	$30.24	small	$0.24	160	$38.40	small	$0.24	484	$116.16
Staples, slash-cut (45/lb)	2"	$2.25/lb	18.8	$42.30	2"	$2.25/lb	7.9	$17.78	2"	$2.25/lb	10.4	$23.40
"J" Staples (81/lb)									1-3/4"	$5.30	16.5	$87.45
Total cost per acre:				**$2001.46**				**$2,959.92**				**$3,297.34**
Earth Anchor System:												
Line posts	4" x 8'	$5.81	172	$999.32	4" x 8'	$5.81	160	$929.60	4" x 8'	$5.81	190	$1,103.90
Earth anchor w/ 6" helix	**¾" x 48"**	$9.75	20	$195.00	**¾" x 48"**	$9.75	17	$165.75	**¾" x 48"**	$9.75	22	$214.50
End posts	6" x 10'	$15.75	20	$315.00	6" x 10'	$15.75	17	$267.75	6" x 10'	$15.75	22	$346.50
9 ga Soft wire	17 ft/lb	$.0.60/lb	20 lb	$12.00	17 ft/lb	$.0.60/lb	17 lb	$10.20	17 ft/lb	$.0.60/lb	22lb	$13.20
Cross arm + brace					48"	$7.20	160	$1,152.00				
12.5 ga Hi-tensile wire (4000ft, 100 lb/roll)	2 strands	$122.00	2.3	$280.60	3 strands	$122.00	2.8	$341.60	7 strands	$122.00	8.8	$1,073.60
Strainers	1/strand	$3.25	20	$65.00	1/strand	$3.25	25.5	$82.88	1/strand	$3.25	77	$250.25
Crimping sleeves (2/splice)	small	$0.24	126	$30.24	small	$0.24	160	$38.40	small	$0.24	484	$116.16
Staples, slash-cut (45/lb)	2"	$2.25/lb	18.8	$42.30	2"	$2.25/lb	7.9	$17.78	2"	$2.25/lb	10.4	$23.40
"J" Staples (81/lb)									1-3/4"	$5.30	16.5	$87.45
Total cost per acre:				**$1,939.46**				**$3,005.96**				**$3,228.96**

* Options used in the estimated establishment and operating cost budgets presented in Tables 12-20.

Table 10. Bird netting and harvest container options for vineyards trained to a single curtain bilateral cordon (high-wire cordon), Geneva double curtain, and mid-wire cordon with vertical shoot positioning (VSP). Items purchased beginning in the first year of production (Year 3).

	Cost/ roll		High-wire Cordon		Geneva Double Curtain		Mid-wire Cordon w/ VSP	
Bird Netting:	**Quantity**		**Cost/ acre**	**Quantity**	**Cost/ acre**	**Quantity**	**Cost/ acre**	
17 x 1,320 ft	$545.00		3.3 rolls*	**$1,798.50**	2.75 rolls	**$1,498.75**	3.67	**$2,000.15**
22 x 1320 ft	$704.00				2.75 rolls*	**$1,936.00**		
6 x 3,280 ft side netting	$294.00						3.0 rolls*	**$882.00**
Harvest Containers:	Year of pur-chase	Cost	**Potential Production per Acre for a Mature Vineyard**					
			(5 tons/acre)		**(6.7 tons/acre)**		**tons/acre)**	
Lugs* (30 lb capacity)	3, 4, 5	$10.25	340	**$3,485.00**	450	**$4,612.50**	375	**$3,843.75**
Need a narrow trailer to haul lugs in & out of the vineyard								
Bins (1,000 lb capacity)	3, 4, 5	$274.00	10	**$2,740.00**	14	**$3,836.00**	11	**$3,014.00**
Need a 3-pt pallet lift to haul bins in and out of the vineyard								

* Options used in the estimated establishment and operating cost budgets presented in Tables 12-20.

Table 11. Labor and machinery requirements, and annual materials cost per acre to operate a mature vineyard trained a single curtain bilateral cordon (high-wire cordon), Geneva double curtain, and a mid-wire cordon with vertical shoot positioning (VSP).

	High-wire Cordon				Geneva Double Curtain				Mid-wire Cordon w/ VSP			
Practice:	**No. times**	**Labor Hrs.**	**Machinery Hrs,**	**Materials Cost**	**No. times**	**Labor Hrs.**	**Machinery Hrs,**	**Materials Cost**	**No. times**	**Labor Hrs.**	**Machinery Hrs,**	**Materials Cost**
Dormant pruning	1	40.0			1	63.6			1	44.4		
Adjusting & tying w/ AgLocs @ $0.07 ea	1	4.5		$3.63	1	7.6		$6.01	1	5.0		$4.03
Brush removal	1	1.2	1.2		1	0.9	0.9		1	1.3	1.3	
Fertilize w/ urea	1	0.6	0.3	$32.45	1	0.5	0.3	$29.98	1	0.7	0.4	$36.03
Insect & disease control	11	9.6	4.8	$728.50	11	8.2	4.0	$728.50	11	10.6	5.2	$728.50
Weed control	2	3.0	2.0	$50.80	2	2.8	1.8	$42.63	2	3.4	2.2	$56.16
Mowing	5	1.7	1.7		5	1.5	1.5		5	1.9	1.9	
Canopy Management:												
Suckering & basal shoot removal	1	9.1			1	15.1			1	10.1		
Cluster thinning based on shoot length	1	4.5			1				1	5.0		
Shoot positioning	1	18.2			2	30.3			3	20.0		$4.98
Lateral shoot removal in the fruiting zone	1	13.6			1	22.7			1	10.1		
Petiole Analysis	1	0.3		$15.00	1	0.3		$15.00	1	0.3		$15.00
Harvest (to haul lugs to and from the vineyard	1	12.5	5.0		1	16.8	6.7		1	13.8	5.5	
Total:		**132.8**	**17.0**	**$830.83**		**188.4**	**16.7**	**$822.11**		**140.2**	**19.6**	**$844.69**

* Options used in the estimated establishment and operating cost budgets presented in Tables 12-20.

Table 12. Summary of the estimated cost to establish and operate a one acre vineyard trained to a single curtain bilateral cordon (high-wire cordon).

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	6.2	$109	3.1	$62	$162		$165	$15	$513		($513)	($513)
Yr. 1 Plant	49.3	$662	7.1	$82	$2,083							
Yr. 1 Trellis	45.2	$706	12.9	$147	$2,273							
Yr. 1 Culture	76.0	$999	20.2	$261	$1,097							
Year 1 Total	170.5	$2,367	40.2	$490	$5,452		$165	$285	$8,760		($8,760)	($9,272)
Year 2	57.2	$769	6.8	$112	$530		$165	$604	$2,179		($2,179)	($11,452)
Year 3	116.2	$1,526	14.0	$219	$5,577	$218	$165	$918	$8,622	$3,000	($5,622)	($17,074)
Year 4	132.3	$1,667	16.0	$241	$2,286	$435	$165	$1,168	$5,961	$6,000	$39	($17,035)
Year 5	137.4	$1,786	17.0	$253	$1,602	$543	$165	$1,153	$5,501	$7,500	$1,999	($15,036)
Year 6	132.8	$1,729	17.0	$253	$830	$543	$165	$1,008	$4,528	$7,500	$2,972	($12,064)
Year 7	132.8	$1,729	17.0	$253	$817	$543	$165	$829	$4,336	$7,500	$3,164	($8,900)
Year 8	132.8	$1,729	17.0	$253	$830	$543	$165	$640	$4,160	$7,500	$3,340	($5,560)
Year 9	132.8	$1,729	17.0	$253	$817	$543	$165	$439	$3,945	$7,500	$3,555	($2,005)
Year 10	132.8	$1,729	17.0	$253	$830	$543	$165	$226	$3,746	$7,500	$3,754	$1,748

Table 13. Summary of the estimated cost to establish and operate a 2 acre vineyard trained to a single curtain bilateral cordon (high-wire cordon).

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	12.4	$217	6.2	$123	$325		$330	$30	$1,025		($1,025)	($1,025)
Yr. 1 Plant	98.6	$1,323	14.2	$165	$4,027							
Yr. 1 Trellis	90.4	$1,412	25.8	$294	$4,276							
Yr. 1 Culture	152.0	$1,999	40.4	$521	$2,106							
Year 1 Total	341.0	$4,735	80.4	$980	$10,409		$330	$555	$17,009		($17,009)	($18,034)
Year 2	114.4	$1,538	13.6	$224	$1,060		$330	$1,177	$4,328		($4,328)	($22,364)
Year 3	232.4	$3,052	28.0	$437	$8,320	$435	$330	$1,719	$14,292	$6,000	($8,292)	($30,654)
Year 4	264.6	$3,333	32.0	$483	$3,188	$869	$330	$2,085	$10,288	$12,000	$1,712	($28,942)
Year 5	274.8	$3,571	34.0	$505	$2,487	$1,087	$330	$1,976	$9,956	$15,000	$5,044	($23,898)
Year 6	265.6	$3,458	34.0	$505	$1,661	$1,087	$330	$1,645	$8,686	$15,000	$6,314	($17,584)
Year 7	265.6	$3,458	34.0	$505	$1,633	$1,087	$330	$1,265	$8,279	$15,000	$6,721	($10,863)
Year 8	265.6	$3,458	34.0	$505	$1,661	$1,087	$330	$863	$7,904	$15,000	$7,096	($3,766)
Year 9	265.6	$3,458	34.0	$505	$1,633	$1,087	$330	$439	$7,452	$15,000	$7,548	$3,782
Year 10	265.6	$3,458	34.0	$505	$1,661	$1,087	$330	$0	$7,041	$15,000	$7,959	$11,741

Table 14. Summary of the estimated cost to establish and operate a 5 acre vineyard trained to a single curtain bilateral cordon (high-wire cordon).

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	31.0	$544	15.5	$308	$812		$825	$75	$2,563		($2,563)	($2,563)
Yr. 1 Plant	246.5	$3,308	35.5	$412	$9,859							
Yr. 1 Trellis	226.0	$3,531	64.5	$736	$10,286							
Yr. 1 Culture	380.0	$4,998	101.0	$1,303	$5,133							
Year 1 Total	852.5	$11,836	201.0	$2,451	$25,278		$825	$1,365	$41,756		($41,756)	($44,319)
Year 2	286.0	$3,844	34.0	$560	$2,649		$825	$2,895	$10,774		($10,774)	($55,093)
Year 3	581.0	$7,629	70.0	$1,093	$16,550	$1,087	$825	$4,121	$31,303	$15,000	($16,303)	($71,396)
Year 4	661.5	$8,333	80.0	$1,206	$5,894	$2,173	$825	$4,837	$23,268	$30,000	$6,732	($64,664)
Year 5	687.0	$8,928	85.0	$1,263	$5,142	$2,716	$825	$4,446	$23,320	$37,500	$14,180	($50,484)
Year 6	664.0	$8,646	85.0	$1,263	$4,152	$2,716	$825	$3,557	$21,159	$37,500	$16,341	($34,143)
Year 7	664.0	$8,646	85.0	$1,263	$4,083	$2,716	$825	$2,575	$20,107	$37,500	$17,393	($16,750)
Year 8	664.0	$8,646	85.0	$1,263	$4,152	$2,716	$825	$1,533	$19,135	$37,500	$18,365	$1,615
Year 9	664.0	$8,646	85.0	$1,263	$4,083	$2,716	$825	$0	$17,533	$37,500	$19,967	$21,582
Year 10	664.0	$8,646	85.0	$1,263	$4,152	$2,716	$825	$0	$17,602	$37,500	$19,898	$41,480

Table 15. Summary of the estimated cost to establish and operate a one acre vineyard trained to a Geneva double curtain.

Year	Labor		Machinery		Materials Cost	Harvest Cost (tons/A)	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	6.2	$109	3.1	$62	$162		$165	$15	$513		($530)	($530)
Yr. 1 Plant	42.2	$622	6.1	$71	$1,756							
Yr. 1 Trellis	63.6	$927	10.1	$123	$3,230							
Yr. 1 Culture	64.2	$830	17.8	$211	$892							
Year 1 Total	170.0	$2,380	34.0	$405	$5,878		$165	$296	$9,123		($9,123)	($9,635)
Year 2	78.2	$979	5.8	$95	$489		$165	$630	$2,353		($2,358)	($11,994)
Year 3	167.7	$2,145	12.9	$196	$4,924	$315	$165	$952	$8,696	$4,350	($4,346)	($16,340)
Year 4	205.4	$2,607	15.8	$229	$2,953	$630	$165	$1,178	$7,762	$8,700	$938	($15,402)
Year 5	195.9	$2,490	16.7	$239	$1,537	$728	$165	$1,079	$6,238	$10,050	$3,812	($11,590)
Year 6	188.4	$2,398	16.7	$239	$822	$728	$165	$826	$5,178	$10,050	$4,876	($6,718)
Year 7	188.4	$2,398	16.7	$239	$811	$728	$165	$533	$4,874	$10,050	$5,176	($1,542)
Year 8	188.4	$2,398	16.7	$239	$822	$728	$165	$232	$4,575	$10,050	$5,475	$3,933
Year 9	188.4	$2,398	16.7	$239	$811	$728	$165	$0	$4,341	$10,050	$5,709	$9,642
Year 10	188.4	$2,398	16.7	$239	$822	$728	$165	$0	$4,352	$10,050	$5,698	$15,339

Table 16. Summary of the estimated cost to establish and operate a 2 acre vineyard trained to a Geneva double curtain.

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	12.4	$217	6.2	$123	$325		$330	$30	$1,025		($1,025)	($1,025)
Yr. 1 Plant	84.4	$1,244	12.2	$142	$3,445							
Yr. 1 Trellis	127.2	$1,855	20.2	$246	$6,095							
Yr. 1 Culture	128.4	$1,661	35.6	$422	$1,695							
Year 1 Total	340.0	$4,759	68.0	$810	$11,235		$330	$576	$17,710		($17,710	($18,735)
Year 2	156.4	$1,958	11.6	$191	$979		$330	$1,228	$4,685		($4,685)	($23,420)
Year 3	335.4	$4,289	25.8	$391	$7,797	$630	$330	$1,808	$15,246	$8,700	($6,546)	($29,966)
Year 4	410.8	$5,214	31.6	$457	$3,908	$1,260	$330	$2,133	$13,303	$17,400	$4,097	($25,868)
Year 5	391.8	$4,981	33.4	$478	$2,458	$1,456	$330	$1,843	$11,546	$20,100	$8,554	($17,314)
Year 6	376.8	$4,797	33.4	$478	$1,644	$1,456	$330	$1,300	$10,005	$20,100	$10,095	($7,219)
Year 7	376.8	$4,797	33.4	$478	$1,621	$1,456	$330	$694	$9,375	$20,100	$10,725	$3,506
Year 8	376.8	$4,797	33.4	$478	$1,644	$1,456	$330	$0	$8,928	$20,100	$11,395	$14,901
Year 9	376.8	$4,797	33.4	$478	$1,621	$1,456	$330	$0	$8,682	$20,100	$11,418	$26,319
Year 10	376.8	$4,797	33.4	$478	$1,644	$1,456	$330	$0	$8,705	$20,100	$11,395	$37,714

Table 17. Summary of the estimated cost to establish and operate a 5 acre vineyard trained to a Geneva double curtain.

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	31.0	$544	15.5	$308	$812		$825	$75	$2,563		($2,563)	($2,563)
Yr. 1 Plant	211.0	$3,110	30.5	$355	$8,511							
Yr. 1 Trellis	318.0	$4,637	50.5	$614	$14,691							
Yr. 1 Culture	321.0	$4,152	89.0	$1,055	$4,106							
Year 1 Total	850.0	$11,898	170.0	$2,025	$27,309		$825	$1,415	$43,473		($43,473)	($46,035)
Year 2	391.0	$4,895	29.0	$476	$2,446		$825	$3,021	$11,664		($11,664)	($57,699)
Year 3	838.5	$10,728	64.5	$978	$16,416	$1,575	$825	$4,377	$34,894	$21,750	($13,144)	($70,843)
Year 4	1,027.0	$13,035	79.0	$1,143	$6,772	$3,151	$825	$4,998	$29,924	$43,500	$13,576	($57,267)
Year 5	979.5	$12,452	83.5	$1,194	$5,223	$3,640	$825	$4,136	$27,470	$50,250	$22,780	($34,487)
Year 6	942.0	$11,992	83.5	$1,194	$4,111	$3,640	$825	$2,722	$24,484	$50,250	$25,766	($8,721)
Year 7	942.0	$11,992	83.5	$1,194	$4,053	$3,640	$825	$1,174	$22,878	$50,250	$27,372	$18,651
Year 8	942.0	$11,992	83.5	$1,194	$4,111	$3,640	$825	$0	$21,762	$50,250	$28,488	$47,139
Year 9	942.0	$11,992	83.5	$1,194	$4,053	$3,640	$825	$0	$21,704	$50,250	$28,546	$75,685
Year 10	942.0	$11,992	83.5	$1,194	$4,111	$3,640	$825	$0	$21,762	$50,250	$28,488	$104,173

Table 18. Summary of the estimated cost to establish and operate a one acre vineyard trained to a mid-wire cordon with vertical shoot positioning (VSP).

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	6.2	$109	3.1	$62	$162		$165	$15	$513		($513)	($513)
Yr. 1 Plant	54.2	$810	7.8	$90	$2,296							
Yr. 1 Trellis	76.5	$1,127	13.1	$149	$3,576							
Yr. 1 Culture	82.7	$1,078	21.2	$275	$982							
Year 1 Total	213.4	$3,015	42.1	$514	$6,855		$165	$347	$10,896		($10,896)	($11,408)
Year 2	63.5	$854	7.5	$123	$591		$165	$736	$2,469		($2,469)	($13,877)
Year 3	134.3	$1,759	16.8	$256	$3,611	$239	$165	$1,014	$7,421	$3,300	($2,702)	($17,620)
Year 4	138.1	$1,805	19.0	$276	$2,483	$478	$165	$1,213	$6,421	$6,600	$179	($17,441)
Year 5	141.5	$1,847	20.1	$295	$1,598	$598	$165	$1,182	$5,683	$8,400	$2,567	($14,874)
Year 6	141.5	$1,847	20.1	$294	$844	$598	$165	$1005	$4,753	$8,250	$3,497	($11,377)
Year 7	141.5	$1,847	20.1	$294	$829	$598	$165	$795	$4,528	8,250	$3,722	($7,765)
Year 8	141.5	$1,847	20.1	$294	$844	$598	$165	$572	$4,320	8,250	$3,930	($3,725)
Year 9	141.5	$1,847	20.1	$294	$829	$598	$165	$336	$4,069	8,250	$4,181	$456
Year 10	141.5	$1,847	20.1	$294	$844	$598	$165	$0	$3,749	8,250	$4,501	$4,957

Table 19. Summary of the estimated cost to establish and operate a 2 acre vineyard trained to a mid-wire cordon with vertical shoot positioning (VSP).

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Expenses	Income	Profit *or* (Expense)	
Pre-plant	12.4	$217	6.2	$123	$325		$330	$30	$1,025		($1,025)	($1,025)
Yr. 1 Plant	108.4	$1,619	15.6	$181	$4,454							
Yr. 1 Trellis	153.0	$2,253	26.2	$298	$6,899							
Yr. 1 Culture	165.4	$2,157	42.4	$550	$1,876							
Year 1 Total	426.8	$6,029	84.2	$1,029	$13,229		$330	$680	$21,297		($21,297)	($22,322)
Year 2	127.0	$1,707	15.0	$246	$1,182		$330	$1,443	$4,909		($4,909)	($27,231)
Year 3	268.6	$3,518	33.6	$511	$5,585	$478	$330	$1,947	$12,091	$6,600	($5,768)	($32,999)
Year 4	276.2	$3,611	38.0	$552	$3,396	$956	$330	$2,245	$11,091	$13,200	$2,109	($30,890)
Year 5	283.0	$3,694	40.2	$588	$2,427	$1,195	$330	$2,100	$10,335	$16,500	$6,165	($24,725)
Year 6	283.0	$3,694	40.2	$588	$1,689	$1,195	$330	$1,708	$9,206	$16,500	$7,294	($17,430)
Year 7	283.0	$3,694	40.2	$588	$1,658	$1,195	$330	$1,270	$8,736	$16,500	$7,764	($9,666)
Year 8	283.0	$3,694	40.2	$588	$1,689	$1,195	$330	$805	$8,302	$16,500	$8,198	($1,469)
Year 9	283.0	$3,694	40.2	$588	$1,658	$1,195	$330	$336	$7,802	$16,500	$8,698	$7,230
Year 10	283.0	$3,694	40.2	$588	$1,689	$1,195	$330	$0	$7,497	$16,500	$9,003	$16,233

Table 20. Summary of the estimated cost to establish and operate a 5 acre vineyard trained to a mid-wire cordon with vertical shoot positioning (VSP).

Year	Labor		Machinery		Materials Cost	Harvest Cost	Land Charge	Interest *or* Lost Opportunity	Annual			Accumulated Income *or* (Expense)
	Hrs.	Cost	Hrs.	Cost					Total Expenses	Income	Profit *or* (Expense)	
Pre-plant	31.0	$544	15.5	$308	$812		$825	$75	$2,563		($2,563)	($2,563)
Yr. 1 Plant	271.0	$4,048	39.0	$454	$10,927							
Yr. 1 Trellis	382.5	$5,633	65.5	$745	$16,869							
Yr. 1 Culture	413.5	$5,392	106.0	$1,374	$4,559							
Year 1 Total	1,067.0	$15,073	210.5	$2,571	$32,354		$825	$1,678	$52,501		($52,501)	($55,064)
Year 2	317.5	$4,268	37.5	$616	$2,955		$825	$3,564	$12,228		($12,228)	($67,292)
Year 3	371.5	$8,794	84.0	$1,277	$11,509	$1,195	$825	$4,746	$28,346	$16,500	($11,846)	($79,138)
Year 4	690.5	$9,027	95.0	$1,380	$6,136	$2,390	$825	$5,341	$25,100	$33,000	$7,900	($71,238)
Year 5	707.5	$9,236	100.5	$1,470	$4,915	$2,988	$825	$4,855	$24,289	$41,250	$16,961	($54,278)
Year 6	707.5	$9,236	100.5	$1,470	$4,223	$2,988	$825	$3,819	$22,562	$41,250	$18,688	($35,590)
Year 7	707.5	$9,236	100.5	$1,470	$4,146	$2,988	$825	$2,695	$21,361	$41,250	$19,889	($15,701)
Year 8	707.5	$9,236	100.5	$1,470	$4,223	$2,988	$825	$1,504	$20,247	$41,250	$21,003	$5,302
Year 9	707.5	$9,236	100.5	$1,470	$4,146	$2,988	$825	$0	$18,665	$41,250	$25,585	$27,887
Year 10	707.5	$9,236	100.5	$1,470	$4,223	$2,988	$825	$0	$18,743	$41,250	$22,507	$50,394

Based on the estimated establishment and operating cost budgets developed for vineyards trained to a single curtain bilateral cordon (high-wire cordon), Geneva double curtain (GDC) and mid-wire cordon with VSP, it takes considerable time and financial commitment to establish and operate a vineyard, and several years before the vineyard becomes profitable on its own. Our estimates indicate that it will take approximately 240 to 290 hours (Years 0-2) to establish a one-acre vineyard if planting and trellising are done in the same year, and it takes approximately 133 to 190 hour per year to maintain an established vineyard.

Vineyard Best Management Practices – Time and Financial Commitment:

Rank your level of time commitment per acre or ability to hire labor for:

Management area: **Time Commitment per acre**	**Best Practice**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Need Improvement: Prioritize Changes**
Years 1-2 (Site preparation, planting & trellising	Can commit 240-290 hours for planting, trellising, training & cultural practices	Can commit 210-240 hours for planting, trellising, training & cultural practices	Can commit 180-210 hours for planting, trellising, training & cultural practices	Cannot commit 180 hours for planting, trellising, training & cultural practices
Years 3 and beyond	Can commit more than 140 hours for pruning, shoot thinning, shoot positioning, weed and pest control, and harvest per year.	Can commit 120-140 hours for pruning, shoot thinning, shoot positioning, weed and pest control, and harvest per year.	Can commit 100-120 hours for pruning, shoot thinning, shoot positioning, weed and pest control, and harvest per year.	Cannot commit more than 100 hours for pruning, shoot thinning, shoot positioning, weed and pest control, and harvest per year.

Our estimates indicate that it will cost from $16,000 to $18,000 to bring one acre of vineyard into bearing in Year 3, and then an additional $2,500 to $3,500 per year from year 4 and beyond to maintain it excluding bird netting and harvest containers. A person can assume that it will cost approximately $660 per acre in the year prior to planting (Year 0) to prepare the site - soil preparation, soil testing and cover cropping. If soils need any soil amendments (lime, sulfur, phosphorous, potassium, magnesium, or a micro-nutrient) to optimize conditions, it would increase the cost of establishment in Year 0. In Year 1, the cost of grapevines and trellising materials are the major expense. If a person raises their own vines from cuttings, they can reduce the cost for the vines. However, one should remember that all patented cultivars cannot be propagated without written consent of the patent holder and royalties & licensing fees paid to them. It is best to purchase patented cultivars from nurseries that are licensed to propagate them.

The estimated cost of the trellis systems were based on the use of pressure-treated pine post. If a person is able to use alternative materials for line and end post, one may cut down on the cost of trellis construction. In doing this, one must account for the strength and longevity of alternatives as well as labor involved in accessing the alternatives.

Year 2 should be devoted to training the grapevines to prepare them for producing a partial crop in Year 3. Pest control becomes more important and should include a good weed control program to minimize competition for water and nutrients, and controlling diseases and insects that attack the foliage. Scouting the vineyard on a regular basis will enable you to identify any disease or insect issues before they become a problem. If all goes well, the vineyard can be brought into production in Year 3. Once in production, controlling diseases and insects that attack the fruit must be considered and increased pest control measure undertaken. Summer canopy management practices (shoot thinning, shoot positioning and maybe cluster thinning) and dormant pruning will add to the financial commitment for operating the vineyard.

Vineyard Best Management Practices – Time and Financial Commitment:

Rank your level of financial commitment per acre per year for:

Management area: **Financial commitment per acre per year.**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvement: Prioritize Changes Here**
Year 0 (site preparation)	$500-$700	$300-$500	$300-$250	Less than $250
Year 1 (Planting, trellis construction, & cultural practices)	$8,400-$11,000	$7,000-$8,000	$6,000-$7,000	Less than $5,000
Year 2 (Training, labor, weed & pest control, and interest)	$2,200-$2,500	$2,000-$2,200	$1,200-$1,800	Less than $1,000
Years 3 & beyond (Fruiting years: labor for pruning, vine management, weed & pest control, harvest, and interest.)	$2,500-$3,500	$2,000-$2,500	$1,500-$2,000	Less than $1,500

Grape Cultivars for Minnesota

Selecting grape cultivars to plant is important and can be the difference between a successful vineyard and one destined to fail. There a number of factors that must be taken into consideration in selecting the cultivars that best meet your needs.

1. What are your marketing plans? Will you be growing grapes for wine, juice and jelly, fresh table consumption, or some combination of these options? Some cultivars are specific for wine making, while others have multiple uses.
2. Is the cultivar adapted to your climatic conditions?
    a. Does it possess sufficient cold hardiness? Cold hardiness of grapevines can be reported as minimum temperature the vine can survive, or the temperature at which primary cane buds begin to exhibit winter injury. The cane buds are the most tender portion of a grapevine and because injury to these buds affects cropping potential it is a more important consideration when selecting cultivars to plant.
    b. Is the length of your growing season and accumulated growing degree days (GDD) sufficient to properly mature the fruit? Grape cultivars are classified by their season of maturity, with approximate maturity date being influenced by the regional and local growing conditions (GDD). Ideally, the growing season should be long enough to mature the grapes and allow the vines to acclimate for the winter before the first killing frost.
    c. What is the potential for a spring frost? Grape cultivars break bud at different times in the spring with cultivars such as La Crescent and Marquette being very early compared to Prairie Star or Frontenac. Early bud-breaking cultivars should be planted on the least frost-prone sites of your property.
3. How marketable is the cultivar? Marketability is reflected by demand for the grapes and higher prices paid. Once a vineyard is in production, it costs about the same to grow grapes that are in high demand as it does to grow those in low demand.
4. How productive is the cultivar and does it have any issues that can affect productivity? Cultivars differ in their production potential with Frontenac being a productive cultivar while St. Pepin has low production potential. Some cultivars such as La Crescent are prone to pre-harvest berry drop (shelling).
5. Does the cultivar exhibit good disease and pest resistance? Disease and pest control can be a major expense in an established vineyard. If a cultivar exhibits good resistance to some of the major diseases and pests, a grower may be able to cut back on some pesticides or extend the time between sprays.
6. Does the cultivar exhibit sensitivity to any chemicals? Grapevine sensitivity to sulfur or copper fungicides can be an issue, particularly if you are considering organic production. Sensitivity to 2,4-D, dicamba, and other growth regulator herbicide drift is an issue for vineyards in areas where these herbicides are commonly used, and significant exposure to one of the products could mean the loss of the crop and maybe death of sensitive grapevines.

When considering what grape cultivars to grow in Minnesota and other cold climates, there are four groups to select from:

1. **Northern hybrids -** These are a new class of cold hardy grape hybrids based on *Vitis riparia* that were bred for cold climates and are redrawing the boundaries of viticulture in North America. The Swenson hybrids were bred with our conditions in mind by Elmer Swenson of Osceola, Wisconsin. The University of Minnesota has an active grape-breeding program. University of Minnesota grape breeder, Peter Hemstad and fruit breeding project leader, Jim Luby are credited with the release of four successful winter hardy cultivars. The University of Minnesota Enology Project, is exploring methods to make quality wines from these grapes. For more information on the University of Minnesota Grape Breeding and Enology Program, visit www.grapes.umn.edu The USDA Specialty Crops Research Initiative (SCRI) Nor thern Grapes Project (http://northerngrapesproject.org) is also evaluating cultural and winemaking practices to improve the quality of wines made from northern grapes and marketing them.

2. **French-American hybrids -** are interspecific hybrids of *V. vinifera* with several native American wild species (*V. labrusca, V. lincecumii, V. riparia, V. rupestris, V. aestivalis*). Some of them have excellent fruit quality, though they are not yet as well-known as Cabernet Sauvignon, Chardonnay or other famed European cultivars. They were bred to impart resistance to the root form of grape phylloxera into European cultivars. In general, they are better adapted to northern climates than the pure *V. vinifera* grapes of Europe and make sound, often outstanding wines. However, French-American hybrids (often referred to as French hybrids) were bred for French conditions, so winter hardiness is only an accidental characteristic. Maréchal Foch, for example, seems to tolerate most of our winters uncovered, at least in southern Minnesota.
3. **American cultivars -** are the old standard cultivars of eastern North American grape growing areas based on *V. labrusca* cultivars and hybrids. Most famous of these would be Concord, Niagara, Delaware and Worden. There are many others. Most of them are marginal in our cold climate. Hardy ones with some *V. riparia* parentage, that include many of the Swenson hybrids, have been listed in the Northern hybrid group.
4. ***Vitis vinifera* cultivars -** famed in Europe and California, are the most susceptible to damage from low winter temperatures. They require extra care and attention and need to be covered in winter for cold injury protection. Even so, some early cultivars bear and ripen well. If you would like to try growing *V. vinifera,* choose early-ripening cultivars.

Leaf characteristics will aid in identifying some of these hybrids. American cultivar, a color mutation of Frontenac Noir found at the University of Minnesota Research Station at Excelsior, characteristically have thick leathery leaves that are pubescent (fuzzy) on the undersides. *Vitis vinifera* cultivars and wild *V. riparia* vines have leaves that are more glabrous (shinny) with no pubescence on the undersides. The hybrids vary in these leaf characteristics depending on the percentage of *V. labrusca* to *V. vinifera* and *V. riparia* parentage is present in the cross. Some Swenson hybrids based on *V. riparia* x *V. labrusca* crosses have somewhat leathery leaves with some pubescence on the underside, while Northern hybrids that are primarily *V. vinifera* x *V. riparia* crosses have leaves more characteristic of *V. vinifera* cultivars.

The following section provides descriptions the various grape cultivars suitable for growing in Minnesota and other cold climates. Table 21 (at the end of the section) lists some of the cultural characteristics grape cultivars, while Table 22 rates their susceptibility to common grape diseases, sensitivity to sulfur and copper sprays, and growth regulator herbicide drift.

NORTHERN HYBRIDS

WHITE WINE

AROMELLA (NY 76.0844.24) – (also known as NY 76) Introduced by Cornell University in 2013. Considered hardy, but very prone to growth regulator herbicide drift injury. Vines are vigorous, with semi-procumbent growth habit. Clusters are medium-sized and loose. Grapes mature mid-season; prone to shelling when mature. Wines are aromatic with notes of pineapple, honeysuckle, citrus peel and floral Muscat characters.

BRIANNA (ES 7-4-76) – Cross includes *V. labrusca* and *V. riparia* parentage. This white cultivar, a cross of Kay Gray with ES 2-12-13 was named by Ed Swanson at Cuthills Vineyard. The vine is very cold hardy and shows good fungal resistance. Growers in Nebraska claim it ripens late August - early September and have listed no bud damage to -28^{o} F. White, medium sized clusters and berries that produce nice pineapple aroma and flavor in the wine and can also be used as a table grape.

EDELWEISS (ES 40) – Cross includes *V. riparia* by *V. labrusca* parentage. A very early maturing, white grape that has fairly good hardiness in southern Minnesota. Clusters are medium to large, sometimes weighing a pound or more. Berries are medium in size and very juicy. The flavor is pleasant as the grape matures but becomes very strong when dead ripe. Harvested just prior to full maturity (i.e. 14-16 brix), Edelweiss makes a delightful fruity white wine.

FRONTENAC GRIS (MN 1187) – A color mutation of Frontenac Noir found at the University of Minnesota Research Station at Excelsior. This vine is identical culturally to the original red Frontenac (see Frontenac description below). However, the berries ripen to a bronze rather than red and produce a white or salmon tinged white wine. The wine is clean and crisp with an apricot or peach flavor, and is best finished slightly sweet. It can also be used to produce an ice-style wine that is usually salmon or peach colored with pronounced flavors of apricot or peach.

FRONTENAC BLANC – A colorless mutation of Frontenac and Frontenac gris that was independently found by several growers in Minnesota and Canada that has become known as Frontenac blanc. Like Frontenac gris, the vine appears culturally identical to Frontenac. Unlike Frontenac gris, Frontenac blanc makes a true white wine. Initial trial vinifications indicate that Frontenac blanc produces wines that are distinctly different form Frontenac gris in flavor and aroma.

KAY GRAY (ES 1-63) – Cross includes *V. labrusca* and *V. riparia* parentage. Vigorous vine is cold hardy and disease resistant. Medium sized white grapes mature in late August. Cluster is small and compact with one small shoulder. Berries are juicy and bland with low acidity. Kay Gray is best for wine under the following conditions: The grapes must be harvested prior to full maturity (15.5 Brix is ideal), the juice treated with bentonite to remove objectionable aromatics, and then cool fermented, with care taken to prevent malolactic fermentation. Kay Gray musts are extremely susceptible to oxidation. Precautions to avoid oxidation include a minimal amount of racking, and the use of CO^2 whenever the juice, must or wine is to be exposed to air.

LA CRESCENT (MN 1166) – Cross includes 45% *V. vinifera, 28% V. riparia*, and less than 10% each of *V. rupestris, V. labrusca*, and *V. aestivalis* parentage. This white cultivar, a cross between St. Pepin and ES 6-8-25. Vines are very vigorous, reliably cold hardy and productive. It is regarded as reliable in the Twin Cities area. Growth habit is sprawling and drooping. The vine is moderately resistant to powdery mildew and black rot, but is quite susceptible to both foliar phylloxera and downy mildew (on the leaves only) so a good spray regimen is required to keep this vine healthy. Bud break is early, similar to Maréchal Foch, and ripening is mid-season, similar to Seyval Blanc. Clusters are somewhat loose and berries are round, yellow-amber when ripe, fairly small, and prone to shelling. When made dry the wine is rather austere and can be overly acidic, but when finished sweet, delicious melon, citrus, pineapple, tropical fruit and muscat flavors emerge. Wines lack strong herbaceous aromas or those associated with V. *labrusca*.

LA CROSSE (ES 294) – Cross includes *V. labrusca; V. lincecumii; V. riparia; V. rupestris; V. vinifera* parentage. White cultivar of medium size, ripening shortly before Seyval, one of its parents. Juice composition is similar to Seyval but tends to lack character. Vines are considered to be cold hardy, and very vigorous with a semi-upright growth habit. Shoots produce few tendrils and tend to lay down in VSP training systems. Susceptible to black rot, moderately susceptible to downy mildew and powdery mildew. Medium sized, tight clusters with thin skinned berries; prone to sour rot. Vines fruit best in Minnesota when grown with winter protection.

LOUISE SWENSON (ES 4-8-33) – Cross includes *V. labrusca* and *V. riparia* parentage. This extremely cold hardy white wine grape has shown itself to be very reliable well north of the Twin City area. It is of only moderate vigor and bearing capacity. However, it has good disease resistance and few cultural problems. Sugar levels are usually less than 20% and the wine is very light with honey flavors and beautiful flowery aromas. It is best as a quality element when blended with wines of more body like Prairie Star, Lacrosse or Seyval.

PETIT AMI™ (DM 8313.1) – Cross includes *V. vinifera, V. riparia* parentage. A white wine cultivar developed and patented by David MacGregor as Petite Amie in 2007 and later trademarked. Hardy to very hardy grapevine with low to moderate vigor and a procumbent growth habit. Blooms mid-season and can produce up to four small to medium sized clusters per shoot. Exhibits moderate to good disease resistance, but can susceptible to black rot in wet years. Leaves can be prone to the muscat speckle (spot), a physiological disorder. Wines have a fine muscat flavor.

PRAIRIE STAR (ES 3-24-7) – Cross includes *V. vinifera, V. rupestris, V. labrusca, V. aestivalis* parentage. A vigorous, upright growing white wine grape with good disease resistance and reliable cold hardiness. It ripens in mid-season with excellent body and sugar/acid balance. It imparts body and balance to blended wines and was originally released as a blending cultivar but has been seen to produce very creditable varietal wines as well. Canes are fragile and break off easily when training or in high wind. Does best on the VSP Trellis. Berry set is an issue when rain occurs during bloom.

ST. PEPIN (ES 282) – Cross includes *V. labrusca, V. lincecumii, V. riparia, V. rupestris* and *V. vinifera* parentage. White sister seedling of La Crosse but pistillate (requires cross-pollination). Earlier, fruitier, slightly less hardy, blends well with La Crosse to make a very nice German style wine. Also makes an outstanding juice. Good disease resistance. Low to moderately productive.

RED WINE

FRONTENAC (MN 1047) – Cross includes *V. vinifera* and *V. riparia.* Introduced by the University of Minnesota in 1996, this cultivar quickly rose to popularity in Minnesota. A cross between *V. riparia* 89 and the French hybrid Landot 4511, this is a very cold hardy vine, and has borne a full crop after -30° F. Good resistance to powdery mildew and near-immunity to downy. Very susceptible to foliar phylloxera. Small black berries on medium to large clusters that are usually slightly loose. Berry splitting and bunch rot have been rare, even in wet years. Frontenac has been a consistently heavy producer and sometimes requires cluster thinning. In Minnesota it ripens in late-midseason, about 10 days after Foch. Although sugar levels rise very early, it is important to let the fruit hang long enough to fully mature in order to reduce the acidity to workable levels. Fortunately, the pH does not often rise to dangerous levels. Brix of 24-25° is not uncommon. Versatile grape for wine making. When made as red wine, it typically has a pleasant cherry aroma with berry and plum evident in many cases. Herbaceous characters are almost entirely absent. The color is usually a garnet red, but can become excessively dark with long periods of skin time. Can be made into an attractive rosé usually with a bright red color and cherry flavors. Has produced excellent port-style desert wines. Malolactic fermentation is essential to reduce the wine's high acidity. Tannin levels are usually relatively low.

GENEVA RED (NY 34791) – (also known as Geneva Red 7, GR 7) Introduced by Cornell University in 2003. Cross includes *V. labrusca, V. riparia, and V. vinifera* parentage. Considered a hardy, early to mid-season maturing blue cultivar (in ISU trials, up to a 3 week difference in maturity between southern and northern sites was observed). Vines are very vigorous with a semi-procumbent growth habit; best suited to a GDC training system; requires basal shoot and lateral shoot thinning. Clusters are medium-sized and tight. Grapes are relatively low in acids. Wines are medium to dark red with notes of cherry or red berry aromas in warm years; some *labrusca* notes in cool years.

HASANKY SLADKY – (also known as Baltica or Kazan Early) is a cross of Dalnyvostochyni #60 with *V. amurensis*. It is hardy to approximately -31° F (-35° C). This blue grape has long, slightly loose clusters with small- medium berries. The juice is clear, not red. It is best suited to light red "cafe" wines. The wines are quite fruity, with some nice tannins in the mouth and with no hint of foxiness. The wine is reminiscent of a Beaujolais nouveau. In cool climates, the acidity tends to be high and has to be reduced with malolactic fermentation. In the vineyard, it is quite disease resistant, except for a moderate susceptibility to powdery mildew.

MARQUETTE (MN 1211) – Introduced in 2006 from the University of Minnesota, Marquette originated from a cross between MN 1094 and the French hybrid Ravat 262, which has Pinot noir as one parent (includes *V. riparia, V. vinifera* and other *Vitis* species). Resistance to common grape diseases (downy mildew, powdery mildew and black rot), has been good and the vine requires only a minimal spray program. Infestation by foliar phylloxera has been moderate but less than Frontenac. Growth habit is moderately upward, open and orderly. Vine vigor appears to be site specific ranging from very vigorous on optimum range soil pH to moderately vigorous on higher pH soils. Shoots typically have two small to medium-sized clusters per shoot, thus avoiding the need for cluster thinning. Bud break is early, similar to La Crescent, and tends to bear lightly. Acid levels are lower than Frontenac, and harvest °Brix of 23-25 are not uncommon. Marquette typically produces complex red wines with V. vinifera-like color, moderate tannins, and notes of cherry, black currant, raspberry, and black pepper with no hybrid characters. In some tastings it has been rated better than pure *V. vinifera* wines.

PETITE PEARL – A red wine release from the work of Tom Plocher of Hugo, MN, a cross of MN1094 and ES4-7-26. Extremely cold hardy, reliable, and while late maturing is able to ripen reliably in the Minneapolis/St. Paul Area. The vine offers good tannins and low acids, quite rare in northern hybrids. The clusters are small and compact, vine exhibits a trailing or drooping growth habit and has been very disease resistant. The vine does not appear to be a heavy bearing but its combination of low acidity and notable tannins make it a promising new grape for the region.

SABREVOIS (ES2-1-9) – Cross includes *V. labrusca* and V. *riparia*. This sister seedling to St. Croix is an extremely vigorous growing, very disease resistant red wine cultivar that is already popular in Quebec. It seems less prone to root injury in snowless winters than its sister St. Croix. It needs a large trellis like a Munson or GDC to deal with its extreme vigor. It produces a powerful and often complex red wine that is valuable in blending and seems amenable to carbonic maceration. Fully cold hardy, ripens mid-season.

ST. CROIX (ES 242) – A popular red *V. riparia* by *V. labrusca* hybrid wine cultivar in Minnesota. Winter hardiness has been variable but is roughly similar to Foch. Grafting on a hardy rootstock such as Suelter is beneficial as this vine has been seen to suffer dramatic, even fatal root injury in snowless winters. Produces medium-sized, tight clusters with soft, thin-skinned berries. Sugar varies depending on pounds per vine. Acid very low. Color, size of berries very similar to Beta in appearance. Juice is pale rose. Maturity is mid-September. Vines are extremely vigorous with a trailing growth habit, best grown on a GDC or Munson training system. Excellent fruity wines have been made from St. Croix by fermenting a portion of the must using carbonic maceration techniques.

VALIANT – A *V. labrusca* x *riparia* hybrid from South Dakota State University. This vine is productive and is the hardiest known cultivar, hardier than Beta or King of the North. Unfortunately it is extremely susceptible to downy mildew and black rot. Clusters are small but well filled. The black fruit ripens very early and is much lower in acid than Beta. The berries are too small for fresh eating, but it makes excellent fresh juice or jelly and some wineries value it as a wine cultivar especially for port-style red wines.

TABLE CULTIVARS

BLUEBELL – Cross includes *V. labrusca* and V. *riparia*. An old University of Minnesota introduction that almost disappeared but is now being planted again. It is a high quality Concord style, seeded eating cultivar, makes good fresh juice, and is finding a place as a red wine grape as well. In the southern part of the state it is fully cold hardy, reliable and very disease resistant. In western Minnesota it sometimes does poorly due to the high pH of the soils. Ripens early to mid-season.

KING OF THE NORTH – An extremely hardy blue *V. riparia* by *V. labrusca* hybrid grape excellent for wine, juice, or jelly. The vine is hardy to -37^{o} F, very vigorous and productive with some susceptibility to downy mildew. Medium sized loose clusters of medium berries are juicy but remain tart, late into September. Very popular in other areas as a wine cultivar producing a rich, aromatic and grapey, labrusca-style red wine. Good for grape juice, jelly and tart eating this grape is of unknown origin but appears to be a labrusca-riparia hybrid and has proven to be extremely cold hardy.

MARS (Arkansas 1508) – (also known as Mars Seedless) Released from the University of Arkansas table grape breeding program in 1984. Cross includes *V. labrusca* and *V. vinifera* parentage. Buds are rated hardy, and most hardy of the American seedless table grape cultivars. Berries are large and round, and transition from a mahogany to deep blue/black during the harvest season which can extend for almost 3 weeks and lends well to the farmers market trade. Matures early to mid-season. Average cluster weight in ISU trials was .35 lbs. Vines are very vigorous with a procumbent growth habit, best suited for Munson or GDC training systems. Vines are productive and unlike other American seedless table grapes, productivity on secondary buds is good. Cluster thinning at bloom is recommended. Vines exhibit very good resistance to the common grape diseases. Suitable for growing areas suited for Edelweiss.

SWENSON RED (ES 439) – Cross includes *V. labrusca and V. riparia* parentage. A very high quality red seeded table grape. Clusters are medium to large and quite compact. Berries are large with thin edible skins. The flesh is "meaty" like a good California table grape, and the flavor is fruity but without *labrusca* flavor. Can be cold pressed into an acceptable white wine. The grapes also keep very well in cold storage. Two faults of this cultivar are that it is quite susceptible to downy mildew and is not hardy enough to fruit reliably in most of Minnesota without winter protection.

SOMERSET SEEDLESS (ES 12-7-98) – Cross includes *V. labrusca, V. riparia, V. vinifera* and other small amounts of American *Vitis* species. A pink to red seedless cultivar of medium sized berries on small to medium loose clusters. It is extremely early, ripening in August in Minnesota, most seasons. It is a very handsome, juicy and delicious eating cultivar but is only moderately cold hardy although probably the hardiest of the seedless grapes now available.

SUMMERSWEET (ES5-4-35) – Cross includes *V. labrusca* and *V. riparia* parentage. An extremely hardy blue seeded table grapes both early ripening and good flavored. It is very disease resistant and bears reliably well north of the Twin Cities. It has only moderate vigor but bears well with medium size berries on small tight clusters.

TROLLHAUGEN (ES3-22-18) – Cross includes *V. labrusca* and *V. riparia* parentage. A blue seedless cultivar with small to medium sized berries in small tight clusters. It is very early to ripen typically 3-4 weeks before Concord. Cultivar has favorable table and dessert characteristics but fruit does not hang well nor does it store well. Only moderately cold hardy it will suffer injury during some winters.

FRENCH HYBRIDS

The French hybrids listed have been grown in Minnesota but have shown winter injury. They are not considered completely hardy for this area.

MARECHAL FOCH (Kuhlmann 188-2) – Cross includes *V. riparia, V. rupestris,* and *V. vinifera* parentage. Maréchal Foch is easily the hardiest of the French hybrids and often produces fruit in Minnesota even when left unburied. Formerly the most widely planted grape in Minnesota, locally grown Foch wines have won numerous awards over the years. However it is not reliable in Minnesota when left uncovered and has shown root injury in snowless conditions as well. This has led to its rapid decline in recent years. Moderately vigorous cultivar with small clusters and berries. Needs long cane pruning for sufficient yields. Good disease resistance. Partial secondary crop in event of spring freeze. Wine is reminiscent of Burgundy with some herbaceous characters if left on skins too long. Also, given minimal skin contact and cold fermented, Foch produces an excellent true rose. The grapes should not be allowed to hang on the vine after maturity or high pH levels will result in an unstable wine.

AMERICAN CULTIVARS

American cultivars that are grown in Minnesota are also grown extensively across New York, Pennsylvania, Ohio, and other states in eastern North America but under different conditions. Since the mean temperature in January is 10 to 15 degrees colder in Minnesota, many of the grapes that can survive out east may not here. Conditions during the growing season are similar however American grapes grown in the Midwest may have higher acid and less brix.

CONCORD – Cross includes *V. labrusca, with some V. vinifera.* The standard American blue grape, with typical strong *labrusca* flavor leading to high quality juice and jelly. Wine from Concord is often harsh and requires sweetening to be palatable. Because of its very late ripening and marginal hardiness below -20° F, Concord is not recommended except for extreme southern Minnesota.

Cold hardy American cultivars with *V. riparia* parentage that exhibit *V. labrusca* characteristics have been listed in the Northern hybrid group include: **Bluebell, Brianna, Edelweiss, Kay Gray, King of the North, Louise Swenson, Swenson White, and Valiant.**

VINIFERA CULTIVARS

Note that *V. vinifera* cultivars, such as Cabernet Sauvignon, Chardonnay, Pinot Noir and others, have been planted in Minnesota and have experienced complete loss of the vine in severe winters, even though the vines have been buried. Much of the *vinifera* in New York State was lost in 2003 due to a sudden change in December temperatures from 60 degrees to below freezing in a matter of days. The vines had not hardened off properly. *Vinifera* cultivars are not proven in Minnesota and should be considered a risk.

SEVERNYI – An interesting *V. vinifera* x *V. amurensis* hybrid from Russia. The name means “northern” and in initial tests in the Twin Cities, the vine appears to be both hardy and very early ripening. However, it seems to initiate bud break very early and thus appears susceptible to spring frost damage. Wine from Severnyi is a deep red and its flavor is quite interesting and complex. On the negative side, high acid levels make malolactic fermentation essential and the vine is extremely susceptible to powdery mildew. Flowers are pistillate, so it requires cross-pollination. In addition, it is believed to be susceptible to root injury from phylloxera and is thought to need to be planted on a resistant rootstock be reliable. Not widely available.

ADDITIONAL INFORMATION:

Additional information of grape cultivars is available on the ISU Viticulture Home Page in the publication titled **A Review of Cold Climate Grape Cultivars** (http://viticulture.hort.iastate.edu/cultivars/cultivars.html) written by Lisa Smiley in fulfillment of Masters of Agriculture degree. The review was published in 2008 and contains information on 73 cold climate cultivars.

Nurseries that propagate and sell grape cultivars adapted to cold climates are listed in the Resources section of this publication under **Sources of Grapevines.**

Table 21. Characteristics of cold hardy grape cultivars.

Cultivar	Color	Use	Bud Hardiness	Vigor	Growth habit	Harvest season		Cluster wt *in* lb	Market-ability	Comments
						From Lit.	*in* MN			
Aromella	W	W	H	V	SP	M	M/L-Sep	.27 (.17)	3	Extremely prone to 2,4-D and dicamba. Berries prone to shelling when mature.
Beta	B	J	VH	V	P	M	M-Sep	Sm	1	Produces small, acidic berries.
Bluebell	B	T,J,W	VH	V	P	EM	M-Sep	Med	1	High quality *labrusca*-type. Better table quality than Concord, but lighter juice color.
Brianna	W	W,T	EH	V	P	E	L-Aug	.24	4	Breaks bud early mid-season. Harvest before 18 Brix. Does not do well on high pH soils.
Concord	B	J,T,W	H	VV	P	LM	E-Oct	.30	2	Wines have characteristic *labrusca* flavor.
Edelweiss	W	T,J,W	H	VV	P	E	L-Aug	.32	3	Breaks bud very early. Harvest before 17 Brix. Does not do well on high pH soils.
Esprit	W	W	H	V	SP	M	L-Sep	.52	3	Breaks bud mid-season. Easy to shoot position. Wines tend to be mild & fruity.
Frontenac	B	W	EH	V	SU	LM	L-Sep	.34 (.23)	4	Breaks bud early mid-season. Can be very productive. Excellent fruit quality, but high acidity is common.
Frontenac gris	Cu	W	VH	V	SU	LM	L-Sep	.31 (.20)	4	Produces a clean, crisp white or salmon-tinged white wine w/ apricot or peach flavor.
Geneva Red	B	W	H	VV	SP	M	L-Sep	.31 (20)	3	Breaks bed very early. Vines are moderately productive on secondary buds.
Kay Gray	W	T,W	VH	VV	P	E	L-Aug	.21	3	Breaks bud very early. Fruit is relatively low in acids, wines rated good to very good.
King of the North	B	J,T,W	EH	VV	P	M	L-Sep	.25	1	Juice is aromatic with fruity *labrusca* character, acidity is high. Better suited for juice or jelly.
La Crescent	W	W	VH	V	P	EM	M-Sep	.32 (.23)	5	Breaks bud very early. Young shoots are prone to wind breakage. Berry set can be an issue. Prone to shelling.
La Crosse	W	W	H	VV	SU	EM	M-Sep	.25	2	Breaks bud early mid-season. Requires basal shoot and lateral shoot thinning. Clusters are tight; berries are thin-skinned & subject to leaking.
Louise Swenson	W	T,W	VH	MV	SP	EM	M-Sep	.25	2	Exhibits very good disease resistance. Fruit are low in sugar; produces an aromatic wine, but lacks body.
Leon Millot	B	W	H	VV	P	E	E-Sep	.17	3	Productive on secondary buds. Juice relatively low in acids, can be made into a variety wines.
Maréchal Foch	B	W	H	MV	SP	E	E-Sep	.20 (.16)	4	Breaks bud very early. Fruit relatively low in acids; can be made into a variety of wines.
Marquette	B	W	VH	V VV	SP	EM	M-Sep	.25 (.15)	5	Breaks bud very early. Moderately productive on secondary buds. IA studies suggest it is less vigorous on high pH soils.
Mars	R	T	H	VV	P	E	E-Sep	(.35)	3	Can be harvested over an extended period. Produces well on secondary buds.
Petit Ami	W	W	H	MV	P	EM	M-Sep	.35 (.23)	3	Can produce up to 4 clusters per shoot. Fruit thinning is necessary. Shoots are slow to lignify.
Petite Pearl	B	W	EH	MV	P	LM	L-Sep	.20	4	New cultivar. Produces very dark wines with not herbaceous characters.
Prairie Star	W	W	VH	V	SU	EM	M-Sep	.37 (.22)	3	Young shoots are prone to wind breakage. Fruit set is an issue when it rains during bloom.
Sabrevois	B	W	H	VV	SU	EM	E-Sep	.22	2	Can be made into a high acid, medium bodied complex wine with good tannins when harvested early. Better suited for cooler climates.
St. Croix	B	W	VH	VV	SP	EM	E-Sep	.22	4	Breaks bud mid-season. Requires basal shoot and lateral shoot thinning. Berry set can be light. Berries are thin-skinned and prone to leaking.
St. Pepin	W	W,T,J	H	V	SP	EM	M-Sep	.30	4	Produces a very fruity wine with a slight *labrusca* flavor. Requires cross pollination. Low fruit set can be an issue.
Somerset Seedless	R	T	H	MV	P	E	L-Aug	.33	2	Berries are small, very sweet and flavorful.
Swenson Red	R	T,W	H	V	P	M	M-Sep	Med	1	Berries are large, have a meaty texture and adherent skin characteristic of *vinifera* type table grapes.
Swenson White	W	T,W	VH	V	SP	M	M-Sep	.37	2	Breaks bud mid-season. Produces a high quality wine with a pronounced floral aroma.
Trollhaugen	B	T,W	H	V	P	E	E-Sep	Sm	1	Produces sweet berries with a mild "Concord" flavor.
Valiant	B	T,J	EH	V	P	E	L-Aug	.20	2	An improvement over Beta. Not suited for wine.

Codes
Color: B = blue/black; W = white; R = red; Cu = copper.
Use: W = wine; J = juice & jelly; T = fresh table
Hardiness rating: H= hardy (-15 to -25 F); VH = very hardy (-20 to -30 F); EH = extremely hardy (-25 to -35 F).
Vigor: MV = moderately vigorous; V = vigorous; VV = very vigorous.

Harvest season: E = early; M = mid; L = late.
Growth habit: P = procumbent; SP = semi-procumbent; SU = semi-upright; U = upright.
Avg. cluster wt: (*in* ISU trials)
Marketability: (Scale 1 to 5) 1 = low; 5= very high.

Table 22. Relative disease susceptibility and chemical sensitivity of cold hardy grape cultivars.

Cultivar	Disease Susceptibility*							Chemical Sensitivity*			
	Black rot	Downy mildew	Powdery mildew	Botrytis	Phomopsis	Crown gall	Anthrac-nose	Sulfur	Copper	2,4-D	dicamba
Aromella	1	1	1	1	2	?	1	?	?	3	3
Beta	1	1	1	1	?	?	?	?	?	?	?
Bluebell	1	1	1	1	?	?	?	?	?	?	?
Brianna	2	1	1	1	?	?	?	2	1	2	2
Concord	3	1	2	1	3	1	1	Y	1	3	2
Edelweiss	?	1	2	2	?	1	2	N	N	2	2
Esprit	?	2	3	2	?	?	?	?	?	2	3
Frontenac	3	1	2	2	1	?	2	1	1	1	3
Frontenac gris	2	1	2	2	1	?	2	1	1	1	2
Geneva Red	1	2	2	2	1	1	1	N	?	1	3
Kay Gray	1	1	1	1	?	1	?	?	?	?	?
King of the North	1	3	1	?	3	?	1	?	?	?	?
La Crescent	2	3	2	1	3	1	2	1	1	1	3
La Crosse	2	3	2	1	3	1	2	N	N	1	3
Louise Swenson	1	1	2	1	?	?	2	?	?	?	?
Leon Millot	1	2	3	1	1	2	1	Y	1	2	3
Maréchal Foch	2	1	2	1	1	2	2	Y	1	3	3
Marquette	3	1	1	3	?	1	2	1	1	1	3
Mars	1	1	1	1	1	1	1	N	N	2	2
Petit Ami	2	?	?	?	?	?	1	?	?	?	?
Petite Pearl	?	?	?	?	?	?	?	?	?	?	?
Prairie Star	2	1	1	1	?	?	2	?	?	1	2
Sabrevois	1	1	1	1	?	?	?	?	?	?	?
St. Croix	?	2	2	2	3	?	1	1	1	1	2
St. Pepin	1	1	3	2	?	?	1	?	?	?	?
Somerset Seedless	1	2	1	?	?	?	?	?	?	?	?
Swenson Red	1	3	2	2	?	?	?	?	?	?	?
Swenson White	1	2	2	2	?	?	2	?	?	3	3
Trollhaugen	1	1	?	?	?	?	?	?	?	?	?
Valiant	1	3	1	2	?	?	?	1	1	?	?

* Key to rating: 1 = slightly susceptible or sensitive; 2 = moderately susceptible or sensitive; 3 = highly susceptible or sensitive; N = not sensitive; Y = Sensitive; ?= relative susceptibility or sensitivity not established.

[z] Adapted from: Bordelon, B., et al. (*annual publ.)*; Domoto, P., 2007; and McManus, P. et al., 2015

Vineyard Best Management Practices – Cultivar Selection

Rate the factors considered in selecting cultivars:

Management Area: **Cultivar characteristics**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Cold hardiness and zone hardiness for average minimum winter temperatures.	Cultivar exhibits sufficient cold hardiness to perform well in your climatic zone.		Cultivar's cold hardiness is marginally suited for your climatic zone	Cultivar's cold hardiness is not suited for your climatic zone
Length of the growing season (LGS) (frost-free days)	LGS is long enough to properly mature the cultivar.	LGS is marginally long enough to mature the cultivar. Topography is suitable for extending the season.	LGS is marginally long enough to mature the cultivar. Topography is marginal for extending the season.	LGS is not long enough to mature the cultivar.
Growing Degree Days (GDD)	GDD is great enough to properly mature the cultivar.	GDD is marginally great enough to properly mature the cultivar. Topography is suitable for improving GDD.	GDD is marginally great enough to properly mature the cultivar. Topography is marginal for improving GDD.	GDD is not great enough to mature the cultivar.
Topography and the frequency of spring frosts	Earliest bud-breaking cultivars to be grown on sites least prone to spring frosts.		Sequence of bud break was not considered in laying out the vineyard.	
Marketability	Cultivar ranks very high for demand and prices received.	Cultivar ranks high for demand and prices received.	Cultivar ranks moderately high for demand and prices received.	Cultivar ranks low for demand and prices received.
Productivity	Cultivar is productive without any issues that may limit production.	Cultivar is productive with some issues that may limit production.	Cultivar is moderately productive with some issues that may limit production.	Cultivar is moderately productive with several issues that may limit production.
Disease susceptibility	Cultivar exhibits good resistance to most diseases.	Cultivar exhibits moderate resistance to most diseases.	Cultivar exhibits moderate susceptibility to some diseases.	Cultivar exhibits susceptibility to several diseases.
Sensitivity to sulfur or copper fungicides	Cultivar exhibits good tolerance to sulfur or copper sprays	Cultivar exhibits slight sensitivity to sulfur or copper sprays	Cultivar exhibits moderate sensitivity to sulfur or copper sprays	Cultivar exhibits sensitivity to sulfur or copper sprays
Sensitivity to 2,4-D or dicamba herbicide drift	Cultivar exhibits good tolerance both 2,4-D and dicamba drift.	Cultivar exhibits moderate sensitivity to either 2,4-D or dicamba drift	Cultivar exhibits sensitivity to either 2,4-D or dicamba drift	Cultivar exhibits sensitivity to both 2,4-D and dicamba drift.

Starting the Vineyard

Purchasing Grapevines

To obtain the desired cultivars, grapevines should be ordered the season before you intend to plant the vineyard. This is especially important for new cultivars and high quality cultivars that are in high demand and bringing the best prices. Cold hardy northern cultivars are typically propagated from cuttings collected during the dormant season, planted in the nursery in the spring to root and grow, and a dug in the fall for sales the following spring. Therefore, nurserymen have a good idea how many grapevines of a cultivar they will have available for sale by mid-summer. By ordering early, your chances for obtaining what you want is greatly improved.

Dormant rooted grapevines are sold based upon their grade which is determined by the plant age in the nursery, and the amount of root and top growth present on the plants (Table 23). When purchasing dormant rooted grapevines, you are paying for the root system, so it is best to purchase the better grades (1-X, 1-1). These plants have greater stored reserves in their roots and will get off to a better start in the vineyard.

Table 23. Description of the grades use to identify the quality of dormant, rooted grapevines.

Grade	Description
1-X	Grown in the nursery for 1year. Vines produced at least 1 foot of top and root growth with a dense root system.
1-1	Grown in the nursery for 1 year. Vines produced at least 1 foot of top and root growth.
1-2	Grown in the nursery for 1 year. Vines produced 6-12 inches of top and root growth.
1-3	Grown in the nursery for 1 year. Vines produced less than 6 inches off top and root growth. Typically re-planted in the nursery and grown for another year
2-1	Grown in the nursery for 2 years. Vines produced at least 1 foot of top and root growth.

Another option is to purchase green, potted plants. These are plants propagated from cuttings collected during the dormant season and rooted in containers placed in a greenhouse to get them to root and grow sooner, and are sold that spring when it is warm enough to plant them outdoors. These plants do not have the root system of dormant rooted plants, and require special care when planted in the field. This option should only be used if it is the only way to obtain a newly released cultivar, but it may take an extra year to bring them into production.

In some cases, grapevines are propagated on a rootstock to overcome adverse condition such as grape phylloxera tolerance for V. vinifera cultivars, or tolerance to high soil pH conditions. Scion material (canes of the desired cultivar) are collected in the dormant, grafted onto the rootstock during the dormant season, planted in the nursery in the spring, dug in the fall and sold the following spring. They are graded similar to dormant rooted cutting, and orders should be place early. To overcome an adverse soil condition for a specific cultivar, it may be necessary to enter into a custom contract as early as 18 months before planting.

Vineyard Best Management Practices – Starting the Vineyard

Rate your vineyard establishment practices:

Management Area:	Best Practices	Minor Adjustments Needed	Concern Exists: Examine Practice	Needs Improvements: Prioritize Changes Here
Purchasing grapevines	Ordered 1-1 or 1-X grade dormant vines the season before planting.	Ordered 1-1 or 1-X grade dormant vines the winter prior to planting.	Ordered 1-2 grade dormant vines or greenhouse-rooted green plants.	Ordered grapevines a few weeks before planting.

Soil Preparation for Planting

Ideally, soil preparation should begin at least one season before planting. This allows time to eliminate weed and grass competition, improve the soil physical characteristics and optimize its nutrient content. Collect soil samples at this time to determine suitability and if adjustments need to be made to create a soil appropriate for grapes. Your county agent or University Cooperative Extension Service can provide you with instructions and materials on how to take samples and where to send them for analysis (*See* the listing of ***Soil and Plant Analysis Laboratories*** in the **"Resources"** section of this publication). Soils should be tested for soil pH, organic matter (OM), phosphorous (P), potassium (K), magnesium (Mg) and zinc (Zn) as described in the ***Soil Chemical Properties*** section of the **Considering Growing Grapes** portion of this publication. Prior to planting, adjust the soil pH if needed and apply any required P, K and Mg and incorporate as deeply as possible (*See* section on Fertilization and Nutrition for additional information). This is a good first step in preparing your site for planting.

Deep Tillage

The first step in preparing the new vineyard is to plow the site. If the site is in pasture or CRP (Conservation Reserve Program), using a moldboard plow to turn under the vegetation would be appropriate. If the site is currently in annual crop production, chisel plowing would be sufficient. It is best to do this a year before planting. This allows some additional time for the sod to decompose and for frost action to break up clods. In the spring, the plow furrows can be disked over. If sod exists, consider applying glyphosate (Roundup® or generic equivalent) the fall before cultivation.

On former agricultural land, a hardpan or plow pan layer is often present. If it is shallow, it can be broken up with a chisel plow. Many of our northern soils have glacial fragipans that are deeper than plow pans and a sub-soiler is needed to get down deep enough to break them up. These can often be rented on a one-time basis from your county agent. Breaking up these compacted layers allows the vine's roots to penetrate deeper into the soil, improves drainage, and makes subsoil moisture and nutrients more available to the vine. If required, subsoiling should be performed when the soil is dry. This is normally in the fall when existing crops have depleted the soil moisture. This should be done in two directions diagonal to each other with the tractor traveling as fast as possible.

Once the initial plowing, subsoiling, and disk ing or rototilling has been completed in the spring, the main pre-plant activity would be weed control. It is critical, that weeds be well controlled to insure a new planting gets off to a good start.

Pre-plant Weed Control

Weed competition in new vineyard plantings can slow the establishment of the young vines and even reduce their chances of survival. Pre-plant weed control is extremely important because it eliminates weed infestations the season before the vineyard is planted. The result is an attractive, relatively weed-free environment in which the young vines can begin their growth. Both chemical and nonchemical methods of pre-plant weed control have been used with success in Minnesota. A combination of the two methods often produces the best results.

Chemical Control

The addition of glyphosate to the list of approved herbicides for use in horticultural crops has expanded the potential for effective pre-plant weed control by chemical means. Glyphosate is a broad-spectrum, non-residual, systemic herbicide. It is taken up by the plant's foliage and translocated to the roots where it is extremely effective. When used according to label instructions, glyphosate is highly effective in eliminating most annual and perennial weeds and grass.

Proper timing of glyphosate applications is quite important. When attempting to control quackgrass, applying glyphosate in the fall allows the chemical to be absorbed into the root system as the grass enters dormancy and is highly effective. Cultivation of glyphosate-treated quack grass sod the following spring will then produce good results. Glyphosate will control young weeds that are in a phase of rapid growth. It is most effective in controlling perennial weeds when the sugars manufactured during photosynthesis are being translocated down to the roots. This begins shortly after bloom or later during the growing season. In some cases more than one application may be needed for complete control. . If there are no grapevines planted in the vicinity, herbicides containing 2,4-D, dicamba and related chemicals can also be used, and are more effective in controlling broadleaf perennial weeds than glyphosate.

Glyphosate can be applied either with a low-pressure herbicide sprayer for broadcast applications, or with a hand-held compression sprayer or wick applicator for spot treatments. Spray does not need to drench the entire weed to be effective. The wick application eliminates the potential problem of glyphosate particle drift onto grapevines. Grow tubes or vine guards help protect vines from accidental contact, but the bottoms of the tubes must be buried in the soil to prevent up-drafts from drawing the glyphosate particles into the tubes.

Nonchemical Control

Mechanical cultivation and the use of cover crops can be used as a complete pre-plant weed control program or to supplement a chemical weed control program. After tilling over the plow furrows in the spring, regular mechanical cultivation with a disk or rototillers can be continued throughout the summer. Cultivation every week or ten days will kill a large number of weeds as they germinate, but consumes time and fuel. An annual cover crop can be sown after the first month or so of cultivation. Buckwheat, sorghum-Sudan grass and sweet clovers are all easy to grow as pre-plant cover crops and are quite effective in smothering out any weeds germinating after the last spring cultivation. They will provide significant organic matter for the site when tilled in just before planting.

Buckwheat is especially useful on poor soils, as it is very tolerant to acid soils, withstands drought, and is rather undemanding of soil nutrients. Buckwheat should be sown when the weather has warmed up in early June, at a rate of 3 lbs per 1000 square feet or 50-100 lbs/acre. It germinates within a week, and matures to blossom within 45 days. The blossoms are an excellent nectar source for bees and other beneficial insects such as ladybugs and green lacewings. The stand of buckwheat should be mowed before it sets seed and then tilled in, otherwise, it can become a weed in the vineyard. Tilling-in buckwheat adds a modest amount of organic matter to the soil. Often a second crop of buckwheat can be grown the same season.

Sorghum-Sudan grass is best suited to relatively good soils, as it requires a good nitrogen supply and adequate moisture, but can be effective in depleting and excess nitrogen reserves present in the soil from its previous cropping history. Sow at a rate of 1-2 lbs per 1000 square feet or 35-50 lbs per acre in June when warm weather has arrived. Sorghum-Sudan grass produces an extremely thick stand of grass that can reach 6' in height. Under adequate rainfall, several mowings may be needed during the season, yielding an abundance of organic matter for the soil. After the last mowing, the stubble and accumulated grass debris can be tilled into the soil and provide benefit without producing seed or being a weed.

Sweet clovers (annual white and biennial yellow) may help correct several soil problems prior to planting the vineyard. First, they are prolific fixers of nitrogen adding back nitrogen to a severely depleted soil. Secondly and perhaps more importantly for grape culture, sweet clovers can help "open up" compacted soils by virtue of their long (up to 24") thick taproot. Sweet clovers should be sown at a rate of ½-1 lbs. per 1000 square feet or 12-20 lbs. per acre after the weather warms in the spring. For acidic soils, (pH under 6.0), modest application of lime (1 ton/acre) prior to sowing sweet clovers will result in more vigorous growth. Finally, if pre-plant culture begins two seasons prior to planting the vineyard, it may be advantageous to use a mix of annual white and biennial yellow sweet clovers. The annual white will grow nicely the first year, nursing along the biennial yellow. The biennial yellow clover will begin growth early, growing vigorously during the second season. Biennial yellow sweet clover often grows up to 4' tall with heavy stems, so occasional mowing is necessary. Biennial yellow sweet clover dies after the second season and can then be disked into the soil. A significant amount of organic matter can be added to the soil this way. Annual sweet clover would be beneficial for soils that are low in fertility (< 2% organic matter content), but are not recommended on soils that have a high organic matter content (>3%) because excessive grapevine vigor is often an issue on these soils.

As a final step in soil preparation, many growers will sow their permanent ground cover in the fall before planting. Most ground cover species used in northern climates establish best when sown in the fall. In addition, presence of a sod groundcover in the spring will allow you to get on the land sooner to begin planting the grapevines. Refer to the ***Sod Alleys*** section in the **Weed Control in Established Vineyards** portion of this publication for ground cover species to plant.

The other alternative is to sow a final cover crop of cereal ryegrass in the fall at a rate of 100 lbs per acre. The rye will grow to a height of 4-6" before winter comes, and begin to tiller in the spring. In the spring prior to planting grapevines the ryegrass should be mowed and killed with a contact herbicide and left on the soil surface. Cereal ryegrass has allelopathic properties that will inhibit the germination of weed seeds.

Vineyard Best Management Practices – Starting the Vineyard

Rate your vineyard establishment practices:

Management Area: **Soil preparation**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Optimizing the nutritional status of the soil	Amended the soil based on soil test results the season before planting.	Amended the soil based on soil test results in the spring prior to planting.	Amended the soil based on soil test results after planting.	No soil amendments were applied.
Deep tillage	If a fragipan or other restrictive layer is present, subsoiled in the fall prior to planting, otherwise chisel plowed to break up any plow pan.	Subsoiled because it is a good practice.	Chisel plowed to break up any plow pan that might be present.	No attempt was made to break up and restrictive layers or compaction in the soil prior to planting.
Problem perennial weeds and grasses	Took measures to control them the season before planting.		Took measures to control them in the spring prior planting.	Made no attempt to control them prior to planting.

Vineyard Layout and Row Spacing

When possible, layout the vineyard to accommodate the equipment available for management purposes. Row spacing and distance between plants depends upon the vigor of the cultivar, the training and trellis system used and the width of equipment to be used in the vineyard. Between row spacing of 6-9 ft for backyard plantings and 9 to 12 ft for commercial plantings based upon the training system are usually convenient. For single curtain systems such as the high-wire cordon, 10 ft between rows is typically used. On a mid-wire system with VSP, the canopy is narrower and a 9 ft row width can be used. In contrast, with a double curtain system such as the Geneva double curtain or Lyre system, cross arms support the trellis wires as much as 48-52 inches apart, and a 12 ft row spacing is often required. Most cold hardy northern cultivars like Frontenac, La Crescent and St. Croix are vigorous to very vigorous and 8-10 ft between plants within the row is suggested, or using a double curtain training system to accommodate the high vine vigor. Closer spacing of less than 8 feet between vines can be used for less vigorous cultivars or on less fertile sites. If possible, arrange rows in a north-south orientation for maximum sunlight utilization. However, the cost of trellis materials often dictates the row direction because it is much more expensive to establish many short rows that it is to establish longer rows because end posts are much more expensive than line posts. When planting on steep slopes the rows should be laid out across the contour of the land to reduce erosion, and it is best to add an additional foot to the width of the rows because implements towed behind a tractor tend to drift downhill.

When considering a layout for larger commercial vineyards, maintain a 30-40 foot headland (distance between property line and beginning of planted row). This will allow adequate room for turning a tractor and implements at the end of each row. Sections of trellis should be segmented into units no longer than 600 feet (unless using a horizontal braced end post) for proper trellis anchorage and trellis wire support.

Vineyard Best Management Practices – Starting the Vineyard

Rate your vineyard establishment practices:

Management Area: **Vineyard layout and spacing**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Between-row spacing	Training system, width of the equipment and degree of side slope were considered in selecting the row spacing.	Training system was considered in selecting the row spacing.	Only equipment was considered in selecting the row spacing.	Training system, equipment size and degree of side slope were not considered in selecting the row spacing.
In-row vine spacing	Cultivar vigor & soil fertility were considered in selecting the in-row spacing	All cultivars were planted at a wide in-row spacing suitable for very vigorous vines		All cultivars were planted at a narrow in-row spacing suitable for moderately vigorous vines
Row direction	Rows were oriented in a N-S direction to optimize sunlight utilization.	Rows were oriented in a E-W direction to save on trellis materials costs		
Headland	Adequate headland was left at both ends of the vineyard to allow equipment to turn without problems.		Headland on one end of the vineyard is marginal for equipment to turn.	Headland on both ends of the vineyard is marginal for equipment to turn.

Planting

The vines can be planted when the soil is workable in the spring. The soil should not stick to tools, and should not "ball up" when squeezed and rolled in your hands. Avoid planting when the soil is too wet. As a rule, order nursery stock to be delivered around May 1. If the vines are potted and have already sprouted, they should not be set out until all danger of frost is past, usually after mid-May. The vines should be planted in good-sized holes to accommodate the root system. For grapevines propagated from rooted cuttings, the lowest bud can be set either just above or below the soil surface. For grafted grapevines, the graft union should be placed above the soil surface.

Although burying of cold tender vines is becoming rare with the advent of fully hardy cultivars, tender vines that are to be trained for winter protection should be planted at a 30º or 45 º angles (**Figure 10A**). Hardy cultivars may be planted upright (**Figure 10B**). Keeping the vines aligned across rows will also allow cross-cultivation with a tractor during the first year or until the trellis is built. The roots of the young bare-root vines should never be allowed to dry out and should be protected from direct sunlight. Keep them moist until planted. Never soak bare-root vines in water more than 3 or 4 hours since roots need aeration and stored nutrients can leach out. Prune only the broken or dead roots. Dig holes large enough to adequately accommodate the roots. If an auger is used for digging the holes, at least a 12-inch, preferably a 14- to16-inch diameter one should be used. Never stuff large root masses into small holes but spread the roots. Augers are prone to compacting the sides of the hole, particularly when the soil is too moist. Avoid planting when the soil is too moist (when it "balls up" when squeezed in your hand). Even when soil conditions are optimum for planting, it is a good practice to break in the sides of the hole as you plant the vines. Place the vine in the hole, fill the hole with soil and tamp to eliminate air pockets. Leave a depression around each vine at the soil surface to hold water. Water the vine well at this time. Young vines need ½ to 1 inch of water per week. Five gallons of water applied on a 3 x 3 foot area is equivalent to about an inch of rainfall. Stop watering mid- to late-season to promote deep root growth.

Special care must be taken with greenhouse rooted green plants because of the environment they have been growing in. Their leaves are tender because of the different light spectrum, and need to be acclimated to outdoor conditions before planting or initially provided with some protection from direct sunlight when planted in the field. They typically have a very limited root system for the amount of shoot growth present and need to be watered frequently until their roots grow into the soil.

Grow tubes have proven to be valuable in the growth and survival of young vines. If used, they should be set around the vines at planting time, and supported by a stake or bamboo pole pushed securely into the soil. About 1" or so of soil should be pushed up around the bottom of the tube to seal it. This grow tube will act as a little greenhouse, allowing heat to accumulate, causing the new buds to push earlier and allowing the new shoots to develop rapidly. In a cold spring the difference in growth compared to newly planted, unprotected vines can be dramatic. Grow tubes also offer protection from contact herbicides applied after planting, and feeding by deer and rabbits. Grow tubes should be removed early August to allow the shoots to mature and properly harden off. Once the grapevines are dormant, they can be re-set to provide some winter protection from rabbits and voles.

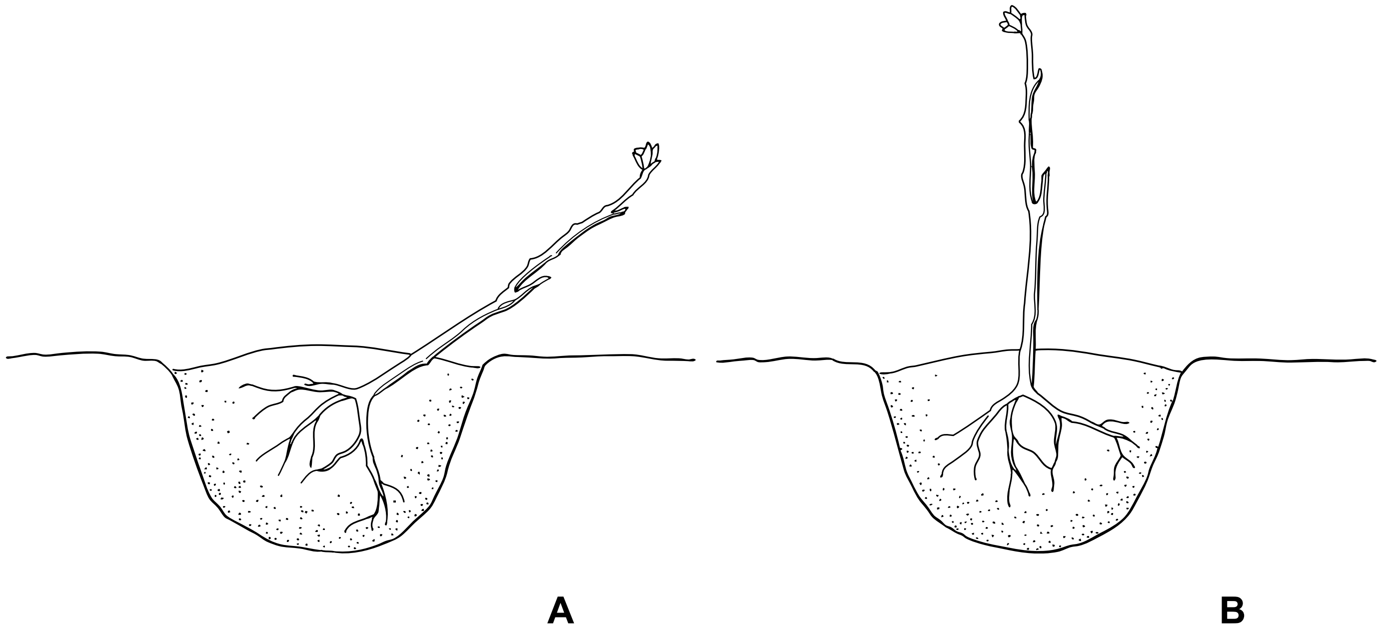


Figure 10. Planting Rooted Cuttings. Horizontal planting for cultivars needing winter protection (A), and vertical planting for cold hardy cultivars (B).

Parts of the Vine

Figure 11 illustrates the parts of a grapevine and the following insert defines the terms.

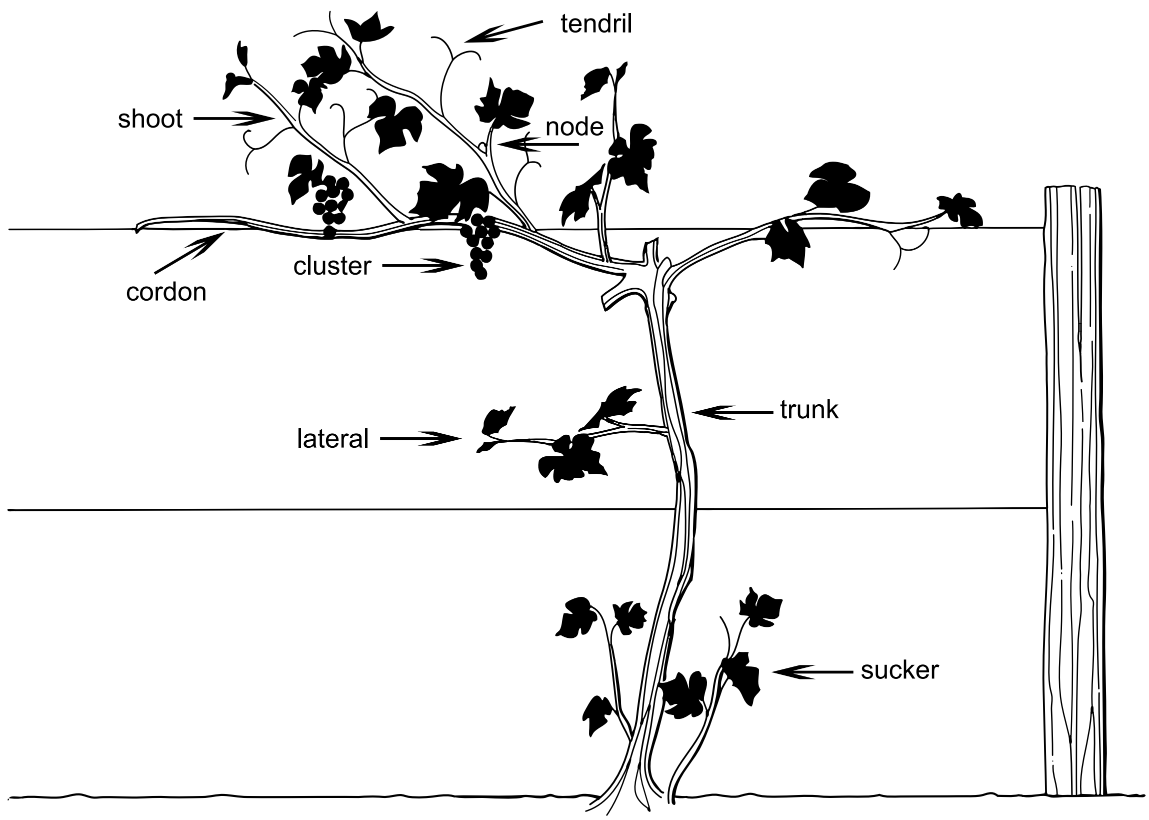


Figure 11. Parts of the grapevine.

Parts of the Grapevine (Illustrated in Figure 11)

Arm – a short branch of old wood extending from the trunk or cordon on which canes or spurs are borne.

Apical dominance – ability of shoots near the tip of a cane or spur to produce hormones that retard growth of more basal buds or shoots.

Basal – in the direction for the roots or base of the vine.

Basal shoot – shoot arising from a bud at the base of a cane or spur.

Bud – a compressed, dormant undeveloped shoot. Buds form at the base of each leaf petiole on developing shoots, lie dormant during the winter and begin growing the following year.

Cane – a shoot after it lignifies (turns brown) and becomes woody.

Canopy – above ground parts of the vine composed of many canes, shoots and leaves.

Cluster – a group of flowers (spring) or grapes that develop at certain nodes on a shoot.

Cordon – a horizontal extension of the trunk usually trained on wires.

Distal – end of a stem towards the growing tip, or end of a cane or spur.

Head – the top portion or crown of the trunk(s) where canes are selected to produce the current season's crop.

Hedging – trimming off the ends of shoots in a vertical shoot positioning (VSP) training system.

Internode – the portion of a shoot, cane or spur between nodes.

Lateral – vegetative growth developing sideways from the main shoot or cane.

Node – thickened portion of a shoot or cane where a leaf is or has been attached and a bud was formed.

(Internode is the portion between two nodes).

Petiole – the stem of a leaf.

Renewal spur – a cane pruned to one or two nodes, generally on an arm or cordon to develop a cane for fruiting the following year.

Shoot – current season growth that emerges from a bud on a cane and bears leaves, fruit and new buds.

Skirting – trimming the ends of shoots in a downward shoot-positioning system such as a single curtain bilateral cordon.

Spur – a cane pruned to five or fewer buds.

Sucker – a shoot that develops from the lower trunk or from underground.

Tendril – a narrow curly growth from stems that coils around objects, supports the shoot and helps the vine to climb.

Trunk – the permanent, above ground upright part of the vine.

Water sprout – unwanted shoot arising from adventitious buds on the trunk or cordon.

First Season Care

The main goal during the first season is development of the vine's root system. Competition from uncontrolled weeds reduces growth and can even kill young vines. Thus, good weed control the first year is extremely important. Close to the vines, and under the trellis, weed control can be accomplished by hand hoeing, mechanical tilling or herbicides. Oryzalin (Surflan®) is a pre-emergent herbicide that is registered for use on first year vines. A common weed control practice is to apply oryzalin to keep new weeds from germinating and glyphosate to kill existing weeds and grass. This combination applied immediately after planting and before new buds begin to emerge will often control weeds for much of the first summer. If vines have broken dormancy, extreme care must be taken to prevent herbicide contact. If grow tubes are used, they will not only help new vines to get off to a good start but will protect new shoots from glyphosate or other contact herbicides. If emerging grasses become a problem, post-emergence grass herbicides such as Poast® (sethoxydim) and Fusilade (fluazifop-p) can be used.

A second goal during the first season is to begin the process of training shoots to develop into the trunks of the vines. As the new shoots develop, a few simple steps should be followed to begin the training process. For hardy cultivars without using grow tubes, train several developing shoots up to the trellis wires on a bamboo stake or strings attached to the base of the stake to maximize leaf area and root development. Tie no more than two shoots to a stake, otherwise shading will delay the maturation of the shoots. Use Max Tapener tape, T-bands™ or similar products to tie the strongest and straightest shoot to the training stake and trellis wire when it becomes long enough (**Figure 12A**). If using grow tubes, tie the shoot(s) that come out of the top of the tube onto the trellis wires above or to the pole supporting the grow tube to keep it off the ground. These methods will ensure that most of the growth of the vine will be directed into a main shoot (**Figure 12B**). For hardy cultivars, the shoots can be trained vertically. If you are growing cold tender cultivars that will have to be covered during the winter, a bit more care is needed to achieve the desired "J" shape (**Figure 12C**). As the shoot grows, it should be pinned to the ground with U-shaped wire hoops for the first 18-24" of its growth. At that point, the shoot can be tied to a piece of twine and encouraged to follow a gentle J-shaped curve up to the lower trellis wire.

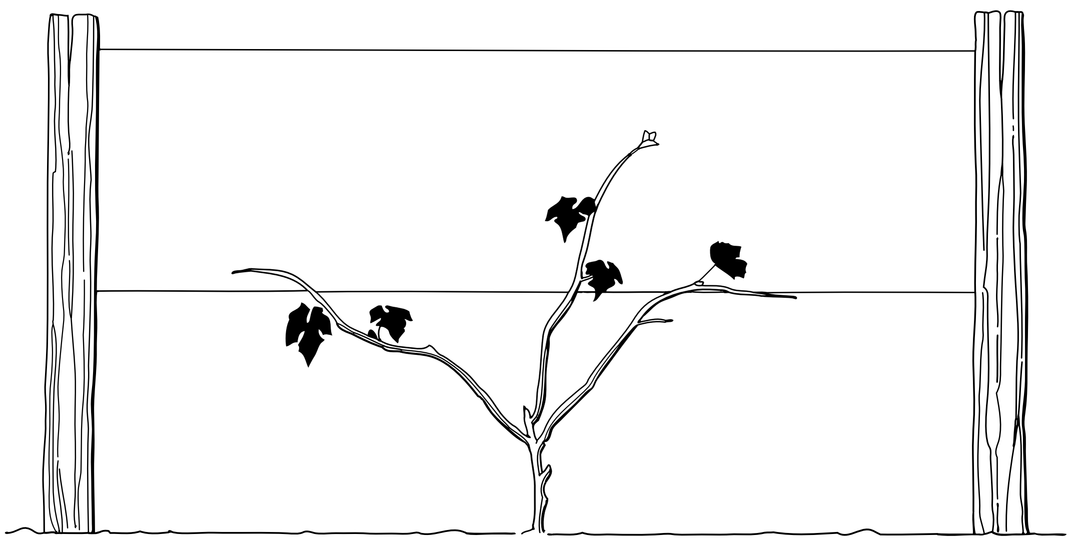


Figure 12A. Training a new trunk for hardy cultivars- straight trunk.

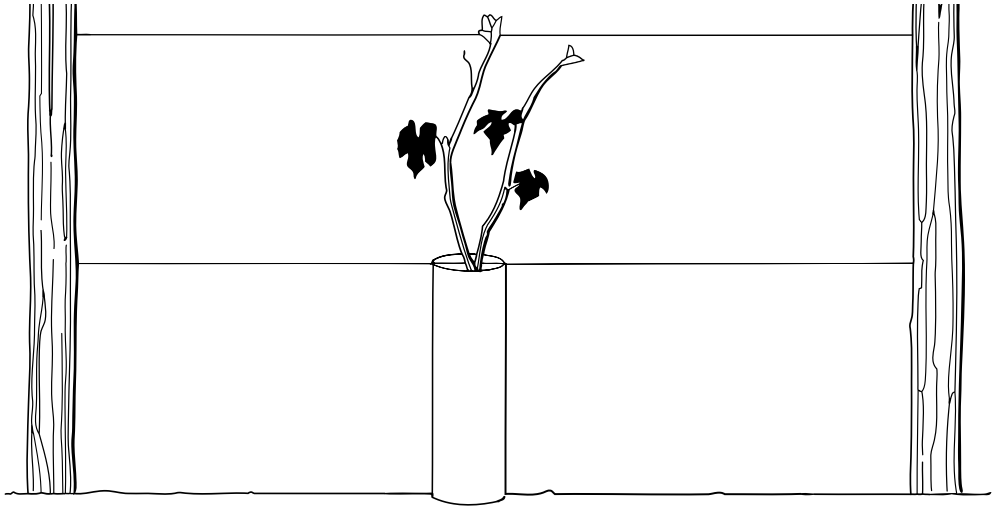


Figure 12B. Training a new trunk for hardy cultivars with a grow tube.

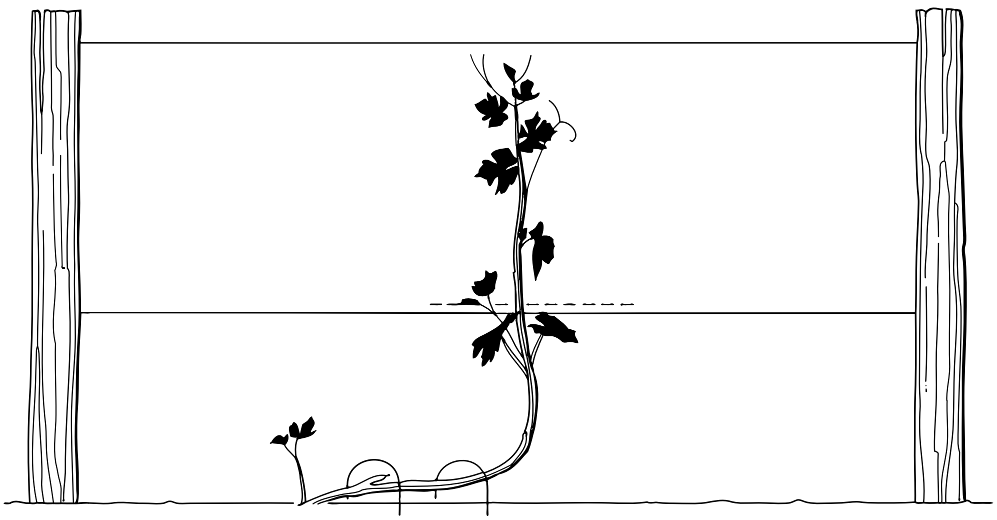


Figure 12C. Training a new shoot to a trunk for tender cultivars- Mini J.

Cold hardy vines do not require winter protection. However, cold tender cultivars need protection. A mound of straw or soil around the base of the vine is advisable to help protect the all-important root system. If there was vigorous growth and the entire trunk was formed, cover the entire trunk of tender cultivars with mulch such as straw, snow, burlap, or for best protection, buried in soil. Do not be diskouraged if new shoots partially or entirely die back over the winter. New shoots (suckers) will appear from the root system when growth appears in the spring. Again select a strong new shoot and resume the training process.

Second Season Care

In addition to continued careful weed control, 50 lbs. /A of N fertilizer (adjusted for soil organic matter) can be applied in the second year. This will encourage a vigorous start. Cultivars especially susceptible to disease may require a more rigorous spray schedule for controlling diseased that affect the shoots and foliage. In many cases vines will form a few fruit clusters this season. It is recommended that these be pinched off since the vine's energy is best directed toward growth of roots and canes.

Normally, the second season is the time when the full vine trunk is formed and shoots are trained onto the trellis wires. Due to many factors, first year vine growth varies widely from vine to vine. Some may make as much as 6-8 feet of growth and more the first year, forming the entire trunk. More commonly, first year growth nurtured during the first season is cut back to a point where the cane is alive with no sign of winter injury (green with no blackish streaks) and at least ¼-inch in diameter. The same training rules described above for first season vines apply as well to the second year's effort to train a shoot into a permanent trunk. When the new, rapidly growing shoot has passed the lower wire, a decision must be made about where to "head" the vine. If a low training system (i.e. a VSP or Fan) is to be used, the new trunk must be topped and tied to the lower wire. If one of the high training systems (i.e. a bilateral high cordon, Kniffin or a Munson system) is to be used, the shoot can be allowed to grow up past the top trellis wire. Then it is topped and secured to the top wire. Topping should be done when the shoot is at least ¼-inch in diameter at the level of the wire to which is it to be secured. Make the topping cut through the node just above the top node to be retained on the trunk. This will provide plenty of room to tie the new trunk tightly to the wire without damaging the top bud on the trunk.

Topping the new trunk in this matter forces the growth of lateral shoots along the new trunk. These lateral shoots will form the first set of fruiting canes and spurs on the young vine. The remainder of the second season is simply devoted to positioning and tying these lateral shoots so that they grow into the desired form. If possible train two lateral shoots in both directions along the trellis wire(s).

Vines that may have died-back to near the ground or cane diameter was less than ¼-inch will need to be cut back to a few buds and started over. On these vines, train 3-4 shoots up the support stake and strings as during the second growing season to establish the trunk.

Third Season Care

Continue to control weeds under the vines, and apply nitrogen fertilizer at about 40-50 lbs. /A (adjusted for soil organic matter). If the trunk was established during the first growing season and canes were established on the trellis wires during the second growing season, the vines are ready to produce a partial crop during the third growing season. With a partial crop, disease control will need to be stepped up to control those diseases that affect the fruit.

Cane-pruned training systems: select canes to tie to the trellis wires for fruiting retaining about 30 buds per vine. Prune the other canes back to 2-3 bud renewal spurs.

Cordon training systems: select canes to form the cordon. These canes should exhibit moderate vigor and be about ¼-inch in diameter at about the fifth or sixth node. It is best to cut these canes back so that they occupy about half to two-thirds of their allotted space on the trellis. This is done to assure that shoots develop uniformly along their length of the cane, otherwise apical dominance to the distal (end) shoots can inhibit the emergence of shoots near the basal end of the cane. If lateral canes formed along the primary canes, they can be pruned back to a single bud if they are at least ¼-inch in diameter, otherwise they should be removed.

Vines had to be cut back to re-establish the trunk: select canes to form the trunk and head them back just below the trellis wire if this was not done during the growing season.

Bull canes: When selecting canes to form the trunk or cordon, avoid using "bull" canes. These are canes that are very thick (>1/2-inch diameter) and have very long internodes that can exceed 6-inches, and tend to have a more oval rather than circular cross-section. They are less cold-hardy and less fruitful than normal canes.

Vineyard Best Management Practices – Starting the Vineyard

Rate your vineyard establishment practices:

Management Area: **Planting and care**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Soil condition at planting	Soil could be tilled without sticking to tools.	Soil at the bottom of the planting hole was somewhat sticky.		Soil near the surface sticks to tools.
Size of the planting hole	Large enough that the roots could be spread out & root pruning was minimal	About 1/3 of the root system had to be pruned for the vine to fit the hole when the roots were spread.	About 1/2 of the root system had to be pruned for the vine to fit the hole when the roots were spread.	Roots had to be wrapped around and stuffed in the hole.
Watering	Water is applied after planting to settle the soil and as needed during the growing season.		Water is applied after planting to settle the soil and rainfall is relied on during the growing season.	Water is not applied after planting or during the growing season.
Green plants	Acclimated to sunlight before planting and watered frequently after planting until the roots grow into the soil.		Not acclimated to sunlight before planting and watered frequently after planting until the roots grow into the soil.	Not acclimated to sunlight before planting or watered frequently after planting until the roots grow into the soil.
First season	Controlled weeds to optimize shoot growth and trained shoots to form the trunk.	Controlled weeds to optimize shoot growth but did not train shoots to form the trunk.	Trained shoots to form the trunk but did not control weeds.	Did not control weeds or train shoots to form the trunk.
Second season	Continue to control weeds, formed the trunk and began training shoots onto trellis wires.	Continue to control weeds, and had to re-train shoots to form formed the trunk.		Did not control weeds, and had to re-train shoots to form formed the trunk.
Third season	Continue to control weeds, if canes were established on the trellis wires in the 2nd season, begin pruning for a partial crop.	Continue to control weeds, if canes were not established on the trellis wires in the 2nd season, continue to train shoots on the wires.		Did not control weeds, and trunk was not formed during the 2nd season.

Care of Established Vineyards

Vine Canopy Objectives

The vine's canopy is defined as the sum total of its leaves and shoots. The management of this canopy, to achieve good vine health, good wood maturity for the winter, and optimal wine grape quality, is one of the most important activities for growers in cool climates. Some principles of canopy management, paraphrased from an outstanding paper by Dr. Richard Smart (in the South African Journal of Enology and Viticulture, Vol. 11, 1990) are summarized below:

1. **Maximize Sunlight Interception.** This is critical both for proper ripening of the fruit and for good wood maturity. Ideal sun exposure has been shown to occur in vines with narrow vertical canopies, i.e. those with growth spreading out less than 1 foot in width along the trellis. Also in the ideal vine canopy, the leaves and shoots are spread out so that the canopy is never more than 1-3 leaf layers thick at any point. A final rule-of-thumb is that "gaps" should exist in the ideally exposed canopy . . . literally, places where one can look through the vine from one side to the other. A vine with gaps in 20-40% of its surface area will provide good sun exposure even for those leaves and clusters located in the deep interior portion of the vine canopy. Choice of an appropriate training system, balanced dormant pruning, and timely shoot positioning (or summer pruning) will all contribute to achieving good sun exposure in the vineyard.
2. **Minimize Shading.** Vines that fail to meet the sun exposure criteria listed in (1) above will, to varying degrees, be shaded. That is, excessive growth of leaves and shoots beyond a desirable width, depth, and density will create so many layers of foliage, i.e. so much "overgrowth," that the leaves and fruit underneath them will be shaded. Shading of fruit and shoots renders the vine vulnerable to a host of maladies. Reported effects of shading on the fruit include lower sugar accumulation, higher titratable acidity, higher must pH, excessive must potassium, reduced pigmentation, and increased incidence of bunch rots. All of these problems can make winemaking more difficult and adversely affect wine quality. Further, shading increases humidity inside the vine canopy and reduces airflow, creating ideal conditions for mildew. Also, shaded leaves turn yellow and senesce prematurely, at which point they become useless to the vine. Again, proper training, balanced pruning, and application of shoot positioning and/or summer pruning techniques can all serve to minimize shading.
3. **Balanced Growth.** In the healthy, productive vine, there is a good balance between vegetative (leaf and shoot) growth and fruit or crop load. A vine with a good balance between vegetation and crop will usually show good sunlight interception and minimal interior shading. Both fruit and wood maturity will be good. Proper dormant pruning is the key to achieving balanced growth.

Choosing a Training System

Growing grapes in cold climates is challenging by itself. However, managing the cultivar to the training system is one key element in obtaining satisfactory performance from grapevines. With a good match, one can expect to have grapes with less disease, enhanced ripening of fruit, improved cane survival rates and an ample supply of fruitful buds.

The purpose of training the vine is to place its trunk, canes and resulting leaves, shoots and fruit in an optimal arrangement on the trellis. The training system selected will affect the exposure of foliage and fruit to sunlight. The height of the training system will affect the vine's ability to intercept reflected heat from the vineyard floor. This can help reduce acid in the ripening fruit, particularly in late season wine cultivars. Through its effect on foliage density, the training system will determine the amount of airflow through the vine and the susceptibility to disease.

The major actors to be considered in selecting a trellis system:

1. **Simplicity** - simple training systems are often the most economically viable but may restrict yield and quality.

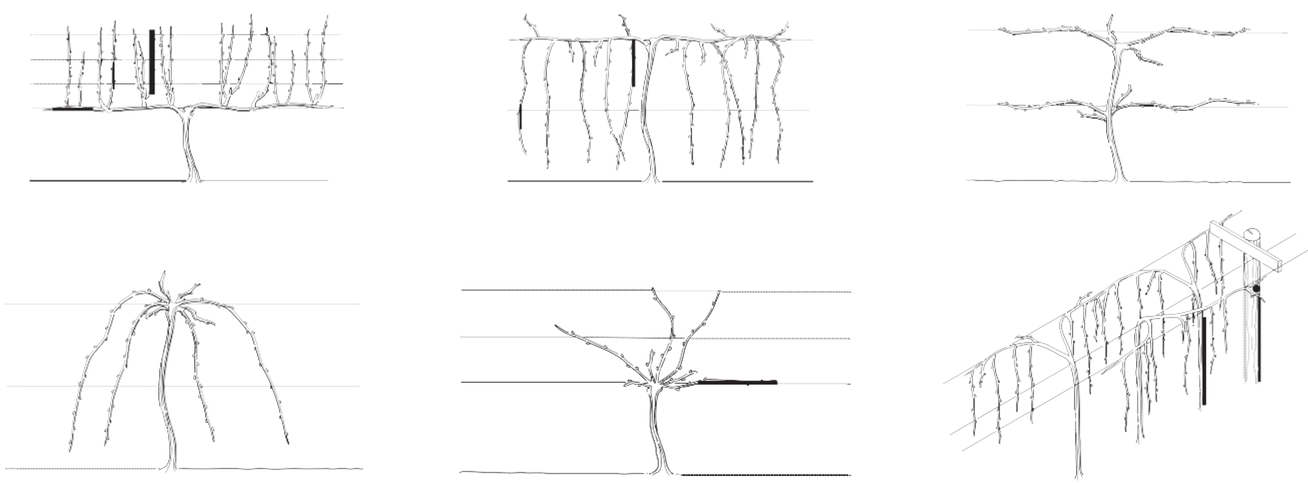
2. **Growth habit of the cultivar**- the training system should adapt to the growth habit of the cultivar. *Vitis vinifera* cultivars typically exhibit an upright growth habit while American cultivars based on *V. labrusca* have a downward (procumbent, trailing) growth habit. Northern and French hybrid cultivars exhibit an intermediate grown habit ranging from procumbent to semi-upright. Cultivars with a procumbent or semi-procumbent growth habit do not adapt well to training systems designed for cultivars with upright growth habits, whereas, cultivars with semi-upright growth habits adapt well to training systems designed for cultivars with procumbent growth habits.

3. **Vine vigor** – the balance between vine vigor and capacity which influences yield and grape quality. The training system should accommodate the vine vigor which is influenced by the cultivar and soil fertility. Within a simple (single curtain) training system, wider in-row vine spacing is used to accommodate vigor, but vine spacing alone may not be enough and a double curtain or split canopy system may need to be used.

4. **The cold tolerance of the cultivar.** How adaptable is the training system to practices that would provide additional winter protection, or recovery from winter injury? Cane-pruned systems tend to be more compatible for tolerating winter injury than spur-pruned, cordon systems.

5. **Economic factors** - the cost and benefits of the more expensive trellis systems must be considered. How adapted is the training system to mechanization?

6. **Environmental factors** - temperature, rainfall, topography, soil, wind and potential frost risk.



According to Dr. Richard Smart in Practical Winery and Vineyard July/August 1997: “We now have the means at our disposal to convert high vigor vineyards, which are prone to disease and produce low quality fruit, into productive ones with less disease and much improved quality. There is a trellising system to successfully make the most of nearly every vineyard.”

Mid-wire Cordon with Vertical Shoot Positioning (VSP)

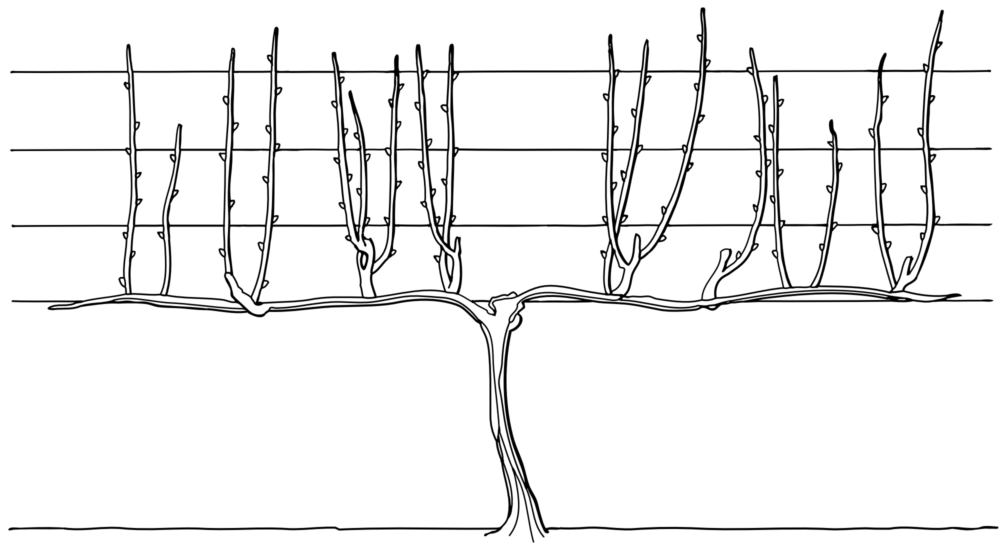


Figure 13A. Mid-wire Cordon with VSP.

This system begins with a short trunk trained to a low cordon wire, 30" to 42" off the ground. Cordons off this short trunk are trained on this wire and spurs from these cordons provide the fruiting wood to produce the crop **(Figure 13A)** Three or more sets of catch wires spaced 10 to 12" apart are fixed above the cordon wire (**Figure 13B**). The catch wires act as foliage traps. The narrow canopy allows sunlight to reach the fruit and renewal zones. Many shoots will naturally grow between the wires that support them in a narrow vertical wall, the rest need to be positioned manually which often requires three of more passes through the vineyard to accomplish the task. With the cordon closer to the ground, reflected heat from the vineyard floor may aid in maturing the crop, but the vineyard will be more prone to spring frosts under radiation freeze conditions.

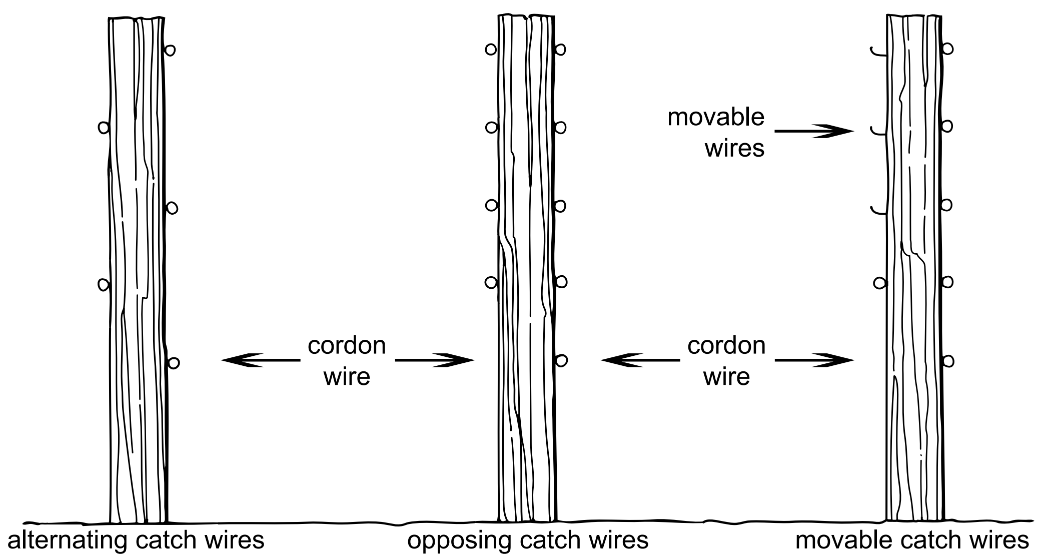


Figure 13B. Three common VSP catch wire configurations.

Some Northern hybrids and other cultivars having a semi-upright growth character are easily trained to this system. Local growers have had success using VSP for Frontenac, Frontenac Gris and Prairie Star. When used for cultivars that have strong downward (procumbent) growth characteristics, such as La Crescent, additional labor is required to maintain the shoots upright and between the catch wires. For cultivars with a strong apical dominance characteristic, spurs should be pruned to two nodes. Vertical shoot position training systems were developed for *V. vinifera* cultivars that have an upright growth habit and exhibit moderate vine vigor. With many northern hybrids cultivars exhibiting high to very high vigor, particularly on fertile (high OM) sites, additional in-row spacing and/or sets of catch wires are often needed, or training to split canopy systems such as the Smart-Dyson or Scott-Henry may be required. In addition, hedging the tops and sides of the vines, and leaf pulling may be required. The system is easy to establish, learn and can be mechanized, but has addition materials and cultural expenses.

Single Curtain Bilateral Cordon

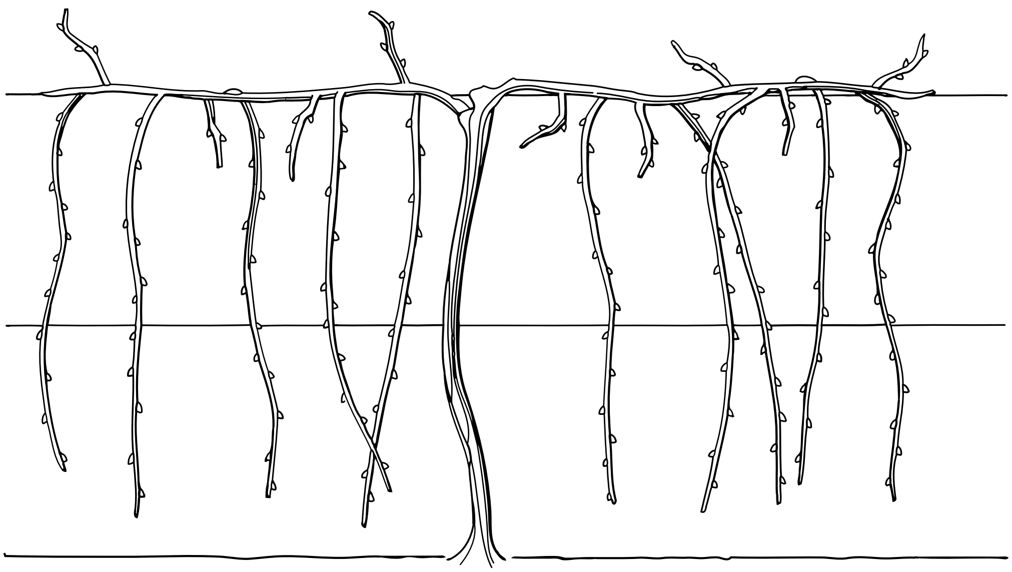


Figure 14. Single Curtain Bilateral Cordon.

The Single Curtain Bilateral Cordon (High Wire Renewal System or High-wire Cordon) is widely used in the cooler climates for cultivars exhibiting procumbent to semi-upright growth habits as it is simple and effective. In this system, two wires are typically used (**Figure 14**). The mid-wire, set at 3- to 4-feet to support the trunk and the top wire at 6-feet, where the cordons are trained horizontally. Short canes and spurs are selected, preferably with the canes pointing in a downward direction. The fruit remains near the top wire, with most of the foliage below it.

This is one of the simplest and cheapest ways of training vines and many practices can be mechanized. Shoot positioning, often referred to as "combing", is practiced to encourage to them to grow downwards, and is typically accomplished with one pass through the vineyard. Fruit exposure to sunlight is good and exposure of buds at the base of canes to enhance next season's crop is likewise very good. The extra height above the ground sometimes provides protection from frost layers below (Jackson, 2001).

Foliage management, although not time consuming, must be undertaken carefully. If shoots are not positioned downwards before fruit set, berries will develop in shade and on later exposure will very likely sunburn. In addition, berries may produce excess tannin, which gives bitter characteristics; however Northern hybrid cultivars are characteristically low in tannins. Bird damage may sometimes be greater with this system (Jackson, 2001).

Because this system is so easy to manage, growers are sometimes tempted to over crop the vines, a practice that leads to low °Brix (sugars or soluble solids) and poor quality wine. One other disadvantage is that because the trunk is up to two times the height of mid-wire systems, the first crop may be delayed by a year. Sometimes growers may crop at mid-height first, and take the trunk to the top wire the next year (Jackson, 2001).

Compared to the mid-wire cordon VSP system, the bilateral cordon system provides more space for shoot growth without trimming and so is easier to manage on a more vigorous site. In addition, positioning the shoots to grow downward, aids to suppress the vigor of the vines. All other things being equal, this extra leaf area can ripen a slightly heavier crop (Jackson, 2001).

Four-Cane Kniffin

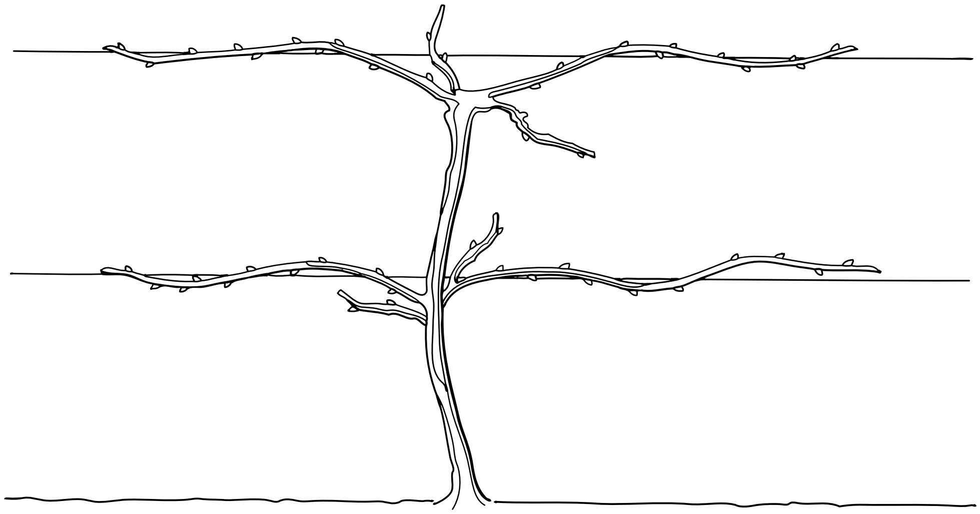


Figure 15. Four-cane Kniffin training system.

The 4-Cane Kniffin system uses a two-wire trellis, with a lower wire placed at approximately 30-36" and a top wire about 60-70" above the ground (**Figure 15**). The trunk is trained to a head that almost reaches the top wire. Two canes each originating just below the top and bottom wires are retained with 7 or more nodes and tied to the wires with other canes originating near the wires being pruned back to 2-node renewal spurs. The canes tied to the wires are replaced each year. Additional labor is required to tie the canes to the wires each year. One problem with the Kniffin system is that for vigorous growing cultivars it is difficult to maintain quality on the bottom wire because of shading, and the system is not adapted to systematic shoot positioning or leaf removal. Also, the longer trunk, even if trained in a J style, can be rather bulky to lay down and cover for the winter. Similar to the 4-Cane Kniffin system, the 6-Cane Kniffin system has wires at 2.5, 4 and 6 feet and is suitable for low vigor sites.

Umbrella Kniffin

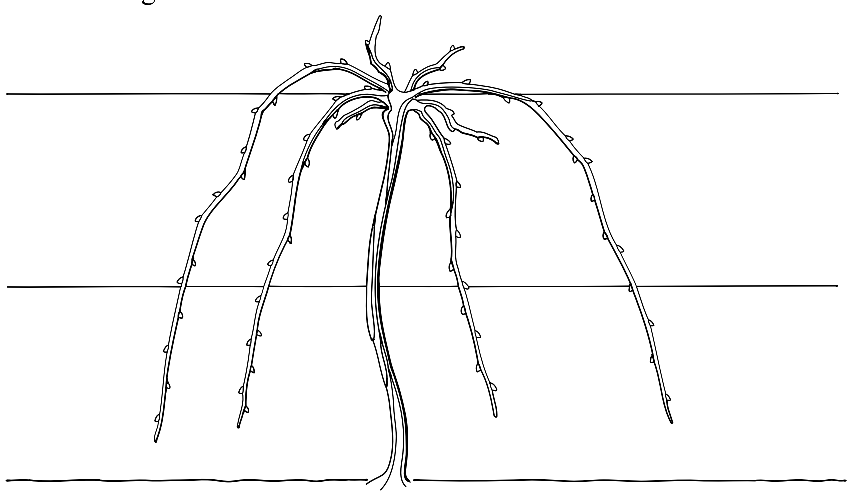


Figure 16. Umbrella Kniffin training system.

Umbrella Kniffin (**Figure 16**) is a variant of the Kniffin system. In the Umbrella, 2-4 canes are looped up and over the top wire and pulled down to a lower wire, where the tips are secured. The bending of the canes in this system overcomes apical dominance and helps to force and distribute growth more evenly along the cane than in a standard Kniffin system. It is suited for American cultivars requiring pruning to long canes. Extra labor is required to tie the canes to the lower wires, and it is not well adapted to shoot positioning.

Fan System

The Fan System allows for maximum flexibility to adjust to frequent winter injury with a minimal retention of permanent vine parts. It spreads the foliage nicely across the trellis resulting in good air circulation and sun exposure, but weeds under the vines can be a serious problem. This is suitable for most French hybrid cultivars and for certain Swenson hybrids such as La Crosse and St. Pepin. This system heads the trunk at a low trellis wire, 18-30" above the ground or even lower and 1-2 suckers are often retained to replace the trunk as needed. Two to 4 canes are spread over the trellis in a "fan" shape and tied at the middle (and if necessary, at the top wire). The fan system is not well adapted to systematic shoot positioning or leaf pulling.

The Spur Pruned Fan System (**Figure 17A**) is used for vines of low-medium vigor. There is a short trunk with a series of spurs (2-4 buds long). Canes growing from these spurs are arranged in a fan. The fruiting zone for this system is narrow and similar to a vine trained to a mid-wire cordon with VSP.

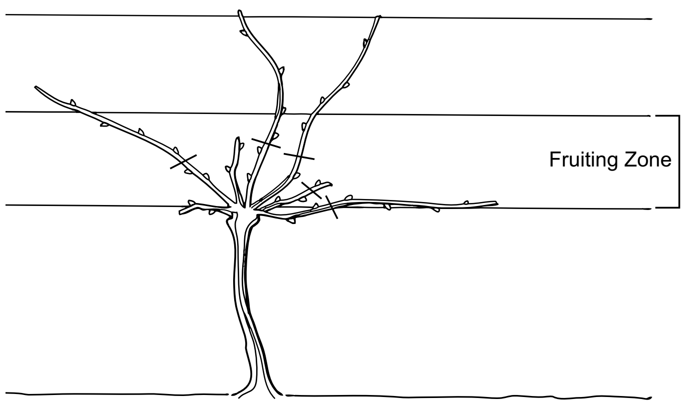


Figure 17A. Fan System (Spur Pruned)

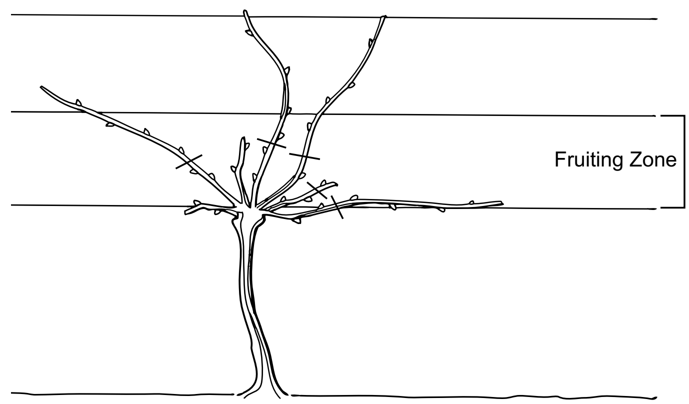


Figure 17B. Fan System (Cane Pruned)

The Cane Pruned Fan System (**Figure 17B**) also has a short trunk, with canes arranged in a fan. There are renewal spurs at the bottom wire. This system works well for more vigorous vines that bear heavily. The fruiting zone is more spread out and will range from the height of the lowest cane to the most upright cane.

Munson System

The Munson system requires the special three-wire trellis (**Figure 18A**). A cross arm is mounted on each trellis post. A wire is fixed at each end of the cross arm. The third or middle wire runs through the posts 3"- 6" below the cross arms. The trunk is headed at this middle wire. Canes or cordons are run in both directions along the middle wire. As shoots grow from the canes, they are positioned to grow up and droop over the outside wires. The fruit all hang about shoulder level, in between the side wires, making harvest very convenient. Also, with the vine so spread out and open in the center, sun exposure and air circulation are excellent. A vigorous vine can be accommodated with a minimal amount of shading (**Figure 18B**). This system is suitable for cultivars with growth habit ranging from procumbent to semi-upright characteristics.

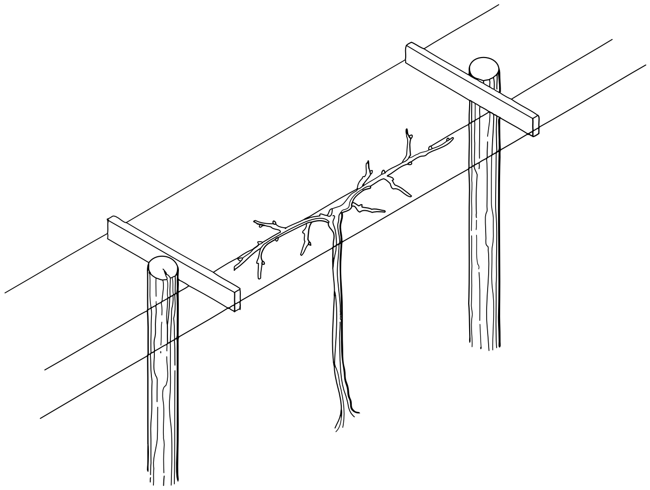


Figure 18A. Munson System (T-Trellis).

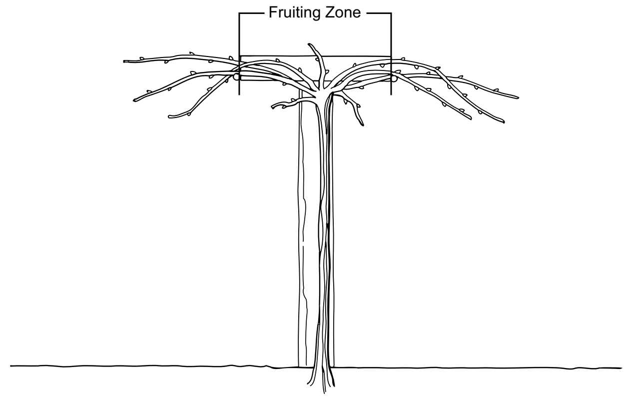


Figure 18B. Munson fruiting zone.

A modified Munson system has been developed for use in vineyards whose rows run east to west (i.e. face south). In a standard Munson system, vines in east-west rows will have excellent sun exposure on their south side, but foliage on their north sides will be shaded. The modified Munson system places the cross arms at an optimal angle (45 degrees for our latitude) for solar reception. The results have been promising – increased yield and better ripening of the canes for winter.

Geneva Double Curtain

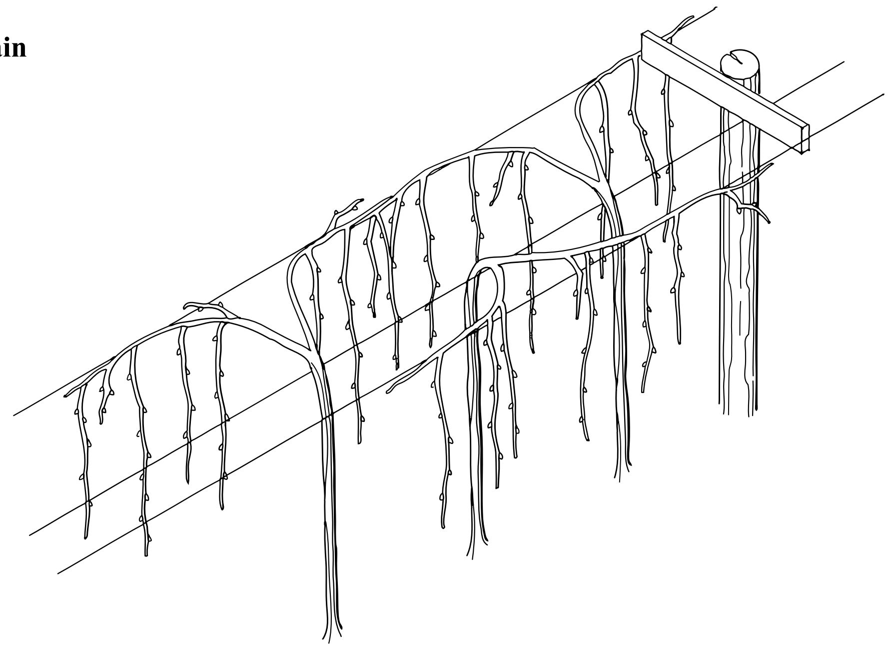


Figure 19. Geneva double curtain (GDC) training system.

Another variant of the divided trellis is the Geneva double curtain (GDC) (**Figure 19**). The GDC can be used for vigorous to very vigorous cultivars with procumbent to semi-upright growth habits that may become too large for high cordon training; especially on fertile sites. By going to the GDC, the vine vigor is distributed over a greater area and becomes more moderated. This system operates the same as the bilateral cordon system, but offers twice the amount of space for the vine canopy. GDC has two high curtain trellises installed 4 feet apart with each wire filling a single segment of both trellises. The minimum row width for this system should be 10 feet with 12 feet preferred. Training to the GDC is very similar to the bilateral cordon system, in that the shoots are encouraged to grow downwards from the top wire. This system enables a larger leaf area to be produced on a given area and also has the advantages of a single curtain for pruning and fruit exposure. Improved quality and dramatically increased yields can be expected (Jackson, 2001). Typically, yields can increase by 60% per vine.

One problem with the GDC is that keeping the large hanging "curtains" sorted out and efficiently absorbing light is time consuming task, and often at least two shoot positioning passes through the vineyard are required to keep the canopy open between the curtains. A poorly managed, overgrown canopy is a disaster. Allowing foliage to fill the gap between the two curtains creates a microclimate that annuls any advantages (Jackson, 2001). Many growers find they do not have the time or labor available to do it adequately and this effectively negates the advantages the GDG offers, attempting the grow the same cultivar on the site trained to a single curtain system would be an even greater disaster. Therefore, a grower must be committed to performing the necessary practices when the GDC is selected as the training system. It often requires an extra season of training to completely form the cordons because twice as much space is available for each vine. If the cordons or trunks are damaged by winter injury and must be replaced, it may take two seasons, rather than just one, to replace them. Thus, it is suited only to the most vigorous growing sites and for our hardiest cultivars. The system has been used in Minnesota with some success for Kay Gray, St. Croix and Beta. Edelweiss and Concord and other very vigorous cultivars may also benefit from this system.

Mini-J System

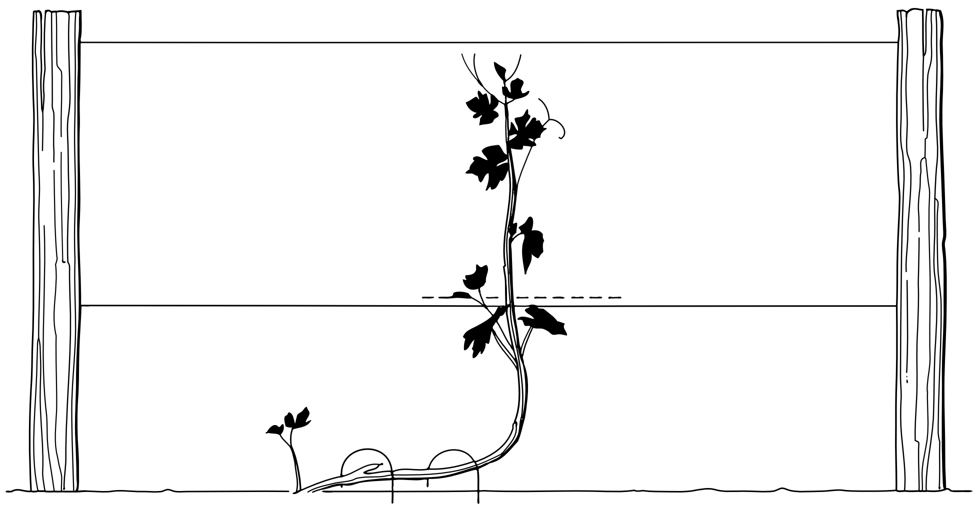


Figure 20. Mini-J training system.

If you have decided to grow a marginal or cold tender cultivar that requires winter protection, the trunk is trained at an angle to allow easier bending and burying of the trunk and vine in fall. You can also train the vine along the ground for 12" or so before it is trained upward onto the trellis to form the curved or Mini-J trunk (**Figure 20**). As the trunk grows thicker and heavier this method of training makes bending and covering much easier. This training system can be used for most trellis systems to help facilitate the covering of cold tender grapes.

A Note on Multiple Trunks

In a study done at Cornell University, vines of the Delaware cultivar with single trunks were compared to vines with two trunks. During a particularly severe winter, 95% of the vines with single trunks were killed to the ground. Ninety-five percent of the vines with double trunks lost one trunk, but only 40% of these vines lost both trunks, so 60% of the vines with multiple trunks had one trunk still functional. While the vineyard with single trunks had to be completely re-established (with a near complete loss of productivity), partial productivity of the second vineyard having multiple trunks was possible.

It has been previously stated in this guide that if you are growing grapes that are reliably cold hardy, multiple trunks may be of little value. However, in 2012, following an unusually warm March that advanced grape bud development, a mid-April freeze occurred when early bud-breaking cultivars such as Marquette and La Crescent were in the bud swell to early burst stages of development and caused considerable trunk and cordon injury to the vines. Multiple trunks require extra time to develop, require extra pruning and often have quality problems associated with them. However, multiple trunks are recommended if you are growing marginal cultivars that may regularly suffer cold injury, growing tender cultivars that need to be buried, or if you live in an extremely cold area. **Developing trunks of different ages is recommended because trunks of the same age tend to respond to cold stress similarly.** One older and one newer trunk may allow for better bud survival on one than the other. When multiple trunks are cultivated, each remains smaller and more flexible for a longer period of time, facilitating winter protection. When one of the multiple trunks becomes too bulky to be covered, it simply can be removed, without loss of productivity. Also, developing multiple trunks is well suited for replacing cordons to maintain productivity as blind sections develop.

Building the Trellis

The choice of a training system goes hand in hand with the choice of trellising system. It is best to build the trellis during the first year when the trunks are being formed. This keeps the foliage off the ground, reduces the danger and severity of spring frost damage and allows better air circulation around the foliage. Keep in mind that some Grade 1-X or 1-1 vines could grow to 8 feet the first year and this growth could exceed the height of training stakes.

Trellis systems should be constructed to carry heavy crop loads, withstand high winds and last at least 20 years. Posts serve two functions: the line posts provide vertical support to trellis wires while end posts provide anchor points for tightening wire and maintaining wire tension. Wood posts usually prove to be superior to steel or concrete and are treated with chemical preservatives. Wood posts that have been commercially pressure treated with pentachlorophenol (PCP, or penta) or creosote should last some 20 years. Avoid using landscape timbers for line posts! They are not pressure-treated with preservative and do not last very long. Untreated native timber alternatives to treated post with exceptional resistance to decay include Osage orange, black locust and red mulberry. Eastern red cedar is rated as being very resistant to decay. Steel line posts can be a less expensive alternative to wood posts, but often do not provide sufficient lateral strength and the vine rows will lean over. This can be remedied by using a combination of steel and wood line posts.

The trellis should be 6 feet high overall and consist of line posts and sturdy braced end posts. End posts should be 5 to 6 inches in diameter for long trellis runs, and should be about 4 feet longer than the final height of the trellis. A horizontal (H-brace) or diagonal braced end post with 9 gauge low carbon (soft) steel brace wire attached to a post placed 6 to 7 feet from the end post can be used for any row length, and is required for rows that are over 600 feet long (**Figure 21A**). An anchored end post driven in at a 60 degree angle with either an earth anchor or tie back post set far enough back to form 60 degree angles can be used on rows less than 600 feet long (**Figure 21B**).

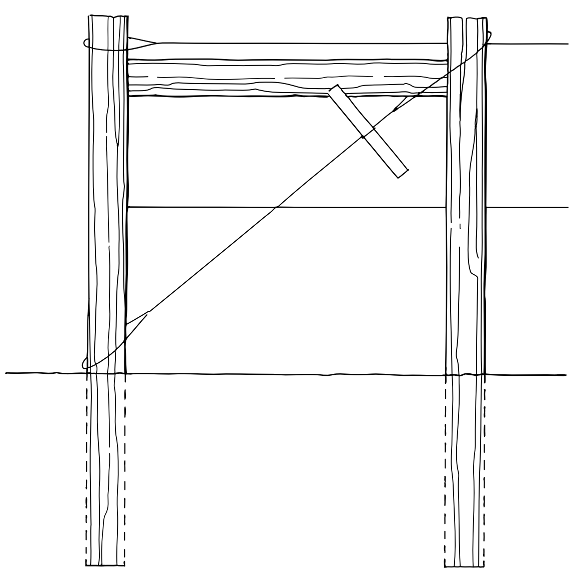


Figure 21A. Horizontal End Post

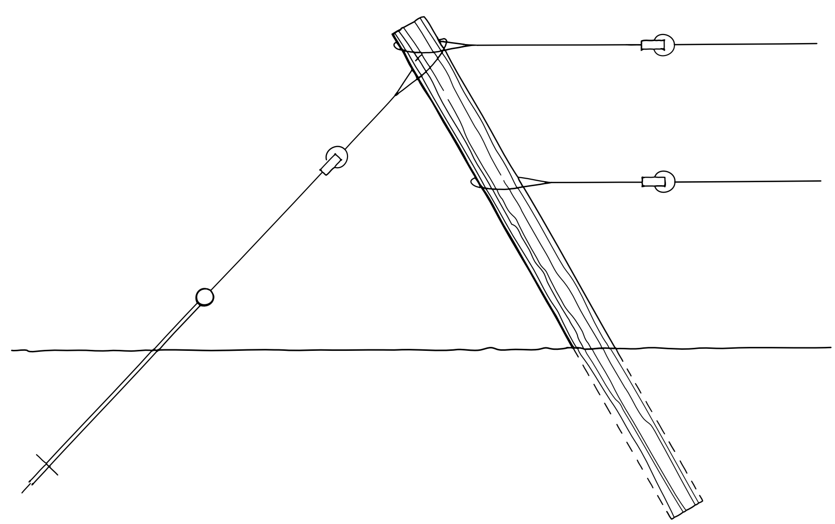
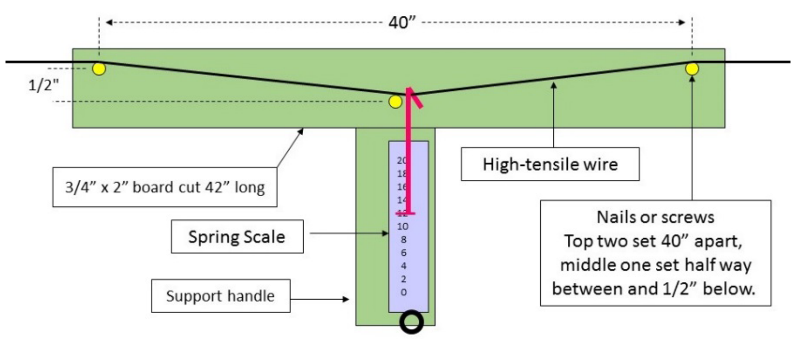


Figure 21B. Anchored End Post with Earth Anchor.

Line posts may be 3.5”-4” inches in diameter and should be 2 feet longer than the height of the trellis when a post driver is used to install them with the narrower end being inserted into the ground. When an auger is used, they should be 3 feet longer than the intended trellis height and inserted with the wider end going into the ground. Line posts for 7 foot vine spacing should be 21 or 28 feet apart. Line posts for 6 or 8 foot vine spacing should be 24 feet apart. Line post should never be spaced more than 30 feet apart. The number of wires is based on the chosen training system. The wire carrying the weight of vines should be 12.5 gauge high-tensile galvanized steel. The other wires on the trellis, such as catch wires, can be somewhat lighter.

High-tensile wire cannot be twisted and is very resistant to stretching. Therefore, crimping sleeves are used to tie off ends of wires to posts and other objects, and for splicing wires. Tension can be applied to lines less than 200 feet long with a Wirevise™ or Gripple®. For lines longer than 200 feet, in-line strainers are used. Load-bearing wires should be tensioned to about 250 pounds. A gauge can be constructed to measure the tension (**Figure 22**). During the winter, the wires will shrink and add additional tension. Therefore, some tension should be manually backed off, or tension springs on each wire can be used at an additional cost.



Attach the spring scale to the wire and pull the wire to the middle nail. Read the pounds tension required to pull the wire to the nail and multiply by 20 to determine the wire tension.

For example: a pull of 12.5 lbs x 20 = 250 lbs tension on the wire.

Adapted from: **How to Build Orchard and Vineyard Trellises,** US Steel, Pittsburg, PA

Figure 22. Building and using a tension gauge for high tensile trellis wires.

Trellis Considerations

- High-wire trellis training systems are used on vines with procumbent or trailing growth habits. High-wire trellis systems should have a 12.5 gauge high-tensile wire at 6 feet, near the top of the line post. An additional wire to support the trunks is optional.
- Vertical Shoot Positioning (VSP) training systems can be used on vines with upright growth habits. The VSP training system has a 12.5 gauge high-tensile mid-wire cordon wire at 36 to 42 inches off the ground with double catch wires spaced every 10-12 inches above. These catch wires can be of a lighter gauge wire.
- For the Kniffin and Fan Training systems, (2 or 3) wires placed at 2.5, 4 and 6 feet on the posts with staples will provide the framework for the vines.
- For the Munson system, the central wire can be led through holes drilled in the posts about 3-4" below the cross-arms. A 2x4 cross-arm 2 or 3 feet long is attached to the top of the post, and two more wires are attached to the tips, so that the trellis looks like a set of old fashioned phone wires.
- The trellis for use with the Geneva double curtain looks somewhat like the Munson trellis, but, as this is for extremely vigorous cultivars, must be more substantial than other trellises. The posts, cross-arms, wires and bracing must be capable of bearing the increased pressure, which this system will place on them. It is recommended that the end posts be at least 6" in diameter, with a horizontal end post system being better adapted than the anchored end post system. The cross-arms should be metal and the wires for the cordon should be 12.5 gauge high tensile galvanized wire. Prefab metal cross-arms are readily available.
- With any trellising system, the wires should be loosely stapled to the line posts to allow for changes in length of the wire with temperature and to let the load on the wires distribute to several line posts.

For detailed information on training systems and trellis construction:

An excellent resource on trellis construction is the Unites States Steel bulletin **How to Build Orchard and Vineyard Trellises**. It was first published in 1982 and copies are still available.

An article titled ***Training Systems for Grapevines*** by Paul Domoto that appears in **Northern Grapes News** (Sept. 2014, Vol. 3, Issue 3) covers other training systems used for grapevines in northern climates http://northerngrapesproject.org/wp-content/uploads/2014/09/2014SeptNGPnewsletter.pdf

PowerPoint presentations:

Domoto, P. 2002. ***Constructing a Vineyard Trellis***. ISU Ext. Viticulture Home Page. http://viticulture.hort.iastate.edu/info/pdf/domototrellis.pdf (also available on www.mngrapes.org)

Domoto, P. ***Installing a Vineyard Trellis***. ISU Ext. Viticulture Home Page. (a step by set pictorial essay) http://viticulture.hort.iastate.edu/research/pdf/installtrellis.pdf

Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Choosing a training system**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Growth habit of the cultivar Training system is adapted to the growth habit of each cultivar being grown.		Single curtain bilateral cordon training system was selected because it is adapted to most growth habits.	Mid-wire cordon with VSP training system was selected regardless of cultivars' growth habit.	Growth habit of the cultivar was not considered in selecting the training system.
Cultivar vigor	Training system with adjustment for in-row vine spacing will accommodate the cultivar's anticipated vigor at my vineyard site.	Training system with adjustment for in-row vine spacing will accommodate the cultivar's anticipated vigor. Soil fertility was not considered.	Training system should accommodate the cultivar's anticipated vigor. No adjustment for in-row spacing was made.	Cultivar vigor and site fertility were not considered in selecting the training system.
Cultivar cod hardiness	The cold hardiness of the cultivar was considered in selecting the training system.			The cold hardiness of the cultivar was not considered in selecting the training system.
Trellising materials	Selected trellising materials that would last at least 20 years.		Cut costs by using lesser quality materials.	
End post design	Used an end post anchoring system appropriate for the row length.	Used an H-brace system regardless of row length.	Skimped on recommended distances between end post and anchor.	Uses an anchored end post system on rows greater than 600 ft.

Pruning

Pruning is defined as the removal of plant parts to regulate crop size, improve crop quality, and achieve an optimal balance between vegetative (leaf and shoot) growth and fruit production. In grapevine management, the term usually refers to the removal of parts of or even entire canes during the late dormant season, and retaining only selected buds for that season's fruiting.

A vigorous grapevine will produce hundreds of buds during the growing season. If all these buds are allowed to remain on the vine into the next growing season, most of them will grow and bear at least two clusters of fruit. This large load of fruit will not ripen well and also be demanding on the vine, resulting in weak, stunted growth. Such vines will be more susceptible to winter injury and less productive the following season. With proper pruning, there will be enough vegetative growth to properly mature the crop, mature the buds and canes so that they can withstand the winter cold, and store carbohydrate and mineral nutrient reserves in the root system to get the vines off to a good start the next growing season. Annual pruning at this level will result in a moderate crop of mature fruit year after year. A typical crop for a mature vine is 5-25 pounds of fruit per year, depending on the cultivar, vigor, and health of the vine.

There is also the danger of pruning too much. When this occurs, the vines will produce excessive vegetative growth on the few remaining buds and result in a very small crop of very shaded fruit. These vigorous shoots will continue to grow late into the growing season and not harden off well. In addition, carbohydrates manufactured through photosynthesis will be utilized for vegetative growth with less reserves being stored in the trunk and root system. The objective of pruning is to strike a balance between vegetative growth and fruiting by regulating the number of buds retained on the vines.

Formulas for Balanced Pruning

To determine the potential fruit capacity of a grapevine at pruning time, growers can use the concept of *balanced pruning.* This concept was developed for Concord grapevines, but the principle is valid for all grapes and varies in magnitude from one cultivar to another (and to an extent from growing region to growing region) (Dami, *et al.,* 2005).

Balanced Pruning Procedure (*From:* Dami, *et al.,* 2005. **Midwest Grape Production Guide.** Ohio State Univ. Extension Bul. 919-05):

1. Estimate the amount (weight) of one year old wood (canes) on a vine; select the fruiting canes to be retained; and remove all other one-year-old wood (leaving a margin of error).
2. Weigh the one-year-old trimmings from the vine to determine *vine size*. Weight of the one-year old wood is highly correlated to the total leaf area the vine possessed the previous season and its potential to mature a crop. After pruning and weighing a few vines, growers will be able to make more accurate weight estimates and only periodic weighing is necessary afterward. Wood older than a year (if removed) should not be counted in the pruning weight.
3. Apply the vine size value to the pruning formula to determine the total number of buds to leave.

For example, Concord does well with the 30 +10 formula (**Table 24**). This means 30 buds are left for the first pound of trimmings plus 10 buds for each additional pound of wood removed up to 4 pounds. So, if the trimmings weigh 1 pound, leave 30 buds; if 2 pounds, leave 30 + 10 =40 buds; if 2.5 pounds, leave 30 + 10 + 5 = 45 buds; and so on up to 4 pounds. This 30 + 10 formula works well for other American-type table, juice and wine cultivars. For French-American and Northern hybrid cultivars, a 20 + 10 formula or a variation is often used.

For American-type cultivars that typically produce two clusters per shoot, and whose basal and adventitious buds are not fruitful, balanced pruning usually can be achieved by weighing the wood removed at pruning time and adjusting the bud count accordingly.

Table 24. Balanced pruning formulas.*

Lbs of 1-yr-old canes removed	Number of buds retained on the vine for fruiting	
	30 + 10 Formula	20 + 10 Formula
Less than 1	Less than 30	Less than 20
1	30	20
2	40	30
3	50	40
4 or more	60	50

* For grapevines trained to a double curtain (GDC) or split curtain system (Smart-Dyson, Scott Henry) these formula are applied to each curtain.

French and Northern hybrid cultivars are less easily dealt with because: 1) they may carry more than two clusters per fruiting shoot; 2) basal buds are often fruitful; and 3) on some cultivars, even buds arising from the trunk or other old wood are fruitful. In these circumstances, balanced pruning as applied to American-type cultivars (30 +10 formula) may result in over cropping, especially on Chancellor, Seyval and de Chaunac.

Cluster size is another factor that needs to be considered in selecting a pruning formula, particularly if cluster thinning may be necessary. Some very large clustered cultivars will need to be cluster thinned regardless, but if pruning can be used to regulate the crop load, it saves an additional labor expense. **Table 25** shows suggested pruning formulas for cultivars typically grown in northern climates.

Table 25. Suggested pruning formulas for cultivars typically grown in the upper Midwest.[1]

Cultivar	Cold Hardiness	Productivity on secondary buds	Pruning Formula (maximum buds)	Need for Cluster thinning (#/shoot)
Bluebell	Very hardy	No	30 + 10 (60)	No
Brianna	Very hardy	Yes	25 + 10 (55)	Maybe (2)
Concord	Hardy	No	30 + 10 (60)	No
Edelweiss	Hardy	No	30 + 10 (60)	Maybe (1)
Esprit	Hardy	Moderate	25 + 10 (55)	Yes (1)
Frontenac	Very hardy	Yes	20 + 10 (50)	No
Frontenac blanc	Very hardy	Yes	20 + 10 (50)	No
Frontenac gris	Very hardy	Yes	20 + 10 (50)	No
Geneva Red	Very hardy	Moderate	30 + 10 (60)	No
Kay Gray	Very hardy	No	30 + 10 (60)	No
Louise Swenson	Very hardy	No	30 + 10 (60)	No
La Crescent	Very hardy	Moderate	20 + 10 (50)	No
La Crosse	Hardy	Yes	30 + 10 (60)	No
Leon Millot	Hardy	Yes	30 + 10 (60)	No
Maréchal Foch	Hardy	Moderate	30 + 10 (60)	No
Marquette	Very hardy	Moderate	30 + 10 (60)	No
Petit Ami™	Very hardy	Moderate	20 + 10 (50)	Yes (2)
Mars	Hardy	Moderate	30 + 10 (60)	Yes (1) @ bloom
Petite Pearl	Very hardy	Moderate	20 + 10 (50)?	Maybe (2)
Prairie Star	Very hardy	Moderate	30 + 10 (60)	Maybe (2)
Sabrevois	Very hardy	Moderate	20 + 10 (50)	No
St. Pepin	Hardy	No	30 + 10 (60)	No
St. Croix	Very hardy	Moderate	20 + 10 (50)	No
Swenson Red	Hardy	No	25 + 10 (55)	Maybe (1)
Swenson White	Very hardy	No	25 + 10 (55)	Maybe (1)

Adapted *from*: Domoto 2014b.

When practicing balanced pruning, it is not necessary to weight the pruning from each vine. For each cultivar, select some vines that are representative of the variation of vine vigor found in the planting. Prune them and weigh the trimmings. This will allow you to develop you eye for estimating amount of trimmings on a vine and allow you to make vine-to-vine adjustment on the number of buds to retain. Formulas may need to be adjusted to adapt to individual vineyard conditions. Therefore, it's a good practice to maintain annual records of pruning weights, fruit yield and average cluster weight on 8-10 sentinel vines for each cultivar. If there is a drop in average pruning weight for a cultivar, cut back on the number of buds retained for the first pound of trimmings. If there is a steady increase in pruning weight for a cultivar over a two year period, increase the number the buds retained for the first pound of trimmings (Dami, *et al.,* 2005). Managing the vineyard to annually produce from 2.5 to 3 pounds of trimmings would be a good objective.

Because French hybrid cultivars can be so fruitful, Cornell University introduced an alternative approach to balanced pruning that uses a combination of "shoot density" and "balanced thinning". Under this approach, vines are pruned to retain 4-6 buds per foot of row or cordon and thinning of flower clusters is used to achieve consistent yields. At a density of 4-6 shoots per foot, shading and air circulation within the canopy are not a problem with 4-5 shoots per foot being optimum. As with balanced pruning more buds are retained on more vigorous vines so weighing the trimmings of some sentinel vines is still a good practice.

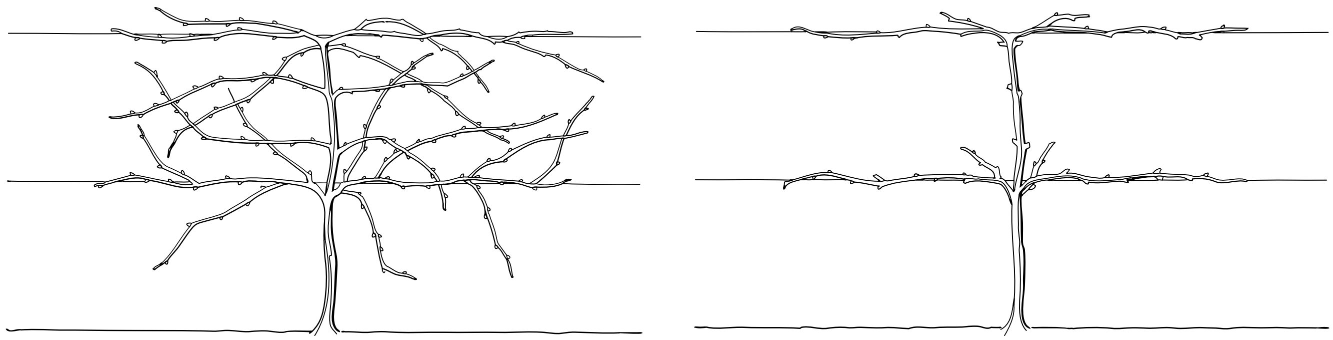
Growers should be particularly attuned to vine vegetative growth after veraison (when berries begin to soften, change color and mature). Research has shown that cultivars need only 15 leaves on a shoot to ripen that shoot's fruit. Shoots that are longer than this only divert the vine's energy into superfluous leaf area. The results of this superfluous vegetative growth can be excessive potassium and high pH in the must, making winemaking more difficult. Therefore, if the grower notes that the shoots are still growing actively (forming new leaves beyond 15) after veraison, the vine is excessively vigorous. The following season, the pruning formula for the vine should be adjusted to increase the crop load and decrease vegetative growth. Quite simply, more buds should be left to fruit. In fact, when in doubt about how to achieve balanced pruning for a particular cultivar, a rough rule of thumb is that the ratio of crop weight to pruning weight (for the current growing season or pruning weigh recorded the following spring) should be about 5-12 (Ravaz index). That is, for every pound of trimmings, one should have left enough buds to produce about 5-12 pounds of fruit.

Most cultivars will perform well using either cane pruning (**Figure 23A**) or spur pruning (**Figure 23B**) and some training systems employ both types of pruning. Some cultivars have a tendency to push many secondary and tertiary buds from the canes and latent buds from cordons. Short spur (2 node) pruning seems to exacerbate this problem whereas cane (6 node) pruning seems to reduce this tendency (Dami, *et al.,* 2005).

Typically, fruiting canes are described in terms of their length and number of buds or nodes: long canes (8-15 nodes), short canes (4-7 nodes), and spurs (2-5 nodes). Fruiting cane length is a function of both grape cultivar and the training system used. For example, small clustered cultivars with unfruitful basal buds and a trailing growth habit (typical of many cultivars), require pruning to long canes to maintain production. In contrast, a cultivar like Seyval, with large clusters, fruitful basal buds, and strong upright growth is well suited to spur pruning.

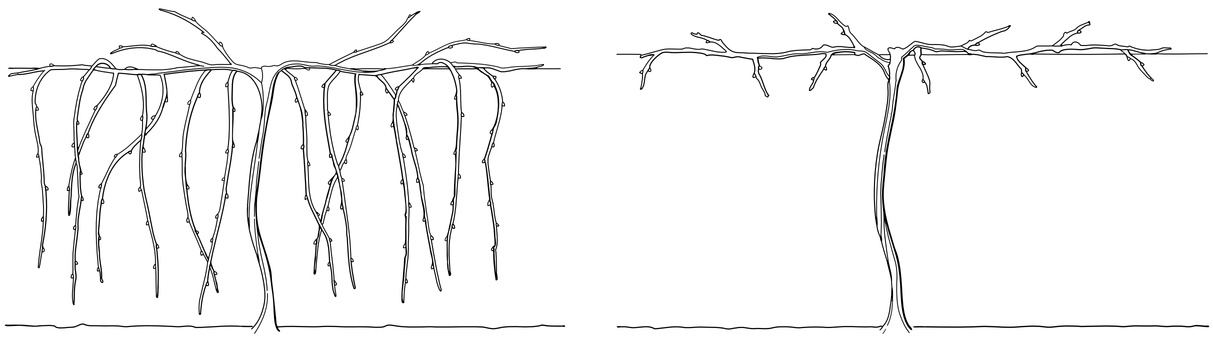
Regardless of how the vine is to be pruned, either to long canes, short canes or spurs, the grower must be sure to leave an "extra" four to six "renewal" spurs of 1-2 buds each to serve the purpose of producing new fruiting wood. The shoots that grow out from these renewal spurs will become next year's fruiting canes. This is practiced to aid in controlling the length of arms arising from the head or cordon of the vines. Special care should be taken during pruning to select renewal spurs that are in a good position to grow shoots with good sun exposure and with proper orientation to the trellis for the desired training system. If time permits, the flowers or clusters should be removed from the renewal shoots, so that all of their energy will go into developing next year's wood. The number of buds left on these renewal spurs should be included in the pruning bud count when practicing balanced pruning or the New York buds per linear foot approach.

Cane or Spur Pruning?



Before *After Pruning*

Figure 23A. Pruning Mature Vines to Canes.



Before *After Pruning*

Figure 23B. Pruning Mature Vines to Spurs.

Selection of Wood for Canes

Grapevines produce fruit only from one-year-old wood, called a *cane*; so long or short canes should be retained during pruning. These canes are selected based on the following criteria (Dami, *et al.,* 2005).

1. Sun Exposure: The most fruitful buds on the vine will lie on canes that received the best exposure to the sun the previous season. These are usually those that lie near the top and outside of the vine canopy and should be retained. Those canes which do not have good sun exposure should be removed.
2. Color: Cane bark should be dark and uniformly reddish-brown in color.
3. Canes should be healthy and free of disease. Canes with obvious symptoms of disease from the previous season (powdery mildew, anthracnose, black rot) should be removed and burned.
4. Size: Canes should be at least 1/4 inch in diameter (pencil size) at about the fifth and sixth buds and nearly the same thickness at the 10th bud. Large diameter (> 1/2-inch) canes, referred to as “bull canes”, (very thick, extremely vigorous shoots) should be avoided and removed, as it will likely be less hardy and less able to bear fruit than canes of more moderate growth.
5. Canes should originate from arms near the main trunk (4-cane, 6-cane and Umbrella Kniffin systems), or near the cordon (bilateral high cordon, Geneva double curtain or Vertical Shoot Positioning systems).
6. Internode length (distance between buds or nodes) should be 5 to 8 inches for Concord-type cultivars (3 to 5 inches for most French and Northern hybrid cultivars).

Finally, if burying vines, care should be taken to keep only spurs and canes that lie parallel to the trellis. This will facilitate laying the vine flat on the ground for winter snow protection. If spurs or canes protrude and hold the vine away from the ground, additional covering material is needed or holes must be dug to accommodate the protruding wood.

When to Prune

Grapevines can be pruned throughout the dormant season. However, fall-pruned vines are more prone to winter injury than those left un-pruned. Growers should wait until late winter or early spring to prune so that uninjured canes can be selected for fruiting. Some cultivars are much more prone to winter injury than others, so if time is limited, growers can prune their hardiest cultivars first and the least hardy cultivars last. This will slow bud break somewhat and reduce the danger of frost damage. It also allows you to judge the survival of the buds and canes so that you can prune accordingly. On tender cultivars, it is easiest to prune in the fall before laying down the vines. The terminal portion of each shoot will not mature and those buds will not survive the winter even if covered (Dami, *et al.,* 2005).

Live buds and canes are green when cut. Pruning cuts should be made about ½ inch beyond the last bud. When lateral shoots are cut off, ½ inch should be allowed to remain beyond the bud to allow for die back at these locations. Recent studies in Michigan have shown that even with tender cultivars needing winter protection, it is good practice to leave more buds on the canes than will be needed. These extra buds, located at the ends of the canes, are the most vigorous and when they begin to grow, suppress growth of buds further back on the cane. After danger of spring frost has passed, the canes can be pruned to their final length, and the remaining buds begin to grow later than they otherwise would have. This practice is often referred to as "double pruning". However, if a grower does not go back to final prune, the arms can become rather long or "leggy" in a few dormant seasons.

Evaluating and Adjusting for Cold Injury*

Because the cane buds are the least hardy portion of grape vines, an important practice is to assess the buds for cold injury before you begin to prune. Even if the cultivar is considered to be very hardy, the buds should be checked because injury can occur at warmer temperatures in the fall while the buds are still hardening off or in late winter following a thaw. With this knowledge, you can adjust the number of buds/nodes retained to better assure a normal crop. Cold injury to grape buds is relatively easy to distinguish. Using a sharp razor or snap blade knife, make a series of cross-sectional cuts across the buds, cutting a little deeper with each slice until the primary bud is exposed. Live buds will appear bright green, while injured buds will appear brown or black in color (**Figure 24**).

When assessing cold injury, it is important to thoroughly sample the vineyard and handle the canes properly. A proper sample should consist of at least 100 nodes collected from each cultivar. A sample of 20 5-node canes collected over an area representative of the vineyard is usually sufficient. When samples are collected following a significant freezing event, they should be brought indoors and allowed to warm for 24 to 48 hours to make the injured buds easier to see. If samples are collected several weeks after a freeze, following a period of warmer temperatures, it is not necessary to warm the samples up, and the canes can even be examined in the field.

The sampled canes should be representative of the type of wood that will be left on the vines at pruning in terms of the node position on the canes. If you typically prune back to 5- or 6-node spurs, then you want to collect a sample that is representative of that type of wood. There can be considerable difference in the extent of cold injury from the base to the tip of a cane. So keep track of the position of the buds as you cut and record the damage so you will know what part of the cane has the most damage.

*(*Domoto, 2014a. Pruning Grape Vines: Evaluating and Adjusting for Cold Injury. Iowa State University).*

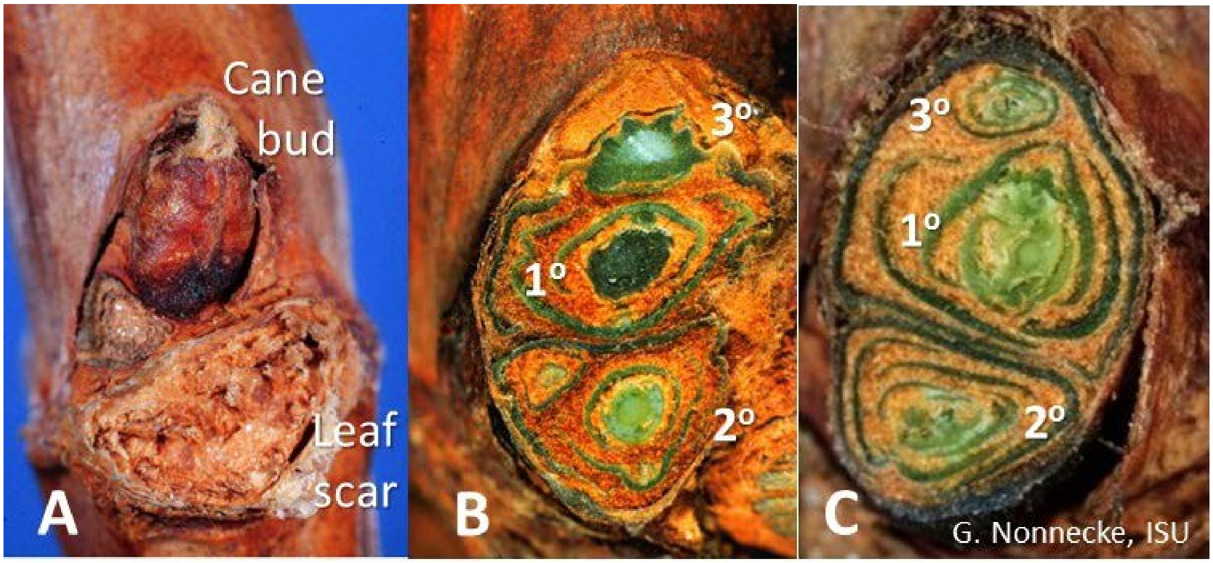


Figure 24. Cane node with bud and leaf scar (A), and cross sections of compound grape buds showing primary bud injury (B) and no injury to the primary bud (C).

Compensating for winter bud injury

For American Cultivars:

American cultivars and some Northern hybrids with strong *V. labrusca* characters are not very productive on secondary buds. By leaving more buds on the vines when winter injury to the primary buds has occurred, you can compensate for the loss of buds and minimize the potential crop reduction (**Table 26**).

Table 26. Compensating for winter primary bud injury on American cultivars in which secondary buds are not very fruitful.

% of Dead Primary Buds	Compensation [z]
Less than 15 %	Prune as normal.
15 to 50%	Adjust the pruning formula proportionally to the bud kill. *i.e. If you experience a 30% bud kill, you will want to leave 30% more nodes than called for by the pruning formula for the cultivar. So if the pruning formula for the cultivar is 30+10 and the vine produce 2 lb of prunings, you would leave 40 + (.30 x 40) = 40+12=52 nodes.* **OR** Pruning formula x (1 + % bud injury) *(30 x 1.3) + (10 x 1.3) = 39 + 13 = 52 nodes.* Extra nodes retained should make up for the percentage that were killed and should produce enough fruit to keep the vines in balance.
More than 50%	**Do not prune**, or only prune to eliminate the canes close to the ground or competing with an adjacent vine. Wait until bud break to prune these cultivars so that a more accurate assessment can be made.

[1]From: Dami, *et al., 2005.* **Midwest Grape Production Guide.** Ohio State University Extension Bul. 919-05.

For French hybrid cultivars:

Many French and Northern hybrid cultivars have fruitful secondary buds. For these cultivars, the increase in number of nodes to retain may not be proportional to the percentage of damaged primary buds. There is not exact formula to determine the number of nodes to retain, but in most cases, an adjustment is necessary and depends on the cultivar's productivity from secondary buds and whether or not cluster thinning is normally practiced:

For cultivars that are not productive on secondary buds, follow the formula used for American cultivars.

For cultivars that are moderately productive on secondary buds and do not require cluster thinning, follow the Cornell model and compensate in proportion to the production loss associated with secondary buds. If the secondary buds are 60% as productive as the primary buds, then there would be a 40 reduction in potential yield and the calculated number of nodes to retain would be 40% of the calculated adjustment (**Table 27**).

Table 27. Compensating for winter primary bud injury on French and Northern hybrid cultivars having fruitful secondary buds.

% of Dead Primary Buds	Compensation [z]
Less than 20 %	Do not change normal pruning practice.
20 to 80%	Increase the number of nodes retained to compensate for a 40% reduction in yield: *i.e. If you experience a 50% bud kill, you would normally want to leave 50% more nodes than called for by the pruning formula for the cultivar. So if the pruning formula for the cultivar is 20+10 and the vine produce 2 lb of prunings, you would normally leave 30 + (.5 x 30) = 30+15=45 nodes. Since the potential crop reduction associated with fruiting on secondary buds is 40%, the number of buds to retain would then be 30 +.4 x 15= 30+6=36 nodes.* **OR** Pruning formula x (1+(.4 yield reduction x % bud injury) *(20 x 1+(.4 x.5)) + (10 x 1+(.4x .5)) = (20 x 1.2)+(10 x 1.2) = 24+12= 36 nodes.* Extra nodes retained should make up for the percentage that were killed and should produce enough fruit to keep the vines in balance.
More than 80%	Prune away only those nodes which will intrude into the space of adjacent vines or which will produce fruit so low that it hangs to the ground. Wait until bud break to prune these cultivars so that a more accurate assessment can be made.

[z] *Adapted from:* Pool, R. 2000. Assessing and responding to winter cold injury of grapevine buds.

http://www.fruit.cornell.edu/grape/pool/winterinjurybuds.html

For cultivars that are productive on secondary buds and may or may not require cluster thinning, generally no adjustment to the number of nodes retained is needed unless the secondary buds are also injured. Then follow the procedure for French and Northern hybrids if the injury to secondary buds is greater than 33%.

For cultivars that are moderately productive on secondary buds and require cluster thinning, no adjustment in the number of nodes to retain is needed if the bud injury is less than 50% since crop load can be made up through adjustments in cluster thinning. If the bud injury is greater than 50%, use the formula for French-American hybrids and evaluate the need to cluster thin.

Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Pruning**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Assessing winter bud injury before pruning	Examined buds for injury & adjusted the number retained per vine based on the extent of injury.	Did not examine buds for injury. Left additional buds with intent to final prune after frost risk passes.	Did not examine buds for injury. Adjusted the number of buds retained based on vine vigor.	Did not examine the cane buds for injury. Pruned all vines to the same number of buds regardless of vigor.
Pruned and weighed the trimmings of some vines.	Pruned and weighed the trimmings of some vines to estimate range of buds to retain based on vigor & adjustment for bud injury.	Pruned and weighed the trimmings of some vines to estimate range of buds to retain based on vigor, but not for bud injury.	Did not prune and weigh trimmings. Left 4 to 6 buds per foot of cordon based on apparent vine vigor.	Did not prune and weigh trimmings. Pruned all vines to same number of buds regardless of vigor.
Annual records to determine if adjustments are needed.	Maintain records on sentinel vines for pruning weight, yield & average cluster weight.	Maintain records on sentinel vines for pruning weight.	Did not prune and weigh trimming. Left 4 to 6 buds per foot of cordon based on apparent vine vigor	Did not prune and weigh trimming. Pruned all vines to same number of buds regardless of vigor.

Canopy Management

The vine enters the new growing season trained to a particular system and pruned to a certain number of buds. Growth begins, and to a large extent, the grower now must live with the consequences of his training and pruning decisions. However, by applying the techniques of suckering, cluster thinning, shoot positioning, leaf removal, and hedging or skirting, the grower still can exert some influence over the vine's canopy, its sun exposure, shadiness, and balance between crop load and vegetative growth.

Vine canopy is the shoot system, which includes the stem, the leaves, and fruit clusters. In the viticulture world, canopy is described by its length, height, width, leaf area, number of leaf layers, and shoot density. Shoot density refers to the number of shoots per foot of row or foot of canopy. **Table 28** describes the characteristics of an ideal canopy (Dami, *et al., 2005)*.

Table 28. Characteristics of an ideal grapevine canopy*

Canopy Characteristic	Optimum Values
Shoot density	4 to 6 shoots per foot of canopy
Number of leaf layers	1 to 1.5
Number of nodes per shoot	12 to15
Canopy gaps	40% to 50%
Cluster exposure	50% to 75%
Ratio of leaf area to fruit weight (sq inches per oz.)	44 to 53
Ratio of leaf area to fruit weight (cm^2 per gram)	8 to 12
Vine size (pruning weight in lbs per ft of canopy)	0.3 to 0.4
Ratio of fruit produced (lbs) for each pound of prunings removed.	5 to 12

From:* Dami, *et al., 2005.* **Midwest Grape Production Guide. Ohio State University Extension Bul. 919.

Annual Growth Cycle of a Grapevine

Annual growth cycle of a grapevine begins in the spring with bud swell and bud burst. Emerging shoots grow rapidly to just prior to bloom and then slow down during the remainder of the growing season as berry development and maturation proceed (Figure 25). During the early phase of shoot growth, reserve carbohydrates (CHO) stored in the roots serve as the major source of energy and proceed to decline. Following bloom, photosynthesis begins to supply sufficient CHO to promote additional shoot growth, berry development, and begins to build back up the CHO reserves in the roots. In a well-balanced grapevine, Shoots should stop growing at or near veraison when the berries begin to accumulate sugars and mature. If shoot growth continues following veraison, the grapevine is overly vigorous and additional cultural practices will need to be conducted to improve the canopy characteristics.

Canopy management practices.

There are five major canopy management practices that growers should follow throughout the growing season. Dry summers require fewer canopy management practices, wet summers require more. Some grape cultivars require all five steps; others require fewer; and certain cultivars and training systems require a repeat of some of the five steps. The Midwest Grape Production Guide (Dami, *et al.*, 2005) outlines the five canopy management steps in the order they should be addressed throughout the season.

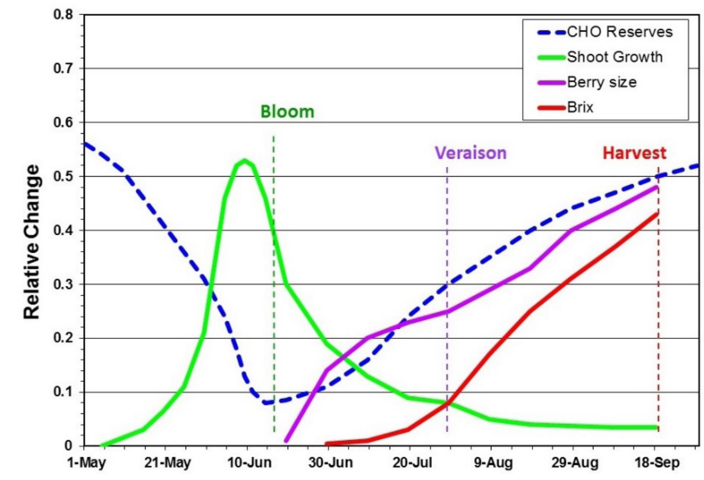


Figure 25. Annual growth cycle of a grapevine.
(Adapted from: Winkler, A.J. *General Viticulture*)

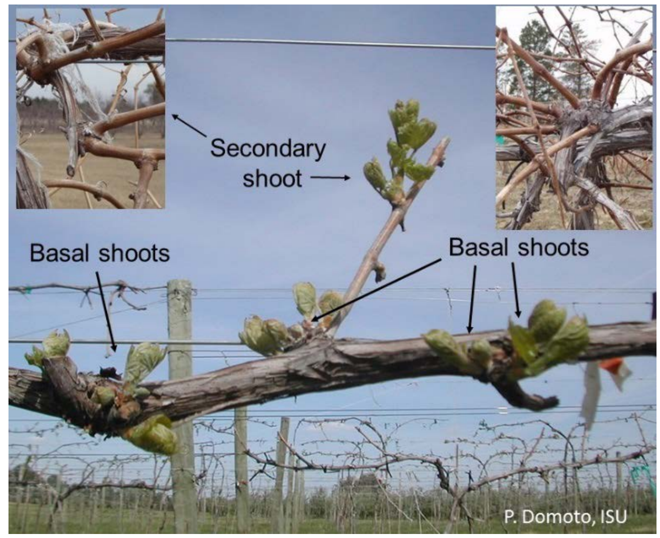


Figure 26. Non-count shoots.

1. **Shoot Thinning (Suckering):** This is the removal of unwanted, adventitious shoots on the trunk, cordon, and canes/spurs.
   - **Suckers** are adventitious shoots arising near or from below the ground. These shoots are very vigorous and consume a lot of CHO reserves if not removed. It is best to snapped them off rather than cutting them off with pruning shears, which leaves basal buds that produce more suckers. Some herbicides are effective in controlling suckers when applied at the proper stage of sucker development (See the section on **Weed Control and Vineyard Floor Management**). On grapevines produced from cuttings, suckers can be retained for trunk replacements or for a second trunk if desired, and should be trained upward. However, sucker control agents should not be used or the suckers need to be protected to avoid contact. On grafted vines, any shoots retained to replace a trunk must originate above the graft union.
   - **Water sprouts** are adventitious, non-count shoots growing on a trunk or cordon. On the cordon they are often referred to as basal shoots **(Figure 26)**. On the trunk, they can be easily rubbed off when they are 1-3 inches long. If adventitious shoots on the cordon are not removed excessive shading in the canopy will occur, and on French and Northern hybrids that are productive on these shoots, over production will occur. They should be removed early in the season when they are visible and easy to identify. A basal shoot can be retained to fill a blind section along a cordon.
   - **Multiple shoot emergence from a node** can occur on some vigorous cultivars such as St. Croix, or when there has been some winter bud injury **(Figure 26)**. These shoots will increase shading and lead to over production in cultivars that are productive on secondary shoots. It is best to thin the nodes to single shoots when the number of blossom clusters can be determined.
   - Any **Unfruitful shoots** on cordons should also be removed unless needed for spur renewal as they'll divert growth from growing canes. This is particularly important when adjustments in bud retention were made to compensate for primary bud injury.

Proper shoot thinning should result in shoots spaced evenly along the cordon length with a density of 4 to 6 shoots/per foot of cordon or canopy. With 8-foot vine spacing, this corresponds to 32 to 48 shoots per vine on a single curtain/high wire cordon (HWC) system, and 64 to 96 shoots per vine on a Geneva double curtain (GDC) training system. It may be necessary to thin shoots more than once, particularly if the procedure was started early in the season.

2. **Shoot Positioning:** Shoot positioning attempts to spread out the vine's growing shoots as much as possible across the available trellis, and not allowing shoots to cross over others or grow along trellis from one vine to the next. A good canopy should have be 1 to 1.5 leaf layers thick with 20-40% of its vertical surface area

perforated by "gaps." Shoot positioning is effective in approaching this goal and thereby enhances color development, fruit maturation, and fruit bud initiation for next season's crop. It also improves air circulation to aid in disease prevention and improve spray penetration.

- **Combing:** This is the generic term for positioning shoots in a vertical downward position (**Figure 27**). Combing is conducted on high trellis systems such as HWC and GDC. While it's important to reduce shading when fruit bud development starts as sunlight exposure is critical for bud fruitfulness, it's best to wait until the shoots are firmly attached to reduce the amount of shoot breakage and make positioning easier. This is after bloom and may be mid-late June or early July in some locations. Shoot breakage is a cultivar characteristic, so start combing on cultivars least prone to breakage and finish it the cultivars that are most prone to breakage such as La Crescent. In single curtain training systems, one pass through the vineyard is usually sufficient. For GDC trained vines, at least two passes are required to make sure that no shoots are crossing over from one curtain to the other.
- **Tucking:** This is the generic term for positioning shoots upward and is used on vertical shoot positioning (VSP) training systems (**Figure 28**). Shoots are held upright by using two or three pairs of permanent or moveable catch wires, spaced 10 to 12 inches apart. Some cultivars, particularly those with few tendrils, may require extra tying with tape in order to keep the shoots upright and "tucked" in the catch wires. Shoots are tucked as they develop and may require up to three passes before bloom, and must be continued until the shoots extend over the top set of catch wires.

Figure 27. Combing high-wire cordon grapevine, before (A) and after (B).

Figure 28. Tucking shoots on grapevines trained to a mid-wire cordon with VSP.

3. **Cluster thinning:** While it's tempting to avoid cluster-thinning altogether for quick vineyard production, it is crucial to the well-being and life span of the vineyard to thin clusters in the first year of production and possibly in future years as well. Factors that determine the need for cluster thinning include the number of shoots retained per vine or linear foot of cordon or canopy, number of clusters produced per shoot, and cluster size. Pruning, serves to minimize the need for cluster thinning, but some additional cluster thinning is sometimes needed. Some French and Northern hybrid cultivars will produce 3 or more clusters per shoot, and there is a need to do some cluster thinning to avoid over cropping. Cluster thinning is most beneficial with large-clustered cultivars such as Brianna, Edelweiss and Seyval that need to be thinned to a single cluster per shoot.

   Cluster thinning can be performed either before bloom or after fruit set.

   - **Pre-bloom thinning:** This consists of the removal of flower clusters and may be done at the same time as shoot thinning. The clusters are easy to see at this time and thinning can be quickly performed. The advantages of removing clusters this early is that berry set is improved (more berries per cluster as a result of less competition with fewer clusters) and the berries will be larger at harvest. There is also an increased yield, increased fruit flavors and sugars, and improved vine size and hardiness associated with pre-bloom cluster thinning. The disadvantage to pre-bloom thinning is that clusters tend to be tighter (as a result of the increased fruit set and larger berries), so bunch rot is a potential problem. For table-type cultivars, pre-bloom cluster thinning is preferred.

- **Post fruit set thinning:** This practice is more common and recommended for cultivars susceptible to bunch rot. Also, adjustments based on berry set can be made. This method is more time consuming because it is more difficult to see the fruit in a more developed canopy.
- **Green drop thinning:** Some cultivars will produce small, tendril-like clusters distal to the main clusters and are often referred to as "nubbins". Other cultivars, such as Leon Millot will set clusters on the lateral shoots. In either case, these clusters lag well behind the primary clusters in their maturity. An optional practice is thin out these lagging clusters at veraison when they are easy to identify and thereby increase the uniformity of maturity.

Regardless of any cultivar characteristics, minimum cluster thinning should follow these guidelines based on post-bloom shoot length:

- Shoots less than 12 inches long, remove all the clusters.
- Shoots 12- to 24-inches long, leave one cluster per shoot.
- Shoots more than 24-inches long, leave two clusters per shoot.

Special Cases: In most vineyards, there are always some vines that fall behind in growth and production, looking several years behind the development of the other vines. These undersized vines should be heavily or completely cluster thinned. This allows the vines to recover by diverting carbohydrates to trunks and roots. This procedure should also be used with vines that have not filled their allotted trellis space.

4. **Lateral (axillary) shoot removal:** Some vigorous and very vigorous cultivars are prone to producing lateral (axillary) shoots along the primary shoots, particularly on fertile soils (**Figure 29**). These lateral shoots cause a lot of shading in both high trellis and VSP training systems. Removing these lateral shoots in the fruiting zone effectively opens up the canopy to improve air movement, spray penetration and sunlight exposure of fruit and buds near the base of the shoots. This results in better color for red wine cultivars, lower juice potassium and slower rise of the juice pH. Lateral shoot removal can be done along with pre-bloom shoot thinning, or during the post-bloom period when shoot positioning is being done.

Figure 29. Young lateral shoot (A), and lateral canes that were not removed during the growing season (B).

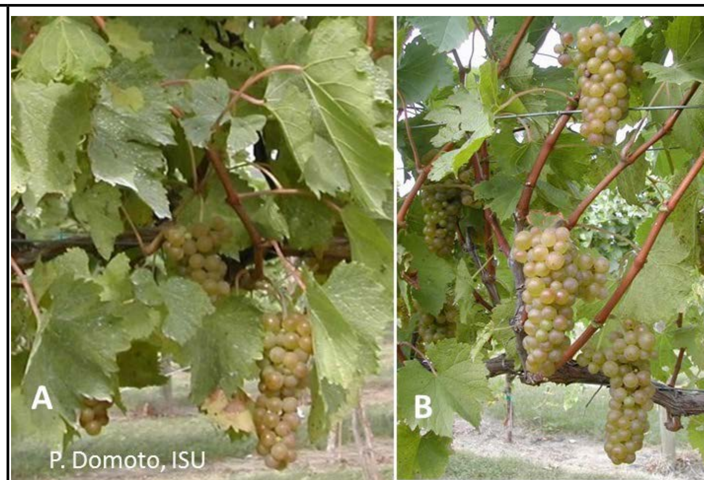


Figure 30. Before (A) and after (B) removing leaves near clusters.

5. **Leaf removal:** Leaf removal is another practice that is sometimes performed to improve the canopy environment (**Figure 30**). Leaf removal (pulling) is done on the shade side of the canopy, which is either the east side of a north-south row or the north side of an east-west row. One to three leaves are removed at the base of each shoot and around clusters. Leaf pulling is either minimally done or completely avoided (depending on the canopy thickness) on the sun side of a canopy in order to avoid sun burning of fruit. There is the risk that leaf pulling can result in increased bird damage because of the exposed berries. Leaf pulling is first performed after fruit set but before veraison. Avoid doing it during or after veraison as this may lead to sun burning the fruit.
6. **Hedging and Skirting:** This consists of cutting shoots that grow beyond the allocated space in a given trellis system in order to control shoot length. It is called hedging for upward shoot training, such as on a VSP system and skirting for downward shoot trained, a high-wire trellis systems.
   - **Hedging:** Overly vigorous vines tend to outgrow their trellis system with shoot growing up and over the top catch wires, and then droop down over the sides of the vine (**Figure 31**). This shades the main portion of the vine canopy. Since a grapevine needs only 15 leaves per shoot to fully mature its crop, any leaves in excess of this number merely divert resources from the ripening fruit. Hedging a foot or so above the top wire or just beyond the 15th leaf and hedging the sides of the vines if needed, can create a better balance between vegetation and crop, and eliminate unnecessary shading.
   - Shoot hedging should be done after bloom when the shoots begin to droop over the catch wires, but before veraison, as this may result in delayed fruit maturity, and a reduction of wood maturity and winter hardiness. It may take one to three passes to complete the job. Local growers have found an ordinary hedge trimmer to be an adequate tool for grapevine hedging.
   - **Skirting:** Many vines do not require skirting at all. However some vigorous cultivars will have shoot tips trailing on the ground which can interfere with traffic in row middles and results in an unkempt appearance. Many will cut the trailing shoot 12 inches from the ground. In general, a minimum of 15 leaves per shoot should be left after skirting in order to mature the fruit and wood, which is not a problem on high-wire trellis systems. Skirting is typically done when the vines are combed. Particularly when long shoots that were growing horizontally along the trellis are combed down. In a well-balanced grapevine, shoot growth should stop at veraison.

Figure 31. Shoots growing up and over the top catch wire of a VSP system (A), and a vine with shoots hedged above the top catch wire (B). Note the use of catch wire post extension to accommodate vine vigor (B).

Figure 32. View from inside the canopy of a Frontenac grapevine trained to a high-wire cordon system exhibiting good canopy gaps and cluster exposure to sunlight.

Canopy management practices of shoot positioning, lateral shoot removal, leaf removal, hedging are employed when needed to promote canopy gaps and cluster exposure to sunlight (**Figure 32**). Along with pruning, these practices and cluster thinning as needed, all function to maintain a balance between vegetative growth and fruiting and promote the production of quality fruit.

Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Canopy management practices**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Shoot thinning	Practiced early season when unwanted shoots could be easily removed.	Practiced later but before bloom when unwanted shoots were harder to remove.	Practiced after bloom when unwanted shoots were difficult to remove.	Shoot thinning was not practiced
Shoot positioning: Combing on high trellis training systems	Combed after the shoots became firmly attached, timing based on cultivar susceptibility to breakage.	Combed after the shoots became firmly attached, but cultivar susceptibility to breakage was not considered.	Combing was done before bloom.	Combing was not done.
Shoot positioning: Tucking on VSP training systems	Tucking was performed as needed, with repeated passes until shoot extended above catch wires.	Tucking was performed, but shoots often drooped over the previous catch wire when done.	Tucking was performed, but shoots would not stay upright between the catch wires.	Tucking was not performed.
Cluster thinning	Dormant pruning kept the need for cluster thinning to a minimum.	Cluster thinning was performed and required a moderate amount of time to perform.	Cluster thinning was performed and required extensive time to perform.	Cluster thinning was not performed even though the vines appeared to be over cropped.
Lateral shoot removal	Vines exhibited moderate vigor and minimum lateral shoot development occurred.	Lateral shoots were evident and removed in the fruiting zone of the vines.	Lateral shoot development was excessive and were removed in the fruiting zone of the vines.	Lateral shoots were evident, but not removed.
Leaf pulling	Vines exhibited moderate vigor with good exposure of the clusters to sunlight, not leaf pulling was required.	Lateral shoot removal was sufficient to allow good exposure of the clusters to sunlight.	Canopy was dense and leaf pulling was practiced.	Canopy was dense, but no leaf pulling was done
Hedging & skirting	Vines exhibited moderate vigor with shoots stopping growth at veraison. No hedging or skirting was required.	Vines were hedged or skirted once to contain them in their space.	Vines were vigorous and were hedged or skirted more than once to contain them in their space	Vines were vigorous, over-growing their space, but were not hedged or skirted.

Fertilization and Nutrition

The condition of your vineyard soil will affect the health of your vines, their productivity, and their ability to withstand drought, pests, and the rigors of the Minnesota winter. Visual inspection to determine nutritional health in the vineyard is at best a shot in the dark approach and by the time symptoms of deficiencies show, it is often too late. This section will diskuss recommendations for fertilizing prior to planting and for a bearing vineyards.

Soil testing:

Pre-plant: Soil analysis before planting a vineyard is a very important practice that is extensively covered in the ***Considering Growing Grapes*** section of this publication. With information on the soil type, this analysis aids in determining if your site is suitable for grapevines. Tests should include: pH, phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn) and organic matter (OM). Samples should be collected for each soil type and cropping history. Results from the tests will determine if the soil pH needs to be adjusted, if any major nutrient amendments are required, and provide some guidance on nitrogen fertilization practices (Table 29). Some nutrients are very immobile in the soil and for this reason any required P, K and Ca (lime) that are indicated by soil analysis, should be applied and tilled into the soil as deeply as possible before planting grapevines.

Table 29. The desirable soil test ranges for grapes.

Test	Desired Range	As pounds/acre[z]	Optimized as
Soil pH	6.0 to 6.5 *or* 7.0		
Organic matter	2 to 3 *or* 4 %	40 to 60 *or* 80	
Phosphorous (P)	>30 ppm	>60	140 lb/A as phosphate (P_2O_5)
Potassium	>150 ppm	>300	360 lb/A as potash (K_2O)
Magnesium (Mg)	100 to 125 ppm	200 to 250	
Boron (B)	0.75 to 1.0 ppm	1.5 to 2.0	
Zinc (Zn)	3 to 4 ppm	6 to 8	
Manganese (Mn)	>6 ppm	>12	

[z] Per plow slice or 8-inches of soil depth.

Bearing Vineyard:

Soil analysis is only good for some nutrients. Soil analysis does not give an accurate indication of the nutrient status of the vine. The value of soil analysis is in the determination if problems related to certain chemical imbalances or excesses such as pH problems exist. With the many types of vineyard soils, the grapevines' deep and far-ranging root system, and the inherent differences in nutrient uptake by different cultivars are largely to blame for the inability to correlate soil nutrient levels and vine nutrient status. Once the vineyard comes into production, tissue analysis will provide a more accurate measure of most essential nutrients in the vines and allow for fine-tuning of the fertilizer program. Tissue analysis in vineyard nutrition is much more effective and reliable than soil analysis. However, if the soil pH required adjustments before planting, a periodic soil analysis is advised.

Tissue Analysis:

Leaf or petiole (leaf stem) analysis can be used to diagnose or confirm nutrient problems after symptoms are present. More importantly, it is a powerful management tool in determining the nutritional needs of the crop. This is achieved by identifying nutritional shortages or excesses before symptoms develop. Often leaf or petiole analysis will reveal that certain fertilizers that are being applied are not needed, resulting in a more economical fertilizer program (Domoto, 2011, Rosen and Domoto 2013).

Leaf or petiole analysis should not be used until the vineyard comes into production unless visual symptoms are evident.

Sampling time for petiole analysis is important because nutrient concentrations in the leaves and petioles change during the growing season. This is most evident for N and K that decline rapidly from bloom to harvest. The two recommended times for sampling leaves and petiole for tissue analysis are at bloom and the period from mid-July through mid-August *or* early veraison when berries begin to soften and change color. For the at bloom sampling time leaves or petioles are collect from nodes opposite of the first cluster, and for the mid-season sampling they are collected from the most recently fully-expanded leaf from fruit-bearing shoots - typically the 5th to 7th leaf from the tip (**Figure 33**).

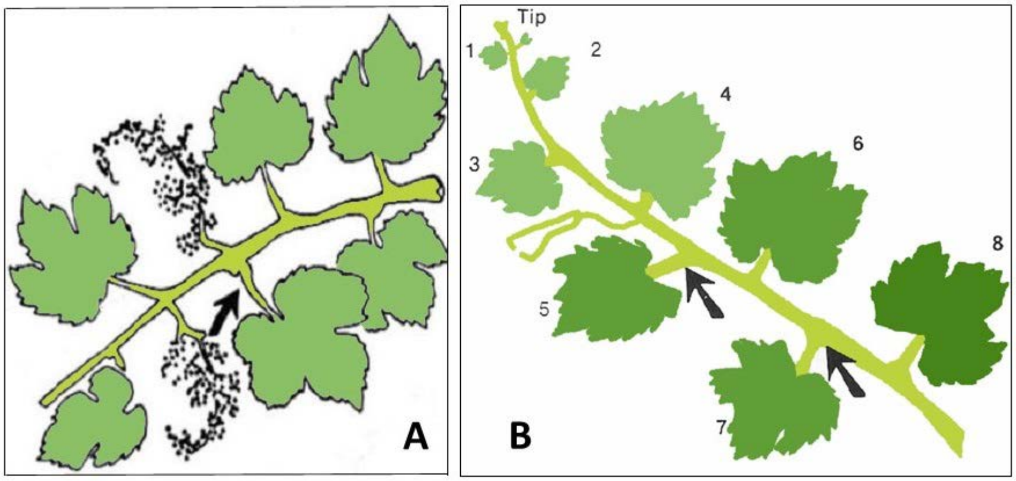


Figure 33. Position of leaves and petioles collected for tissue analysis at full bloom (A) and during the mid-July to mid-August (early veraison) (B) sampling periods. (Adapted from: *Grapevine Nutrition and Fertilization in the San Joaquin Valley.* 1978 Univ. of California publ. 4087)

Because the nutrient concentrations in the grapevines are changing during the season, sufficiency ranges are different for the two sampling periods **(Table 32)**. Those changes are more rapid early in the growing season making the full bloom normal range much wider than the normal range at mid-summer, therefore the preferred time to sample for petiole analysis is during the mid-July to mid-August period with any adjustments of the fertilizer program aimed at the next growing season. However, analyzing for N and B at bloom would allow you to make any collections in your fertilizer program that season.

Table 30. Normal mineral nutrient ranges for grapes based on petiole analysis performed on tissues collected at full bloom and during the mid-July to mid-August (early veraison) sampling periods.

Nutrient	Full Bloom[z, x]	Mid-July to Mid-August (*early veraison*)[y, x]				
	Normal range	Deficient	Below normal	Normal	Above normal	Excessive
Nitrogen (N) %	1.60-2.80 (*2.50*)	0.30-0.70	0.70-0.90	0.90-1.30	1.40-2.00	>2.10
Phosphorous (P) %	(*0.16*) 0.20-0.60	0.12	0.13-0.15	0.16-0.29	0.30-0.50	>0.51
Potassium (K) %	1.50-5.00 (*4.00*)	0.50-1.00	1.10-1.40	1.50-2.50	2.60-4.50	>4.60
Calcium (Ca) %	0.40-2.50	0.50-0.80	0.80-1.10	1.20-1.80	1.90-3.00	>3.10
Magnesium (Mg) %	(0.20) 0.13-0.40	0.14	0.15-0.25	0.26-0.45	0.46-0.80	>0.80
Sulfur (S) %	No data (>*0.10*)	No data	No data	No data (>*0.10*)	No data	No data
Manganese (Mn) ppm	18-100	10-24	25-30	31-150	150-700	>700
Iron (Fe) ppm	40-180	10-20	21-30	31-50 (*100*)	(*101*) 51-200	>200 *?*
Boron (B) ppm	25-50	14-19	20-25	25-50	51-100	>100
Copper (Cu) ppm	5-10	0-2	3-4	5-15	15-30	>31
Zinc (Zn) ppm	20-100	0-15	16-29	30-50	51-80	>80

[z] From Mills, H.A., B.J. Jones, Jr. 1996. *For American hybrids*. Plant Analysis Handbook II. MicroMacro Publ., Inc, Athens, GA

[y] From Dami, *et al*. 2005. Midwest Grape Production Guide. Ohio St. Univ. Ext. Bull. 919

[x] Values in italics developed for Minnesota and Iowa by Drs. C. Rosen and P. Domoto.

Separate petiole samples should be collected from each cultivar, from the same cultivar on different soil types or areas with a different history of fertilization practices. A sample of 100-150 petioles (150-200 from cultivars with short petioles) for analysis should be collected from random vines representative of the cultivar in the vineyard. If the tissue analysis is being use to diagnose a problem, samples can be collected at any time, and separate samples should be submitted from affected and healthy vines (Domoto 2011, Rosen and Domoto 2013).

Petiole samples should be submitted to a laboratory that performs soil and tissue analysis (*See* listing of laboratories in the **Resources** section). It is best to check with the laboratory before collecting the sample(s) to find out if they have any special instructions on sampling procedures, sample preparation, information on current and past cultural practices, pricing and to obtain sampling containers. If the lab does not provide sample containers, the petioles should be placed in common brown paper bag. For more information on petiole sampling procedure *See* **Collecting Grape Petioles for Tissue Analysis** (Domoto, 2011). Tests that should be performed include: total N, P, K, Mg, Ca, S, Mn, Fe, B, Cu and Zn.

When you get the test results back, it will include an interpretation on the sufficiency range of each mineral nutrient. However, this interpretation is computer-generated and the standard ranges being used are often for samples collected at bloom for *vinifera* cultivars. Therefore, check your results with the values listed in **Table 30**. For further assistance in interpreting the results, contact your state's Extension viticulture specialist listed in the **Resources** section.

To fully implement a sound vineyard fertilizer management program, record keeping is essential. Records should be maintained on each cultivar and petiole sampling area for:

- Annual soil and foliar fertilizer applications.
- Petiole analysis results.
- Average annual pruning weights from sentinel vines.
- Annual yield from sentinel vines and total yield for the plot.
- Average cluster weight from sentinel vines.

This information will allow you to fine tune your pruning and fertilizer practices by making adjustment based upon the previous season's results and longer term trends.

Minnesota concerns: [z]

Nitrogen (N) ....too high on organic soils

Phosphorous (P)...........................low mostly in western Minnesota

Potassium (K) ....low on sandy soils and high Mg soils

Magnesium (Mg) ....high on glacial soils with marine origins - low on sandy soils

Zinc (Zn)......................................often low or deficient in petiole samples

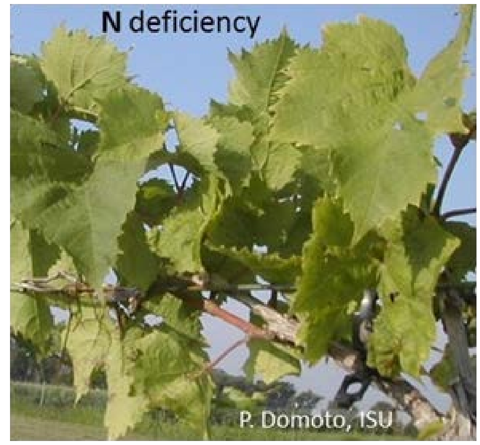
Manganese (Mn)..........................low on high pH soils

Boron (B) ....low on many soils, particularly on sandy soils

Iron (Fe) ....low on high pH soils

[z] *From:* "Vineyard Fertilization Working to Get it Right" a presentation given by P. Domoto at the MGGA Cold Climate Conference in 2006.

Nitrogen



Nitrogen deficiency commonly occurs in grapevines. Low N symptoms include the oldest leaves exhibiting a light-green to yellowish-green color, poor vegetative growth and reduced fruit set.

Nitrogen should be applied when vine uptake is rapid, and N rates should not exceed vine requirements. Nitrogen inputs from mineralization of soil organic matter (**Figure 34**) must be considered when determining N fertilizer requirements. The principal objective of N fertilization is to maximize crop development rather than vegetative growth. Grapevines have a small N demand relative to many other fruit crops. Nitrogen is most critically needed by grapevines during the period of rapid shoot growth in the spring through bloom and early berry development. The need for N declines from midsummer to senescence (Peacock, B., P. Christensen, and D. Hirschfelt. 1998).

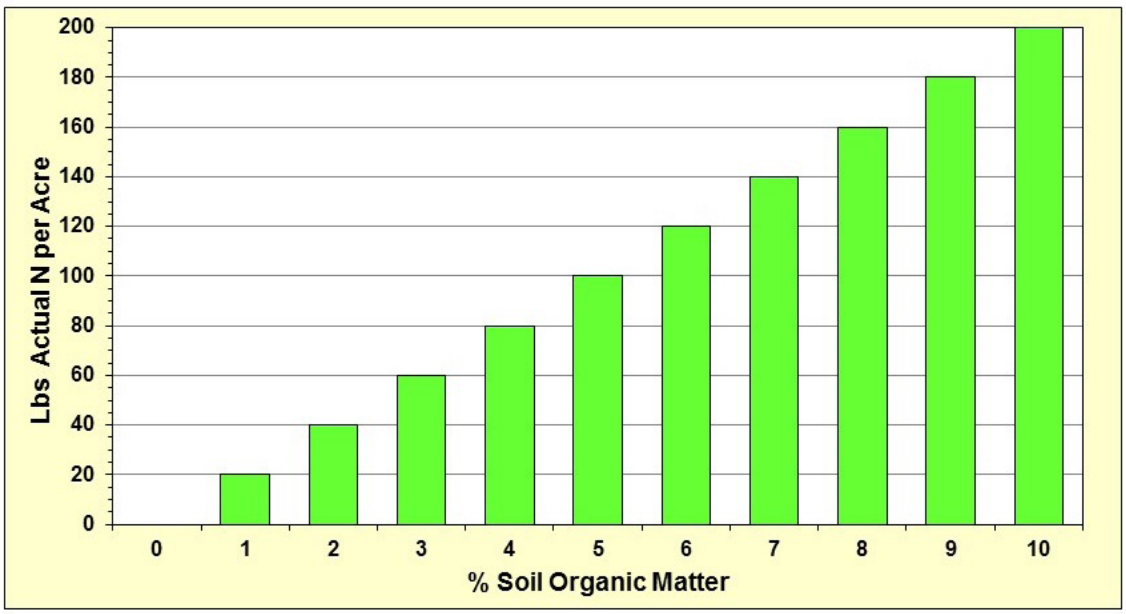


Figure 34. Annual nitrogen released from soil organic matter through mineralization.

Grapes require 40 to 50 pounds of annual nitrogen per acre. Soil with organic matter less than 3% may need added nitrogen the first and second year and supplemental nitrogen based on petiole analysis and the weight of vine trimmings removed in future years. About 0.4 to 0.6 oz. of actual N should be applied around each vine and the remainder broadcast applied. Ammonium sulfate (21-0-0) should be used whenever the soil had to be acidified before planting and urea (46-0-0) can be used whenever the soil pH is in the desired range for grapes (Rosen and Domoto, 2013).

Nitrogen utilized for the initial growth of grapevines up to about bloom is from reserves stored in the roots, and studies have shown that supplemental N applications are most effective when the N becomes available around bloom. The form of N applied also affects its availability. Nitrate (NO_3) forms of N (NO_3-N) are readily available to grapevines and can be applied close to bloom. Ammonium form of N (NH_4-N) must convert to NO_3-N before being take up and needs to be applied much earlier. Some urea can be taken up by grapevines and the remainder needs to convert to NH_4-N and then to NO_3-N before being taken up. Therefore, urea can be applied intermediate between NO_3-N and NH_4-N applications. On sandy soils, it is best to apply the N in split applications, half around bud break and the other half about 4-6 weeks later.

Potassium

Grapevines require high amounts of potassium (K), and deficiencies are common, particularly when vines are carrying a heavy crop. Potassium deficiency symptoms begin to appear in early summer as yellowed (chlorotic) leaf margins of leaves on the middle portion of the shoot. As the season progresses, leaf margins may take on a burned appearance, the leaf may curl upward or downward, and dead areas may appear between the veins. On some cultivars purple or blackened leaf blotches may appear later in the growing season.

The potassium concentration in grapevines can range from 1% to 4% on a dry weight basis, depending on what vine part is sampled and when. That represents a considerable amount of K incorporated into the roots, trunk, shoots, and fruit of a vineyard. Deficiency is likely to occur in cut areas, where the K rich surface soil was removed during land leveling, or on very sandy soils that have low native K fertility. Deep placement of K fertilizer in a concentrated band close to the vine is the recommended application approach. Treatment can correct deficiency for 5 to 10 years, depending on deficiency severity and rate of application (Peacock, 1999).

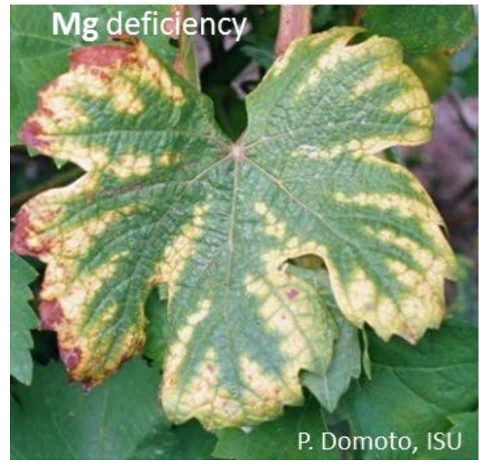
Potassium is relatively immobile in the soil and if applied to the surface may take several years to move down to the roots. For this reason apply K before planting and incorporating it as deep as possible is recommended. The amount of potassium to apply should be based on the soil analysis and adjusted to a minimum of 150 ppm. After year two, petiole analysis will confirm if the vines are receiving adequate K. Excessive levels of magnesium (Mg) in the soil can inhibit the uptake of K and requires additional applications of K to correct the problem. A petiole analysis with determine if this is a problem.

When low K or a deficiency is detected in an established vineyard, it is corrected with high applications of potash (K_2O) fertilizer ranging from 200-400 pound per acre applied in band under the vines. Because it takes time for the soil-applied K to move down to the roots, foliar applications of K are often needed initially to supplement the soil treatment. Foliar applications of K are absorbed by the leaves and can be included in your insect and disease spray program.

Phosphorus

Phosphorus is important for root development in young vines, as well as having a host of effects on mature vines, including wood maturation and fruitfulness. Phosphorus deficiency often shows up as reddened foliage, similar to symptoms that show up on vines suffering from winter trunk injury or crown gall that have restricted the flow of nutrients and carbohydrates to and from the roots. Phosphorous deficiency is extremely rare in Minnesota, and it is unlikely that a grower would have to amend his vineyard soil with additional phosphorus. Because P is so immobile in the soil, pre-plant soil testing and optimizing P before planting is the best solution to avoiding P deficiency issues. Phosphorous deficiency can occur on very sandy soils, but a fairly easy to correct because these soils have a low cation exchange capacity and do not tie-up the P.

Magnesium



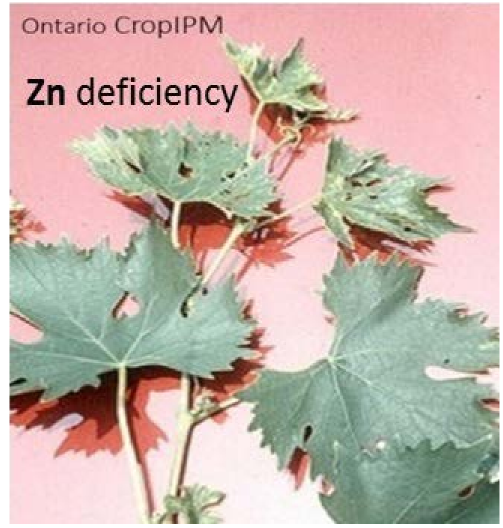
Magnesium (Mg) may be deficient on sandy soils or can excessively high on glacial soils with marine origins that are common to the upper Midwest. Symptoms of Mg deficiency show up as interveinal chlorosis on the older leaves and can progress to marginal scorching. Magnesium is considered somewhat mobile in the soil and if applied to the surface it will be available to the roots. Correcting Mg is dependent on the soil pH. If the pH is below 6.0, dolomitic lime can be applied to raise the pH to 6.5. If the soil pH is in the desired range, low or deficient Mg can be corrected with soil applications of 50-100 lb/A of magnesium oxide (MgO) or 300-600 lb/A Epson salt ($MgSO_4$). Low Mg can corrected with foliar applications of Epson salt applied at a rate of 10 lb per 100 gallons of water in two post-bloom applications.

Trace Minerals

Boron (B) is involved in fruit set, so a common deficiency symptom is clusters with few berries. Its availability can be low on many Midwest soils and deficiencies are showing up in some northern vineyards on sandy soils. Care must be taken to add only the amount indicated by analysis as the range between boron deficiency and toxicity is narrow. Boron is considered mobile in the soil and can be applied to the soil surface. For pre-plant applications, the amount of boron to apply should be based on soil analysis and adjusted to .75 to 1.0 ppm. After the vineyard comes into production, petiole analysis will confirm if the vines are receiving adequate boron. If there is a shortage of B, it can be corrected with a soil application of 2-4 pound of B per acre. However, annual foliar applications often work better. Pre- and post-blooms of Solubor (20% B) applied at a rate of 2-4 lbs per acre beginning then the shoots are about 3-inches long is the recommended practice. You will need to consider if the post-bloom application is needed based experience and whether the cultivar forms loose or tight clusters.

Iron (Fe) can be deficient on high pH soils and some sandy soils. Symptoms of Fe deficiency are commonly referred to as “iron chlorosis” where the area between the leaf veins is light yellow to white in color and the area close to the veins remains green. The youngest leaves will appear to be almost “bleached out”. These symptoms can be temporary in vineyards that have been recently limed and on soils that become waterlogged.

Practices to correct low or deficient Fe include taking measures to lower the soil pH, improving the internal drainage, and not applying more than 2 tons of lime per acre at a time in established vineyards. Soil applications of iron (ferrous) sulfate are not effective in correcting Fe deficiency. Some forms of chelated Fe can be used for soil treatments, but they are expensive and last for about a year. The three common chelating agents for Fe are EDTA, DTPA and EDDHA, and the soil pH is an important factor it their ability to keep the Fe soluble (EDTA up to 6.3, DTPA up to 7.5; EDDHA from 4.0 to 9.0). Foliar applications of ferrous sulfate or iron chelate are often the best approach for correcting low or deficient Fe when applied at 10 to 14 day intervals starting early in the season. They use less material than soil treatments and provide a quick response.



Zinc (Zn) can be low on sandy, high pH, eroded, and terraced or leveled soils. Zinc deficiencies have been observed in some Minnesota vineyards on gravelly soils. Symptoms include small misshapen leaves on shoots with short internodes with a zig-zag growth pattern. On clusters, reduced fruit set and the presents of many "shot" (small green) berries can be a sign of Zn deficiency. The term "little leaf" is often used to describe well the stunted appearance of new growth. Zinc is considered very mobile in the soil and can be applied to the soil surface. Optimizing the soil pH and Zn before planting will reduced the potential for Zn deficiency. The amount of zinc to applied before planting grapes should be based on the soil analysis and adjusted to 3 to 4 ppm (6 to 8 lb/A). When the vineyard comes into production, petiole analysis will confirm if the vines are receiving adequate zinc. Low or deficient Zn can be corrected through the use of early season Zn-containing fungicides [mancozeb (2% Zn, 66 day PHI), Ziram (16% Zn, 10 day PHI)] or foliar applications of Zn-chelates.

Manganese (Mn) can be low on grapes growing on sandy or high pH soils. Symptoms show up beginning as yellow spots between the veins on young normal sized leaves that progress to interveinal chlorosis on older leaves. Optimizing the soil pH before planting will reduce the potential for Mn deficiency. Once the vineyard comes into production, petiole analysis should be used to determine the status of Mn. Low Mn can be corrected through the use of earl season Mn-containing fungicides [mancozeb (16% Mn, 66 day PHI)] or foliar applications of Mn-chelates.

On acid soils, Mn toxicity can be a problem. To reduce the risk of toxicity, soils should be limed before planting to raise the pH into the 6.0 to 6.5 range.

Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Fertilization and nutrition**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Pre-plant soil testing	Conducted soil tests of the vineyard site for each soil type, and optimize the soil pH, status of important nutrients before planting.	Conducted a soil test of the vineyard site, and optimize the soil pH, status of important nutrients before planting.	Conducted a soil test(s) of the vineyard site after planting, and attempted to optimize the soil pH, status of important nutrients before planting.	Did not conduct a soil test(s) before or after planting the vineyard.
Non-bearing years (Years 1 & 2) **fertilization**	Applied N fertilizer annually, adjusting the rate based on the soil OM content.	Applied some N fertilizer annually without adjusting for the soil OM content.	Vines growth was vigorous, did not apply any N fertilizer.	Vine growth was poor, did not apply any N fertilizer.
Production years: **Petiole analysis**	Conducted annual petiole analysis for each cultivar & different soil types, and applied fertilizer based upon the results.	Conducted petiole analysis every 2-3 years for each cultivar & different soil types, and applied fertilizer based upon the results. Maintained records of test results and vine performance.	Conducted a petiole analysis when vines exhibited abnormal symptoms, and applied fertilizer based upon the results.	Conducted a soil test when vines exhibited abnormal symptoms, and applied fertilizer based upon the results.
Production years: **Record keeping**	Maintained organized annual records on petiole analysis test results, fertilizer practices, pruning weights, fruit yield and average cluster weights.	Maintained some records petiole analysis test results, fertilizer practices, and pruning weights.	Did not maintain some records on pruning weights and fertilizer practices	Did not maintain any records petiole analysis results, fertilizer practices or vine performance.

Weed Control and Vineyard Floor Management

Weed control is an important practice in vineyard management. Traditionally, the primary objectives for controlling weeds are to conserve soil moisture and reduce the competition for essential mineral nutrients required by the grapevines. Other benefits for weed control are improving air circulation to reduce the incidence of diseases, reducing cover for voles and other rodents, reducing competition for sunlight in low trellis systems, and improving harvest labor efficiency and satisfaction. For young vineyards, effective weed control is essential to reduce weed competition for water, nutrients, and light during critical periods of active growth to establish the vines and get them producing some fruit by the third growing season. Once the vineyard is well-established, it may continue to be essential to maintain a rigorous weed control program, or it could be cut back depending on the site characteristics. Factors that need to be considered in developing a vineyard weed control program include:

- The available moisture supply from precipitation and irrigation if available.
- The soil's ability to store moisture based on its texture, potential rooting depth and infiltration rate.
- The slope of the field as it affects surface runoff and potential for erosion.
- The soil's fertility [organic matter (OM) content] as it affects vine vigor.
- Inherent vigor of the grape cultivar.
- Sustainability in conserving soil organic matter and maintaining good soil structure.
- Other vineyard practices.
- Labor requirements and costs.

Weed control in vineyards can be separated into practices performed between the vine rows (alleys) and under the vines.

Weed control between the rows

Weed control alternatives between the rows are cultivation or the use of sod in combination with mowing. Each practice has its advantages and disadvantages.

Cultivated alleys: In smaller plantings, weeds can be controlled easily by regular tilling with a rototiller. In larger plantings, tractor cultivation is generally required and may need to be need to be done 4 to 6 times per year. In the spring, weighted disks or tractor driven rototillers seem to be the best method for breaking up vine trimmings and vegetation. Later, a spring-tooth harrow may be used for regular cultivation.

Depending on the frequency of cultivation and timing based on the height of the weeds, cultivating the alleys can conserve soil moisture and minimizes competition for essential mineral nutrients. Also, there is less risk of spring frosts in vineyard with cultivated alleys than those with vegetation because there is nothing to intercept sunlight that warms the soil. However, cultivating the soil increases the risk of erosion and is not recommended for vineyards on steeper slopes. There is the risk of injuring the roots if the cultivation is too deep, and cultivation will lead to soil compaction below the till zone, particularly when the soil is too moist. In addition, you may not be able to get into a cultivated field in a timely manner following a rain, and cultivation does not conserve soil organic matter.

Whenever, cultivation of the alleys is practiced, growing winter cover crops is recommended. Winter cover crops should be sowed sometime in late July or early August. This will provide some competition for the vines and help them harden off for the winter. During the winter, a cover crop reduces soil erosion due to wind and water, insulates the soil and catches snow, both of which will help to protect the vine's roots from the winter cold. The most common annual cover crops are oats, cereal rye, and winter wheat. Oats are preferred because they typically will be killed over the winter, whereas wheat and rye tend to persist into the spring. Cereal rye does have allelopathic (weed suppressing) properties that will aid in controlling weeds in the spring when left on the soil surface as a mulch.

You need to consider these advantages and disadvantages when considering cultivated alleys as related to your specific site conditions. One place where cultivated alleys has potential is where precipitation is very limited and trickle irrigation is practiced under the vines. Also, cultivated alleys are better suited for cultivars that require winter protection when soil is mounded over the vines.

Sod alleys: In Minnesota and other northern climate vineyards, the use of a permanent vineyard ground cover is a good alternative to clean cultivation. A permanent sod provides excellent insulation of the vine's roots against the winter cold and through its insulation effect tends to delay bud break in the spring. The sod will compete for soil moisture and nutrients, but it can also take up any excesses. The timing and frequency of mowing can be used to minimize these disadvantages and can aid in controlling vine vigor. Sod alleys aid in controlling erosion, improve the water infiltration rate, conserve soil organic matter, and allow equipment to travel through the vineyard under adverse conditions. However, vineyard with sod alleys are more prone to spring frosts than vineyards with cultivated alleys.

Ground cover species used for sod alleys are separated into legumes and non-legumes. Perennial legumes are not recommended for most northern vineyards because they fix nitrogen that stimulates vine vigor, delays the hardening off of vines in the fall, and increased the risk of winter injury. However, if a soil has a very low organic matter content and a sandy texture, a low growing moderate nitrogen fixing perennial legume such as Dutch white clover or Korean lespedeza may be beneficial.

Perennial grasses are the preferred groundcover in the alleys of northern vineyards. They grow low to the ground, can withstand traffic, are not too competitive for moisture and nutrients, go dormant during periods of drought, and can take up excess soil moisture and nutrients. Species recommended for northern vineyards include common Kentucky bluegrass, perennial ryegrass, creeping red fescue and other non-competitive fescues. For arid sites such as western Nebraska and the Dakotas, blue gramma, and buffalo grass can be used. Avoid K-31 tall fescue unless the site is very fertile, particularly in combination with a very vigorous cultivar. Under most conditions, K-31 tall fescue is just too competitive to be used in a vineyard.

The competition between perennial sod and grapevines intensifies with each additional year the sod is allowed to grow. Vine vigor and production can begin to drop after a few years of sod competition, and the availability of other nutrients may be reduced. This is particularly true for potassium because the sod takes it up and deposits it near the soil surface. Sod that covers two-thirds of the vineyard floor will require annual applications of about 30 lbs. of actual N/acre, and depending on the soil's OM content, additional N may be needed to maintain the sod.

Weed control under the vines

Weed control practices under the vines can be achieved through cultural or chemical practices or a combination or the two methods. Cultural methods for controlling weeds include cultivation, mowing, mulching, burning and biological, while chemical methods include the use of pre- and post-emergence herbicides. Typically weed control under the vines focuses on the area 18" from either side of the vines for single curtain training systems when sod alleys are used. However, the width of weed-controlled area can be narrowed to cope with excess vine vigor.

Cultivation: In smaller plantings, weeds can be controlled by hand hoeing under the trellis. In larger vineyards, specialized tools such as a "grape hoe" or Weed Badger™ have been useful for controlling these hard-to-reach weeds. The mechanical hoe also is useful for hilling up soil over the vines for winter protection. The one main drawback of mechanical cultivators is that occasional damage to vines can occur. Cultivation has a short term effect of improving the water infiltration rate, but on a long term basis, it leads to crusting of the soil surface and greater runoff of precipitation. Cultivation increases the risk of erosion, can injure the roots near the soil surface, and leads to compaction of the soil below the till zone, particularly when practiced when the soil is too moist.

Mowing: Mowing under the vines is an alternative mechanical method of weed control, but requires specialized equipment that could injure the vines when not properly adjusted. The mowed off ground cover will control erosion, but does compete some for soil moisture and nutrients so it is best practiced in combination with an irrigation system. It is not recommended for young vines because competition for water and nutrients should be kept to a minimum to promote good vine growth. For well-established vineyards, it can be used to control excessive vine vigor. The ground cover serves to control erosion, improves the infiltration rate and soil organic matter content. However, the ground cover increases the risk of spring frosts and can harbor voles and other pests.

Mulches: The use of mulches under the vines conserves soil moisture, improves the infiltration rate and controls erosion. However, the mulch increased the risk of spring frosts and can harbor voles and other pests. Both organic and man-make fabric mulches can be used in a vineyard.

Organic mulches that can be used include wood chips, leaves, straw and corn stalks. These materials will initially tie up available nitrogen and reduce growth, so additional nitrogen fertilizer may be required. They do increase the availability of potassium and phosphorous. Organic mulches improve the soil organic matter content, but can aggravate wet soil conditions, and some straws can introduce new weeds. Thick layers of mulch delay the warming of the soil and thereby delay the release of nitrogen held by the soil organic matter. This can lead to prolonged vine growth in the fall and delayed hardening off of the vines. Grass clippings directed off sodded alleys onto the area under the vines does act as a mulch, but is generally too thin to control weeds. These clippings do serve to improve undesirable characteristics associated with practice that create a bare area under the vines.

Man-made fabric mulches do not compete for nutrient, and can promote an earlier harvest when the fabric has reflective properties. The greatest disadvantages of using fabrics is that they can get caught up in a mower, and create an environment favorable for voles.

Burning: Burning with a flame is another form of weed control, but requires specialized equipment, and requires trunk guards for young vines or any vine with green shoots near the ground that are being saved to replace a trunk. Burning is only effective in controlling weeds that have emerged and are still succulent. Speed of travel is critical when using burning as a weed control strategy. Too slow you can burn the trunks and wooden posts, and waste fuel. Too fast and you get poor weed control.

Biological: Biological forms of weed control include smother crops as used before planting the vineyard, and cover crops in the alleys where cultivation is practiced. Winter cover crops, such as cereal rye could be used under the vines to take advantage of its allelopathic (weed suppressing) properties, but this requires special equipment to seed the rye, and it must be killed either with a contact herbicide or by crushing the stems before the rye tillers in the spring.

Another form of biological weed control is a living mulch. This can be achieved by seeding creeping red fescue under the vines. This grass species lays over and does not require mowing. A living mulch will control erosion, but as with mowing, it does compete some for water and nutrients. Therefore, it is not recommended for young vineyards and irrigation should be considered.

Grazing is another form of biological weed control that is being tried in some vineyards. Most notably this has been with sheep, caged chickens and weeder geese have been tried. For grazing to work, either the cordons need to be set high enough the that the sheep or birds cannot reach the crop, be isolated from the grapevines, or the grapevines need to be treated with a repellent that animals object to.

Chemical Control: Herbicides have proven to be particularly useful for controlling weeds under the vines and can be dramatically save on labor. Both pre-emergence and post-emergence herbicides are commonly used in vineyards. However, due to the sensitivity of the vine to certain herbicides, care must be exercised by the grower both in selecting an appropriate herbicide and in applying it at the proper rate. Table 31 presents a list of herbicides labeled for use in vineyards and restrictions on their usage. Grape growers are urged to identify the problematic weed species in their vineyard before selecting an herbicide. Your university extension office is also available to assist in weed identification.

Table 31. Pre-emergence and post-emergence herbicides registered for use in vineyards with restrictions on usage.

Pre-emergence		Post-emergence
Alion (5-yr AP)	**Princep** (3-yr AP)	**Aim** (3 day PHI)
Casoron (1-yr AP)	**Prowl**	**Fusilade** (50 day PHI)
Chateau (2-yr AP)	**Snapshot** (NB only)	**Gramoxone Inteon** (R)
Devrinol (70 day PHI)	**Solicam** (2-yr AP)	**Poast** (50 day PHI)
Goal (3-yr AP)	**Surflan** (oryzalin)	**Reglone** (NB only)
Karmex (3-yr AP)	**Treflan**	**Rely 280** (Cheetah) (14 day PHI)
Kerb (R)	**Trellis** (165 day PHI)	**Roundup** (glyphosate) (14 day PHI)
Matrix (1-yr AP, 14d PHI)	**Zeus Primel** (2-yr AP)	**Scythe**
	Zeus XC (3-yr AP)	**Select Max** (NB only)
		Venue (pre-bloom)
Restriction abbreviations: AP=after planting; NB=non-bearing; R= restricted use pesticide; PHI=pre-harvest interval.		

* *From*: Midwest Small Fruit and Grape Spray Guide.

Herbicide resistance: When using herbicides to control weeds a concerning issue is the development of "herbicide resistance". This is most evident with pre-emergence herbicides, but can occur with post-emergence herbicides. It occurs when a particular weed can no longer be controlled with a particular herbicide or herbicides with similar modes-of-action. To reduce the risk for developing herbicide resistance, the Herbicide Action Resistance Committee (HRAC) (http://www.hracglobal.com/) developed a code based on mechanism of action for an herbicide and the Weed Science Society of America (WSSA) developed a code based on the herbicide's mode-of-action for both Pre-emergence herbicides (**Table 32**) and post-emergence herbicides (**Table 33**). To avoid developing herbicide resistance when using herbicides:

1. DO NOT USE the same herbicide from year to year.
2. DO NOT USE herbicides that are of the same chemical group.
3. DO NOT USE herbicides that have the same modes-of-action.

Table 32. Classification of pre-emergence vineyard herbicides based on Herbicide Resistance Action Committee (HRAC) and Weed Science Society of America (WSSA) codes.

HRAC code	WSSA code	Mode-of-Action	Pre-emergence Herbicide
B	2	Inhibits enzyme action	Matrix
C 1	5	Inhibits photosynthesis	Princep
C 2	7	Inhibits photosynthesis	Karmex
E	14	Membrane disruption in light	Chateau, Goal, Zeus Primel, Zeus XC
F 1	12	Inhibits carotene synthesis	Solicam
K 1	3	Inhibits cell division	Kerb, Prowl, Surflan, Treflan, (Snapshot)
K 3	15	Inhibits cell division	Devrinol
L	20, 21, 29	Inhibits cell wall biosynthesis	Casoron, Trellis, (Snapshot), Alion

Table 33. Classification of post-emergence vineyard herbicides based on Herbicide Resistance Action Committee (HRAC) and Weed Science Society of America (WSSA) codes.

HRAC code	WSSA code	Mode-of-Action	Pre-emergence Herbicide
A	1	Inhibits lipid biosynthesis	Fusilade, Poast, Select
D	22	Rapidly disrupts cell membranes in light	Gramoxone Inteon, Reglone
E	14	Disrupts cell membranes in light	Aim, Venue
G	9	Inhibits amino acid synthesis	Glyphosate (Roundup, touchdown, Hancho, Ritter, etc.)
H	10	Inhibits amino acid synthesis	Rely 280, Cheetah
Z	27	Unknown, differ from others	Scythe

Pre-emergence herbicides are sprayed or applied to the soil in the fall or spring before weed seeds germinate. They control weeds by killing the germinating weed seedlings and must be moved into that germination zone by rainfall, irrigation, or shallow cultivation to be effective. Thus, most have absolutely no effect on weed foliage and often need to be tank mixed with a post-emergence herbicide in the spring to control weeds that have already germinated. They pose little threat the vines unless they are leached down into the root zone of the vines by excessive precipitation. Strict adherence to recommended application rates is essential, since many of these compounds can potentially cause damage to the vine's roots. The application rates for these herbicides is given in rate per acre, but only applies to the treated area under the vines and not the field acres the vineyard occupies. For example, if a vineyard rows that are 10 feet wide and the herbicide is being applied under the vines to strip that is 3 feet wide, then the treated area for a field acres would be 0.3 acre, or 3.33 field acres would be equivalent to one treaded acre. Further, the activity of these pre-emergence herbicides is closely related to the type of soil on which they are applied. Lighter, sandy soils will require a lesser rate of application. Heavier clay or organic soils will require higher rates to achieve the same level of weed control. These pre-emergence herbicides differ in their ability to control various weed types and species (Table 34). The grower must know his vineyard soil type and be able to select an appropriate application rate from the range of rates recommended on the label. Translating the rate into the appropriate sprayer tank mix also is critical to avoid over application and vine damage. The grower is advised to seek out information on sprayer calibration and tank mixing prior to proceeding.

Table 34. Effectiveness of pre-emergence herbicides registered for use in vineyard for controlling various types of weeds.

Herbicide	**HRAC (WSSA)**	**Risk of resistance**	**Broadleaf**		**Grasses**	
			Annual	**Perennial**	**Annual**	**Perennial**
Alion, Casoron	L (20)	Med.	Most	Some	Most	Some
Chateau	R (14)	Med.	Most		Some	
Devrinol	K3 (15)	Low	Some		Most	
Goal	E (14)	Med.	Most			
Karmex	C2 (7)	Med.	Most		Most	
Matrix	B (2)	Low	Some		Some	
Princep	C1 (5)	Med.	Most		Some	
Prowl	K1 (3)	Low	Some		Most	
Snapshot	K1 (3), L (21)	Med.	Most		Some	
Solicam	F1 (12)	Med.	Some		Most	
Surflan	K1 (3)	Low	Some		Most	
Treflan	K1 (3)	Low	Many		Most	
Trellis	L (21)	Med.	Most		Some	
Zeus	E (14)	Med.	Most	Some	Most	Some

Post-emergence herbicides are used to control weeds after they emerge from the soil. They can be applied as a band under the vines, or on a spot treatment basis using a hand-held applicator. They vary in their mode-of-action with some killing on contact, others must be absorbed, and others must be absorbed and translocated to the roots (**Table 33**). Many of these herbicides require a surfactant or other spray additive to be most effective. They can be selective or non-selective regarding the types of weeds they control. For some, the stage of weed development can be critical, while others can be effective in controlling established perennial weeds (**Table 35**). They can cause injury to the vines, so avoid contact with foliage, shoots and clusters when applying. This particularly evident with glyphosate which is absorbed and translocated to the roots. Symptoms often appear the following growing season (**Figures 35- 38**). Suckers and water sprouts near the ground are the first shoots to emerge, so be careful with early applications of these herbicides. When using grow tubes, make sure the bottoms are buried in the soil to avoid a "chimney-effect" drawing in the glyphosate (**Figure 36**).

Table 35. Effectiveness of post-emergence herbicides registered for use in vineyard for controlling various types of weeds.

Herbicide	HRAC (WSSA)	Risk of resistance	Broadleaf		Grasses	
			Annual	Perennial	Annual	Perennial
Fusilade	A (1)	High			Most	Most
Poast	A (1)	High			Most	Most
Select	A (1)	High			most	most
Scythe	Z (27)	Low			Most	Most
Aim	E (14)	Med.	Most	Some		
Venue	E (14)	Med.	Most	Most		
Gramoxone Inteon	D (22)	Med.	Most	Suppress	Most	Suppress
Glyphosate (Roundup, etc.)	G (9)	Low	Most	Some	Most	Many
Reglone	D (22)	Med.	Most	Suppress	Most	Suppress
Rely280 (Cheetah)	H (10)	Low	Most	Some	Many	Many

For banded applications of both pre- and post-emergence herbicides should be applied with fan-type nozzles at or less than 30 psi pressure to produce larger droplets and minimize drift. These nozzles produce a fan-shaped, elliptical pattern so it is important to overlap spray pattern when spraying under the vines from each side of the row. Sprayers should be calibrated to deliver 10-40 gallons of solution per acre unless otherwise stated on the label.

Figure 35. Glyphosate injury on a young vine where the bottom of a grow tube was not buried.

Figure 36. Glyphosate injury from an application made the previous season.

Figure 37. Severe glyphosate injury from an application made the previous season.

Figure 38. Severe glyphosate injury from an application made the previous season affecting just a portion of the vine.

Additional information on herbicides registered for usage on grapes is available in regional Extension Publications:

- Midwest Small Fruit and Grape Spray Guide https://ag.purdue.edu/hla/Hort/Documents/ID-169.pdf
- New York and Pennsylvania Pest Management Guidelines for Grapes
- Michigan Grape Pest Management Guide
- NE Small Fruit Management Guide http://ag.umass.edu/fruit/ne-small-fruit-management-guide
- Guide to Fruit Production, *Ontario Ministry of Agriculture* http://www.omafra.gov.on.ca/english/crops/pub360/p360toc.htm
- CDMS Pesticide Label Database http://www.cdms.net/Label-Database.

Sucker management with herbicides

Some post-emergence herbicides are labeled for controlling suckers with some restrictions.

Rely 280, Cheetah: Apply when suckers are less than 12-inches tall. Do not allow contact with desirable fruit, foliage or green bark.

Aim: Apply when suckers are green. Do not allow contact with desirable fruit, foliage or green bark.

Gramoxone Inteon: Apply when suckers are less than 8-inches tall. Do not allow contact with desirable fruit, foliage or green bark. A RESTRICTED USE PESTICIDE.

Preventing Herbicide Drift and Injury to Grapes*

Grapes are especially sensitive to growth regulator herbicides such as 2,4-D and dicamba. When applied to nearby areas, these herbicides can drift to vineyards and cause significant injury to grapevines. Herbicide concentrations of 100x below the recommended label rate have been reported to cause injury to grapes.

Field observations indicate drift from growth regulator herbicides can injure grapes ½ mile or more from the application site.

Herbicide drift can injure foliage, shoots and flowers. If injury is severe enough or occurs repeatedly, it can reduce yields and fruit quality, and occasionally cause vine death. Drift injury can result in substantial economic loss. In addition, drift to grapes from misapplication of pesticides can result in illegal residues on the exposed crop. Herbicide injury to grapevines can last several years after the occurrence of the drift. It may reduce vigor, increase susceptibility to diseases, decrease yield and fruit quality and shorten the life of the vineyard.

Injury from growth regulators (2, 4-D and dicamba) usually appears within 2 days of the drift incident as epinasty of the shoot tips (**Figure 39**). Symptoms of 2,4-D injury include characteristic fan-shaped leaves with sharp points at leaf margins (**Figures 40** and **41A**) while cupping is often associated with dicamba exposure (**Figure 41B**). Leaf strapping with deep sinuses, and leaf puckering with constricted veins that may be slightly chlorotic. Exposure to growth regulator herbicide drift can arrest the development of some berries (**Figure 42**), and affects fruit quality, including fruit color, sugar levels and acid content. Shoot tips seldom resume growth after injury, but laterals continue to grow. The result is a very bushy vine with a shade canopy and poor fruit exposure. Injury is particularly severe when multiple incidents occur to the same grape planting over a period of years.

It would be wise to encourage your neighbors and the local weed control crews (road, rail and utility right-of- ways) to use another herbicide or resist from herbicide use altogether near your vineyard, as it may drift for distances in excess of one mile. The local extension agent, local Ag suppliers of herbicides and aerial applicators should be made aware of your vines and their susceptibility to damage. (*Register your site on a sensitive crops registry. The state of Minnesota participates in DriftWatch™ Specialty Crops Site Registry* (http://driftwatch.org).)

* (Ball, D., R. Parker, J. Colquhoun, and I. Dami. 2004)

Figure 39. Early symptom of growth regulator herbicide drift injury is epinasty of the shoot tips.

Figure 40. Severe early season symptoms of growth regulator herbicide drift injury.

Figure 41. Typical fan-leaf injury symptom caused by 2,4-D (A), and cupping pattern caused by dicamba (B).

Figure 42. Green berries caused by exposure to growth regulator herbicide drift.

On occasion, 2,4-D may be needed to clean up invasive broadleaf weeds such as Dutch white clover or dandelions. If used, apply the 2,4-D when the grapevines are dormant, either in the spring before the buds begin to swell or in the fall after a killing frost. Also, a less volatile amine formulation of 2,4-D, such as Formula 40® should be used. In the spring, suckers and water sprouts developing near the soil surface are first to emerge, so be sure they have not begun to grow when using 2,4-D in a vineyard.

Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Weed control and vineyard floor management**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Development of the between the rows program	Based on the availability of moisture, potential for erosion, soil fertility, vine vigor, sustainability, influence on other practices, and labor & cost requirements.	Based on the availability of moisture, potential for erosion, soil fertility, vine vigor, sustainability, and labor & cost requirements.	Based on the availability of moisture, potential for erosion, soil fertility, and labor & cost requirements.	Based on labor and cost requirements only.
Development of the under the vines program	Based on the availability of moisture, potential for erosion, soil fertility, vine vigor, sustainability, ease & frequency of performing, and labor & cost requirements.	Based on the availability of moisture, potential for erosion, soil fertility, sustainability, ease & frequency of performing, and labor & cost requirements.	Based on the availability of moisture, potential for erosion, ease & frequency of performing, and labor & cost requirements.	Based on labor and cost requirements only.
Selecting herbicides	Aware of restrictions on usage when selecting herbicides to use.			Did not consider restrictions on usage when selecting herbicides to use.
Herbicide effectiveness	Considered the effectiveness for control problem weeds in the vineyard.		Did not considered the effectiveness for control problem weeds in the vineyard.	
Pre-emergence herbicides - **herbicide resistance**	Did not use the same herbicide, herbicides from same chemical group or mode-of-action from year to year.	Did not use the same herbicide from year to year.		The same pre-emergence herbicide was used year to year.
Post-emergence herbicides	Avoided contact with foliage, shoots and clusters when applying.		Did not take precautions to avoid contact with foliage, shoots and clusters when applying.	
Herbicide drift	Took measure to alert neighbors, right-of-way crews of the risk to grapevines, and registered on a sensitive crop site.	Registered on a sensitive crop site.	No effort to alert neighbors, right-of-way crews of the risk to grapevines.	

Winter Protection for Tender Cultivars

Covering the grapevines in the fall to protect from winter cold is necessary for all tender cultivars. Fortunately there are new cold hardy cultivars from Elmer Swenson and the University of Minnesota that practically eliminate the need for this practice. Some older cultivars such as Beta, Suelter, Kay Gray, King of the North, Bluebell and Valiant do not need to be protected. Edelweiss, St. Croix, La Crosse, and Maréchal Foch will survive and fruit most years on better sites in southern Minnesota but need protection to fruit reliably. Virtually all the French hybrid cultivars and all the V. vinifera cultivars are cold tender and require winter protection. In fact, V. vinifera cultivars such as Chardonnay and Gewürztraminer, and no doubt others, have shown the ability to ripen here and produce very palatable wines. Some growers are willing to cover these cultivars to be able to make their home-grown wines.

Even the cold hardiest of the Northern hybrids may need protection during the first winter when grown in the coldest regions, particularly on a fertile soils. When vines grow vigorously during the first growing season, the shoots are often slow to lignify (bark turns brown) in the fall and properly harden off. Typically, these vines experience cane some die-back. When the die-back is nearly to the ground and new shoots have to be trained up to form the trunk, it can put them into a vicious cycle of greater vigorous growth, delayed hardening off and die-back in successive years. Thus, there remains a place for winter protection for tender cultivars and cold hardy cultivars under special conditions that are not that uncommon in the upper Midwest.

When covering is required, most growers prune tender vines in the fall as they are taken from the trellis. This reduces the vine bulk that must be covered. Some growers use soil. Others prefer to use a straw or shredded cornstalk mulch. Still others simply allow snow to cover the vines. When soil is used, there is never any problem with expense or availability of material, and the grower can be assured that the vines will be well protected. Tests have shown that the soil temperature at two inches rarely goes below 10o F. However, labor and timing can be problems. For example, cold tender and marginal vines are normally pruned in the fall after they have been defoliated by a hard frost. However, during a mild fall, pruning must be started before it can be certain that the vines have hardened off. In any case, this pruning must be completed and the entire vineyard covered before the soil freezes, otherwise covering with soil becomes impossible. Some years there is plenty of time, but in other years the ground freezes early. In the spring, the vines must be uncovered before the buds swell. Swelling buds can be very fragile and can break off when the soil is removed unless extreme care is used. Moreover, in a wet spring buried buds are seen to rot and fail to push, so uncovering should be done as early in the spring as possible.

The necessity for covering and uncovering vines with soil has led to experimentation with methods that ease the labor and speed up the operation compared to hand shoveling. In one such method, a trench or furrow is dug with a grape hoe or single-bottom plow about a foot out from the base of the vines. The vines are then cut down from the trellis, pruned, and placed in the trench. Covering with the loose soil is then relatively simple. One person can do all these operations. In a second method, the vines are cut from the trellis and pruned. Then, one person holds them down while a second person, operating a grape hoe, throws up a bank of soil on each side of the vines. This method works well except that the soil in the center of the row must be brought back to the sides before it can be done again the following year.

If a mulch is used to cover the vines, the rush to complete pruning and covering is not so great, although it must still be finished before severe cold weather arrives. Mulch materials are lighter than soil and is labor-saving in that way. Other advantages are that the mulch can be incorporated into the soil during the following summer and surface roots of the vines are not cut. Using mulch does have some disadvantages. Mulches make excellent cover for voles (mice), and some growers have reported extensive trunk damage from them. Rodent management in the fall helps control this problem. In addition, care must be taken to weigh down these mulch materials since they are light enough to blow away and leave the vines unprotected. Finally, mulch materials can be expensive.

In Minnesota and western Wisconsin, snow cover often comes in late November or early December and remains through most of March. During such winters, additional covering of the vines is not necessary. Merely laying them on the ground and pinning them with wire staples about 10 inches long or holding them down with stones, boards, logs, or other heavy objects has proven satisfactory. During open winters, when there is little or no snow cover during January, injury will occur to tender vines that are just lying on the ground. Marginally hardy vines, however, have survived open winters with little damage. These vines should be raised and tied to the trellis as soon as the threat of severe cold is gone in the spring.

In one important observation, local growers have noticed that vines that were uncovered, but not tied immediately to the trellis, showed more cold damage than vines of the same cultivar in the same vineyard that had been tied up. Those left lying on the ground sprouted fewer and less vigorous shoots, had considerably more bud damage, and produced less fruit than the other vines. Thus, after uncovering, vines should be tied to the trellis as soon as possible.

Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Winter protection**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Tender cultivars	Vines are taken off the trellis, laid down and covered with soil or a mulch each winter.	Vines are taken off the trellis and laid down each winter.		No winter protection provided.
Marginally adapted cultivars	Vines are taken off the trellis, laid down and covered with soil, mulch, or not covered each winter.	No winter protection provided.		
Cold hardy cultivars	Vines exhibited moderate vigor, with shoots lignifying early during the first growing season. No protection required.	Vines exhibited high vigor, with shoots slow to lignify during the first growing season. Vine are taken off the trellis and provided winter protection.	Vines exhibited high vigor, with shoots slow to lignify in the fall during the first growing season. No winter protection provided.	

Vineyard Pest Management

The control of diseases, insects and problem wildlife ("pests") that attack the grapevine foliage, fruit or both is important if you want to produce sustained yields of quality fruit. If not controlled, these pests significantly reduce yields or render the crop unmarketable. To effectively control these pests you need to:

1. Learn to identify the various pests that attack grapes or their injury symptoms.
2. Undertake cultural practice that will reduce the chances of infection or damage caused by the pest.
3. Select pesticides that will effectively and sustainably control the various pests.
4. Properly and safely apply pesticides with minimal adverse effects on the environment.

This section will provide an introduction to some of the important grape pests found in Minnesota and the upper Midwest. Additional information on the pests covered and other pests of grapes, and their control can be found in several publications:

- Midwest Small Fruit and Grape Spray Guide
- Midwest Small Fruit Pest Management Handbook
- Midwest Grape Production Guide
- Wine Grape Production Guide for Eastern North America
- Grape IPM Guide for Minnesota Producers
- Pocket Guide for Grape IPM Scouting in the North Central and Eastern U.S.
- FruitEdge Fruit IPM Resources for new and emerging pests of the Midwest.

Applying Pesticides

The Sprayer: Depending upon the size of the vineyard, pesticides can be applied with simple hand-held devices such as a compression sprayer (one that you pump air into to diskharge the spray) to sophisticated tractor driven air blast (mist blower) sprayers. Regardless of the size of the sprayer, they can be divided into those that deliver the pesticide mixture under pressure that forms droplets as it is diskharged from an orifice and delivered it to the target (hydraulic sprayers), and those that disperse the pesticide mixture into an airstream that delivers it to the target (air blast/mist blower sprayers). Both systems are available as small systems that you can carry to large tractor driven systems that are capable to covering several acres. Regardless of size, hydraulic systems are less expensive, but they are restricted to high-volume dilute applications of the pesticides which is about 200 gallons of liquid per acre for a vineyard that has developed a full canopy. Air blast systems are more expensive, but can be used for concentrate application where the concentration of pesticide is increased in the spray tank and fewer gallons of liquid applied per acre. This can be taken one step further by calibrating the sprayer for row-volume spraying which allows you to adjust the volume of spray applied per acre based on the size and density of grape canopy. Sprayer calibration and row-volume spraying are covered in the **Midwest Small Fruit and Grape Spray Guide.**

Applying Pesticides Safely and Effectively

Pesticides used improperly can be injurious to man, animals, plants, and the environment. Inhalation or skin contact with many pesticides can have immediate short-term toxic effects on humans ranging from minor skin and throat irritation to headaches, dizziness, and nausea. The long-term effects of repeated exposure to various pesticides are only beginning to be understood, but are even greater cause for concern. Pesticides that are improperly mixed and applied can cause damage to vines, to soil microorganisms, and, over the long term, to our lakes and streams. Growers should keep in mind some basic principles of pesticide application safety:

1. Read pesticide labels. The label is the law. Understand the toxicity of the material you are applying and the proper rates of application for grapes.
2. Know your sprayer. Understand how to mix pesticides in your sprayer and calibrate it to produce the desired rate of pesticide delivery.
3. Be aware of weather conditions. Spray at times that minimize drift. Be aware of temperature and moisture conditions that tend to enhance the activity of certain pesticides and increase their phytotoxicity.
4. Know the pH of your spray water, and adjust it if necessary. Many pesticides are pH sensitive and break down rapidly in alkaline water. Check the pH of the spray mixture and add a commercial buffering agent (Buffercide, Buffer-X, Unifilm, LI 700) or granular food grade citric acid if the pH is above 7.0.
5. Observe the re-entry period (REI). Do not allow people access to your vineyard for the time period specified on the pesticide label without personal protective equipment (PPE) as specified by the pesticide label.
6. Observe harvest restrictions (pre-harvest interval, PHI) . Know how close to harvest you can safely apply each pesticide. This period from spray application to harvest can range from 0 days for sulfur and fixed copper materials to 66 days for mancozeb. Also, do not use an extender type spreader-sticker (such as Nu-Film 17®) in late season sprays. These materials will likely extend the activity of the pesticide well into harvest and leave harmful residues on the fruit. Clearly, good planning is of the utmost importance in late season sprays.
7. Store pesticides safely. Pesticides should be stored in their original container, out of the reach of children, and under lock and key, if necessary, to deny access.
8. Protect yourself when handling and applying pesticides. Wear the PPE specified by the pesticide label. Typically this includes un-lined rubber gloves and rubber boots, a respirator approved for pesticide usage, and eye protection. When spraying without an enclosed cab, a waterproof rain suit, or Tyvek® suit with a hood is good protective outerwear. When you are done spraying, wash the contaminated clothing by itself in a standard detergent. Then run a wash cycle through with the machine empty to remove any residues from the machine.

When in doubt about rates of application toxicity, or sprayer calibration, ASK QUESTIONS before you proceed.

Also, excellent publications are available from your university extension office to help you apply pesticides safely.

Handling Pesticides: (*from:* Midwest Small Fruit and Grape Spray Guide)

1. Know the pesticide toxicity and act accordingly.
2. When mixing pesticides do not breathe the dust, powder, or vapor. Always mix outdoors.
3. Do not smoke, eat, or drink when handling or applying pesticides.
4. Stay out of drift from spray or dust.
5. Rinse liquid containers with water at least three times and pour rinsate into spray tank as it is being filled. Punch holes in metal and plastic containers and crush. Dispose of these and all other pesticide containers where there will be no contamination of crops or water supply. Do not re-use pesticide containers.
6. Have a “buddy” around when using acutely toxic organophosphates, just in case.
7. For maximum safety, get an appropriate blood test before the season starts and periodically during the season.
8. Consult a doctor immediately if unusual symptoms develop during or after spraying.
9. Symptoms such as blurred vision, nausea, headaches, chest pains, weakness, diarrhea, or cramps indicate possible pesticide poisoning.
10. Wash hands thoroughly before eating or smoking.
11. Bathe and change clothes daily, and wash contaminated clothing separate from other laundry. Always store a pesticide in its original container, never in an unmarked container.

12. Never trust your memory.
13. Always store pesticides under lock and key and keep them away from children. Always use an anti-siphon device when filling the spray tank from a domestic water source.

Management Tips for Safety: (*from:* Midwest Small Fruit and Grape Spray Guide)

1. Maintain accurate spray records – application rates, pesticides used, total gallonage, area treated, stage of vine development, and weather data.
2. Be prepared to show records to the EPA or state regulatory agency.
3. Do not contaminate forage crops or pastures.
4. Do not allow animals to graze.
5. Prevent excess drift.
6. Maintain equipment in top condition.
7. Protect children, pets, livestock, and the environment from pesticide contamination.
8. Follow all label instructions on re-entry times for pesticides.
9. Inform all worker of re-entry restrictions and information of safe pesticide use and/or training to meet OSHA requirements.
10. Comply with the Right-To-Know law. Have complete product labels readily available for workers to see. Have Materials Safety Data Sheet (MSDS) for each product you use available for workers to see for rescue or fire for personnel to use in case of emergency. Sample pesticide product labels and MSDS sheets are available at CDMS Pesticide Label Database http://www.cdms.net/Label-Database.
11. Provide pesticide safety training for pesticide handlers and other workers to comply with Worker Protection Standard (WPS).
12. Regularly inspect and maintain personal protective equipment used when applying pesticides.

Additional information on spray schedules for grape pest control can be found in **Midwest Small Fruit and Grape Spray Guide** (Bordelon, B., R. Foster and N. Gautier, *editors*). The spray guide is an annual publication that is available from most Extension Publication Distribution Centers in the North Central Region. A pdf version is posted at: https://ag.purdue.edu/hla/Hort/Documents/ID-169.pdf

Vineyard Best Management Practices – Vineyard Pest Management

Rate your vineyard pest management practices:

Management Area: **Applying pesticides**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Pesticide label	Thoroughly read the pesticide label for first aid, hazard to humans & domestic animals, personal protective equipment, environmental hazards, directions for use, agricultural use requirements, storage & disposal, application procedures, restriction on use, & application rates.	Read the pesticide label for first aid, personal protective equipment, environmental hazards, directions for use, agricultural use requirements, storage & disposal, application procedures, restriction on use, & application rates.	Read the pesticide label for personal protective equipment, directions for use, agricultural use requirements, storage & disposal, application procedures, restriction on use, & application rates.	Read the pesticide label for directions for use, agricultural use requirements, application procedures, restriction on use, & application rates.
Worker protection and safe handling of pesticides	Train workers on the proper safe handling of pesticides, & comply with Worker Protection Standard and Right-to-Know law. Have pesticide labels and MSDS sheets on file.		Comply with Worker Protection Standard and Right-to-Know law. Have pesticide labels and MSDS sheet on file.	Do not train workers on the proper safe handling of pesticides, or comply with Worker Protection Standard and Right-to-Know law. No pesticide labels and MSDS sheets on file.
Pesticide sprayer	Calibrate the sprayer annually, and maintain in top working condition.	Calibrate the sprayer every 2nd year, and maintain in good working condition.	Calibrate the sprayer every 3rd year, and maintain in fair working condition.	Sprayer has not been calibrated since it was purchased.
Pesticide safety	Wear the proper personal protective equipment when mixing & applying pesticides, and know the symptoms of pesticide poisoning.	Wear the proper personal protective equipment when mixing & applying pesticides.		Do not wear the proper personal protective equipment when mixing & applying pesticides.
Pesticide storage	Store pesticides in their original containers, out of reach of children & under lock & key.			Do not store pesticides out of reach of children & under lock & key.
Record keeping	Maintain detailed records of pesticide applications made during the season, including weather conditions at the time of application.	Maintain detailed records of pesticides applications made during the season.		Lax on maintaining records of pesticide applications made during the season.

Grape Diseases

Fungal diseases can be a major problem in Minnesota and the upper Midwest. Black Rot, Bunch Rot, Downy Mildew, and Powdery Mildew are native to this area and attack many cultivars. Susceptible cultivars can usually be grown only through the use of frequent, regular, and well timed fungicide sprays. Alternatively, growers who prefer to minimize fungicide spraying should select from those cultivars that exhibit low susceptibility to these diseases (*See* **Table 22** in the section on Grape Cultivars for Minnesota).

A first step for every grower is to learn to recognize the symptoms of these grape diseases. In addition, knowledge of disease life cycles is essential for proper planning of spray applications and cultural manipulations that reduce disease potential. This chapter provides an introduction to some of the important grape diseases found in Minnesota and the upper Midwest.

Anthracnose

In recent years Anthracnose caused by *Elsinoe ampelina* has become a serious problem in many northern vineyards. Frontenac, Frontenac gris, La Crescent, Marquette and many of the Swenson hybrids are moderately susceptible to this disease. In warm, humid, wet seasons it can be very destructive when left untreated.

Anthracnose will affect any green succulent part of the grapevine including stems, leaves, tendrils, berries with lesions, and on shoots with berries being the most common and distinctive. Symptoms on young, succulent shoots first appear as numerous small, circular, and reddish spots (**Figure 43A**). Spots then enlarge, become sunken, and produce lesions with gray centers and round or angular edges with dark reddish-brown to violet-black margins eventually surround the lesions (**Figure 43B**). Lesions may coalesce, causing a blighting or killing of the shoot. A slightly raised area may form around the edge of the lesion. Infected areas may crack, causing shoots to become brittle. Anthracnose lesions on shoots may be confused with hail injury; however, unlike hail damage, the edges of the wounds caused by the anthracnose fungus are raised and black. In addition, hail damage generally appears on only one side of the shoot, whereas anthracnose is more generally distributed. Anthracnose on petioles appears similar to that on the shoots. Leaf spots are often numerous and develop in a similar manner to those on shoots (**Figure 44**). Eventually, they become circular with gray centers and brown to black margins with round or angular edges. The necrotic center of the lesion often drops out; creating a shot-hole appearance. Young leaves are more susceptible to infection than older leaves. When veins are affected, especially on young leaves, the lesions prevent normal development, resulting in malformation or complete drying or burning of the leaf. Lesions may cover the entire leaf blade or appear mainly along the veins. Lesions on the rachis appear similar to those on the shoots (**Figure 45A**). On berries, small reddish spots often grow into a rounded, gray lesion with a characteristic "birds eye" spot in the middle (**Figure 45B**) (this disease is sometimes referred to as "birds eye rot"). The edges are often raised slightly with brown or black edges (Ellis and Erincik, 2008).

The fungus overwinters in the vineyards as *sclerotia* (fungal survival structures) on infected shoots. In the spring, these *sclerotia* germinate to produce abundant spores (*conidia*) when they are wet for 24 hours or more and the temperature is above 36° F. *conidia* are spread by splashing rain to new growing tissues and are not carried by wind alone (Ellis and Erincik, 2008).

Anthracnose Control

Prune and destroy (remove from the vineyard) diseased plant parts during the dormant season. This includes infected shoots, cluster stems, and berries. This should reduce the amount of primary inoculum for the disease in the vineyard. It's also important to eliminate wild grapes near the vineyard as they provide an excellent place for the disease to develop and serve as a reservoir for the disease. Keep them as far from the vineyard as possible. The spores are spread over relatively short distances by splashing rain and shouldn't be able to move long distances by wind into the vineyard. Proper canopy management can aid in disease control by improving air circulation and by reducing the drying time of susceptible tissue. These practices include selection of the proper training system, shoot positioning, and leaf removal. Where the disease is established, the use of fungicides is recommended. Fungicide recommendations for anthracnose control consist of a dormant application of Liquid Lime Sulfur in early spring, followed by applications of foliar fungicides during the early growing season (Ellis and Erincik, 2008). Fungicides that are effective in controlling anthracnose are listed in **Table 37**.

Figure 43. Anthracnose on young (A) and older (B) shoots.

Figure 44. Anthracnose on a grape leaf.

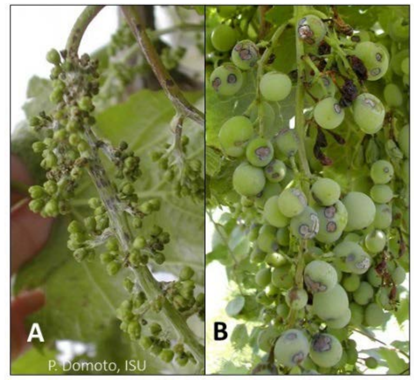


Figure 45. Anthracnose on young rachis (A) and on La Crescent berries (B).

Phomopsis Cane and Leaf Spot

The incidence of Phomopsis cane and leaf spot, once known as "dead arm", appears to be increasing in Eastern and Midwestern vineyards. It is an early season fungal disease caused by *Phomopsis vitcola* that can affect most parts of the grapevine, including canes, leaves, rachises (cluster stem), flowers, tendrils, and berries. It can cause vineyard losses by: 1) Weakening canes, making them more susceptible to winter injury; 2) Damaging leaves, which reduces photosynthesis; 3) Infections of the rachis result in poor fruit development and premature fruit drop; and 4) Infected berries can develop fruit rot at harvest (Anco, Erincik and Ellis, 2011).

Common symptoms of the disease are spots or lesions developing on the shoots and leaves. Small, black spots develop on the internodes at the base of developing shoots. Usually, these spots occur on the first three to four internodes, and often develop into elliptical lesions that may grow together to form irregular, black, crusty areas (Figure 46). Under severe conditions, the infected shoots may crack open. Surface lesions appear to result in little damage to the vines, but serve as the primary source of overwintering inoculum for infections the next growing season. Leaf infections first appear as small, light-green spots with irregular star-shaped margins (Figure 47). Usually only the first one to four leaves on a shoot are affected. In time the spots become larger, turn black, and develop a yellow margin (Figure 48). Leaves become distorted and die if large numbers of lesions develop. Infections on leaf petioles may cause leave to turn yellow and drop off. All parts of the grape cluster are susceptible to infection throughout the growing season, but most infections occur early in the season. Rachis infections may cause the clusters to prematurely wither. Infected clusters that survive often produce infected or poor-quality fruit. Berry infections begin to appear close to harvest as the berries develop a light-brown color. Black spore-producing structures of the fungus (pycnidia) break through the berry skin, and the berry soon shrivels (Figure 49). Phomopsis can be mistaken for black rot, but black rot affects green berries while Phomopsis appears on ripening berries (Anco, Erincik and Ellis, 2011).

Phomopsis overwinters in lesions or spots on old canes and rachises infected during the previous growing season, and requires cool wet weather for spore release and infection. Spores are released early in the spring and are spread by splashing raindrops to developing shoots, leaves and clusters. Practices for controlling Phomopsis include: 1) Cultural practices to increase air circulation and light penetration in the vineyard to reduce wetting periods. 2) Cutting out and destroying any infected or dead canes while dormant pruning. Removing and destroying all rachises left on the vines. 3) Proper timing of early-season fungicide sprays (Anco, Erincik and Ellis, 2011). Fungicides that are effective in controlling Phomopsis are listed in **Table 37.**

Figure 46. Phomopsis lesions on a shoot.

Figure 47. Initial Phomopsis spots on a leaf.

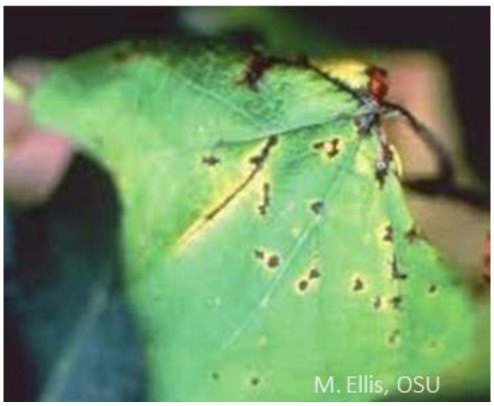


Figure 48. Older Phomopsis spots on a leaf.

Figure 49. Phomopsis on berries.

Black Rot

Black Rot is caused by the fungus *Guidnardia bidwellii*. It overwinters in mummified berries on the vine, in old lesions on leaves, canes and tendrils or on the ground. In the spring, when sufficient heat and moisture are present, this over wintering fungus material releases new ascospores and conidia into the vineyard. These are either splashed by rainfall onto the young grape leaves and shoots or are carried to infection sites in the air. This springtime release of conidia into the vineyard produces the initial lesions on leaves and shoots. If allowed to mature, these initial lesions also produce black rot inoculum. During the warm summer months, this inoculum is released following periods of rainfall, compounding the initial infection. Ascospores may be present in mummified fruit that over winter on the vines. When diskharged into the air, these spores are capable of traveling far, and may be a source of initial spring time infections (Ellis, 2008e).

Black rot first appears as reddish-brown circular spots on leaves during the months of June and July (**Figure 50**). It moves to young shoots where it is visible as oblong purple-black patches and eventually appears on the fruit when the berries are about half grown. Initially, infected berries develop small tan spots. In the later stages of the infection, the disease causes the entire berry to blacken, shrivel and mummify (**Figure 51**). Fruit tends to be attacked one berry at a time, rather than as a cluster. By the time the fruit has ripened to a 6-8% sugar content, no additional new infections occur (Ellis, 2008e).

Control of black rot requires a combination of good vineyard sanitation practices and a well-timed spray program. Sanitation is very important. Destroy mummies, remove diseased tendrils from wires and only select fruiting canes without lesions. It is very important not to leave mummies attached to the vine. Research has shown that mummies on the ground release most or all of their ascospores before the end of bloom. Mummies left up in the trellis can produce ascospores and conidia throughout the growing season, thus making control of this disease much more difficult. If only a few leaf lesions appear in the spring, remove these infected leaves (Ellis, 2008e).

Grapes should be planted in sunny, open areas which allow good air movement. Proper row orientation to prevailing winds and good weed control beneath the vines also enable plants to dry more quickly during wet weather. A good fungicide spray program is extremely important. Early season control (bud break through bloom) must be emphasized. If controlled early, the need for late season (post bloom) applications of fungicide is greatly reduced (Ellis, 2008e). Fungicides that are effective in controlling black rot are listed in **Table 37**.

Figure 50. Black Rot lesions on a leaf.

Figure 51. Black rot on berries (A), and a mummified cluster (B).

Downy mildew

Downy mildew is a major disease of grapes throughout the eastern United States. The fungus causes direct yield losses by rotting inflorescences, clusters and shoots. Downy mildew is most prevalent in wet, humid years. The disease appears first as yellow spots on the top of the leaves, then a downy white growth appears on the undersides of the leaves (**Figure 52**). The infection can spread to eventually cover the leaf completely, causing it to turn brown and fall off prematurely. This premature defoliation is a serious problem because it predisposes the vine to winter injury. Such a severe infection can weaken the vine late in the growing season and make it more susceptible to winter damage. It may take a vineyard several years to fully recover after severe winter injury. Young shoots and tendrils (**Figure 53**), rachises and cluster parts (**Figures 54, 55**) also can be attacked by downy mildew, particularly during the months of June and July (Ellis, 2008).

Downy mildew is caused by the fungus *Plasmopora viticola*, which over winters on old dead leaves on the vineyard floor and possibly in diseased shoots. During rainy periods in late spring and early summer, fungus spores are released into the vineyard, carried to vine tissues in the air or in water splashed up from the ground onto the vine. If sufficient moisture is present on the leaves, the spores germinate and the infection begins. The lesions caused by this initial infection mature and then produce mildew spores themselves. Under conditions of high humidity (such as heavy dew on the leaves) and optimal temperatures of 50-60^{o} F, this secondary batch of spores is released to infect other vines (Ellis, 2008).

Both cultural and chemical means contribute to successful control of downy mildew. First, the only cause of initial downy mildew infection is overwintering fungus present on dead leaves. Dead leaves and berries should be removed from vines and the ground after leaf drop. A spring cultivation of the vineyard that tills in the dead leaves, berries and other debris will also greatly reduce the potential of over wintering spores to reach the developing vines in the spring. When pruning, select only strong, healthy, well-colored canes of the previous year's growth. Secondly, downy mildew on vines can propagate itself into a secondary infection only if a film of moisture is present on the leaf surface. Cultural methods which promote good air circulation and rapid leaf drying will combat these secondary infections. Such methods include selecting a vineyard site with good airflow, controlling weeds and tall grasses in the vineyard and surrounding areas. Spacing, canopy management practices such as shoot positioning and lateral shoot and leaf removal will help open the canopy for improved air circulation and spray coverage and avoiding overcrowding. (Ellis, 2008). Fungicides that are effective in controlling downy mildew are listed in **Table 37**.

Figure 52. Downy mildew on the bottom and top side of leaves.

Figure 53. Downy mildew on young shoot and tendrils.

Figure 54. Downy mildew on a young cluster.

Figure 55. Downy mildew on berries.

Powdery Mildew

In Minnesota and the upper Midwest, powdery mildew can be a problem almost every year on susceptible cultivars. The disease first appears on the upper surfaces of leaves as indistinct white patches, which later develop a powdery appearance (**Figure 56**). These can enlarge so that the entire leaf takes on a powdery appearance. In severe cases, the entire leaf may turn brown and curl upward by late season (or expanding infected leaves may become distorted and stunted) (**Figure 57**) and drop prematurely, resulting in poor wood maturity and a reduction in vine hardiness. If blossom clusters are affected, the flowers may wither and drop without setting fruit. Infections on cluster stems often go unnoticed, but can be very damaging. Infected rachises may wither and dry up, resulting in berry drop (shelling). Affected berries may have spots on the surface similar to those on the leaves, or the entire berry may be covered with the white, powdery growth (**Figure 59**). Infected berries often are misshapen or have rusty spots on the surface. Severely affected fruit often split open. When berries of purple or red cultivars are infected as they begin to ripen, they fail to color properly and have a blotchy appearance at harvest. Berries are susceptible to infection until their sugar content [^{o}Brix, or soluble solids (SS)] reaches about 8%. Infected clusters are of no use in winemaking because the characteristic musty odor of powdery mildew persists in the wine (Ellis, 2008f).

Powdery mildew is caused by the fungus *Uncinula necator*. It was previously thought that the powdery mildew fungus over wintered inside dormant buds of the grapevine. Recent research in New York has shown that almost all overwintering inoculum in Northeastern U.S. comes from cleistothecia, which are fungal fruiting bodies that overwinter primarily in bark crevices on the grapevine. In the spring, airborne spores (ascospores) released from the cleistothecia are the primary inoculum for powdery mildew infections. Ascospore diskharge is initiated when 0.1 inch of rain occurs with an average temperature of 50^{o} F. Most mature ascospores are diskharged within 4-8 hours. Ascospores are carried by wind. They germinate on any green surface on the developing vine, and enter the plant resulting in primary infections. The fungus produces another type of spore (conidia) over the infected area after 6-8 days. The conidia and fungus mycelia on which they are formed give the powdery or dusty appearance to infected plant parts. On young shoots, infections are more likely to be limited, and they appear as dark-brown to black patches that remain as dark patches on the surface of dormant canes (**Figure 59**). These are the sexual fruiting bodies (cleistothecia) of the fungus. Cleistothecia are formed on the surface of infected plant parts in late fall. Many of them are washed into bark crevices on the vine trunk where they overwinter to initiate primary infections during the next growing season (Ellis, 2008f).

The conidia serve as "secondary inoculum" for powdery mildew infection throughout the remainder of the growing season. It is important to note that a primary infection caused by one ascospore can result in the production of hundreds of thousands of conidia, each of which is capable of causing secondary infections that spread the disease (Ellis, 2008).

Powdery Mildew Control

Temperatures of 68-77° F are optimal for infection and disease development, although infection can occur from 59-90° F. Temperatures above 95° F inhibit germination of conidia and above 104° F they are killed. It is important to remember that powdery mildew can be a serious problem in drier growing seasons when it is too dry for other diseases such as black rot or downy mildew to develop. Select an open planting site with direct sunlight. Plant rows in the direction of the prevailing wind in order to promote good air circulation and faster drying of foliage and fruit. Prune and train vines properly in such a way as to reduce shading and increase air circulation (Ellis, 2008f). Fungicides that are effective in controlling powdery mildew are listed in **Table 37**.

Figure 56. Powdery mildew on leaves.

Figure 57. Severe powdery mildew on older leaves.

Figure 58. Powdery mildew on berries.

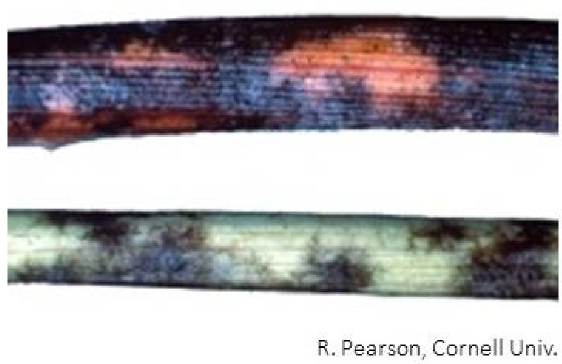


Figure 59. Powdery mildew on a shoot and cane.

Bunch Rots:

Grapes can be infected by several late season bunch rots that cause serious crop losses if not controlled. These diseases include Botrytis bunch rot, ripe rot, bitter rot and sour rot. It is important to be able to identify these rots because control measures differ between them.

Botrytis bunch rot, sometimes referred to as gray mold, is caused by the fungus *Botrytis cinerea*. Cultivars which tend to be tight-clustered seem the most susceptible. The infection of ripe berries can result in significant loss of yield. In the initial stages of the disease, the infected berries (which may be one or a few within the bunch or the entire bunch) will become soft and watery. Then berries of white cultivars become brown and shriveled, and those of purple cultivars develop a reddish color (**Figure 60A, B**). Under high relative humidity and moisture, infected berries usually become covered with a gray growth of fungus mycelium. Generally, healthy berries touching infected berries will become infected. Rotted berries generally shrivel with time and drop to the ground as hard mummies. The fungus also can cause a blossom blight that can result in significant crop loss early in the season (**Figure 60C**) (Ellis, 2008b).

The fungus overwinters in grape mummies, dead grape tissues, and other organic debris in and around the vineyard. It's also on many other plant hosts, so growers always should assume that the fungus is present in the vineyard.

During the spring, the fungus germinates from small, dark, hard resting structures known as sclerotia, and produces spores (conidia) which spread the disease. These spores are produced throughout the growing season. As blossoms die, the spores germinate and colonize dead flower parts. Using the dead tissue as a food base, the fungus invades living tissue. After penetrating the berry, the fungus may remain dormant until the fruit sugar content increases and acids decrease to a level that supports fungus growth. Symptoms then develop readily under warm, moist conditions. Unfortunately, berries that escape bloom-time infection may become infected at or near harvest under favorable environmental conditions. Also, any wound on the berry provides an excellent infection site for the fungus, even in the absence of favorable environmental conditions. Birds, insects, hail, and powdery mildew are common causes of wounds. Swelling during ripening in tightly packed clusters causes pressure that also can rupture the berries. Wet and humid conditions around the berries and leaves greatly enhance disease development. The longer wet conditions persist, the greater the probability of infection, even to undamaged berries (Ellis, 2008b).

Practices for controlling Botrytis bunch rot include: 1) Cultural practices to increase air circulation and light penetration in the vineyard to reduce wetting periods. Leaf removal around clusters on mid- and low-wire cordon trained vines before bunch closing has been shown to reduce infections in New York and California vineyards. 2) Preventing wounding by controlling insects, birds and other grapes diseases. 3) In commercial vineyards, effective fungicides applied beginning at bloom and other appropriate tines during the growing season. Fungicides that are effective in controlling Botrytis bunch rot are listed in Table 37.

Ripe Rot occurs on ripened berries at or near harvest. It is caused by fungi in the genus *Colletotrichum*, and is a disease that is more common to warm, humid grape growing regions of the U.S., but was found on Frontenac and Frontenac gris grapes growing in Vernon County, Wisconsin in 2010 (Figure 61A) (Jordan, 2010). Ripe rot symptoms begin as circular, reddish-brown spots on the berries. These later enlarge to cover the entire berry. Small black fruiting bodies develop on berries (Figure 61B). Under wet, humid conditions, salmon to orange-colored, "goo" spores will begin to develop on the surface of the fruit (Figure 61C). Once a berry begins to shed spores, the infection can spread rapidly within the cluster and to surrounding clusters, particularly under warm, wet (including dew and fog) conditions (Jordan, 2010).

Ripe rot overwinters as dormant mycelium in old infected berries and infected pedicels (berry stems). Controlling ripe rot includes: 1) Good vineyard sanitation practices – proper dormant pruning and destruction of canes, mummies and old rachises. 2) Early season fungicide spray program targeting black rot and other early season diseases (Smith, 2013). Following veraison, spray options are Captan or strobilurin fungicides (Jordan, 2010).

Bitter Rot caused by *Melanconium fuligineum* is a fungal disease of grapes that is more common to warmer grape growing regions of the United States. It gets its name from the bitter taste that develops in infected berries, and the use of 10% infected berries can make the wine undrinkable. Bitter rot can affect young shoots, the rachis and berries. When the rachis is infected early in the season, it is killed and the berries shrivel and remain attached. When the rachis is infected late in the season, berries may fall from the cluster. Berry infection during maturation is most obvious symptom. This begins as a brownish, water-soaked lesion that spreads rapidly, often forming concentric rings (Figure 62A). The infected berries usually maintain their shape and are dull brown in color. In 2 to 3 days the skin is ruptured by black fungal structures (Figure 62B). The infected fruit shrivel into black mummies that closely resemble black rot which bitter rot is often confused with (*black rot affects green berries before veraison, while bitter rot affects maturing berries after veraison*) (Ellis, 2008c) .

Practices for controlling bitter rot include: 1) Cultural practices to increase air circulation and light penetration in the vineyard to reduce wetting periods. 2) Preventing wounding by controlling insects, birds and other grapes diseases. 3) being able to distinguish between bitter rot and black rot because a spray program for black rot generally stops as veraison, which would be disastrous if bitter rot is present. 4) a fungicide spray program that is recommended for controlling most common grape diseases should be beneficial in controlling bitter rot. (Ellis, 2008c)

Sour Rot is caused by a disease complex that affects both grape yield and wine quality. Cultivars with tight clusters and thin skins tend to be more susceptible to the disease. Symptoms of sour rot (Figure 63) may be mistaken for Botrytis bunch rot since both diseases begin as a soft watery rot. However, the lack of Botrytis fungal growth on the fruit surface and the presence of an obvious vinegar odor are indicative of sour rot. As the rot progresses, berries leak juice and collapse as the disease spreads through the cluster. Large numbers of fruit flies are also attracted to the infected clusters and can spread the disease (Hartman and Kaiser, 2008)

Sour rot has been associated with a number of undesirable yeasts, bacteria and decay fungi. Wounds caused by insects, other fungal diseases, hail, birds, etc. provide an entry point for these organisms. Practices for controlling sour rot include: 1) Planting cultivars with loose clusters. 2) Good sanitation practices, removing and destroying any remaining mummies and rachises during dormant pruning. 3) Cultural practices to increase air circulation and light penetration in the vineyard to reduce wetting periods. 4) Providing protection against insects and bird that may injure the fruit. 5) There are no fungicides specific for controlling sour rot. Following a season-long fungicide spray program for other diseases will aid in managing sour rot (Hartman and Kaiser, 2008).

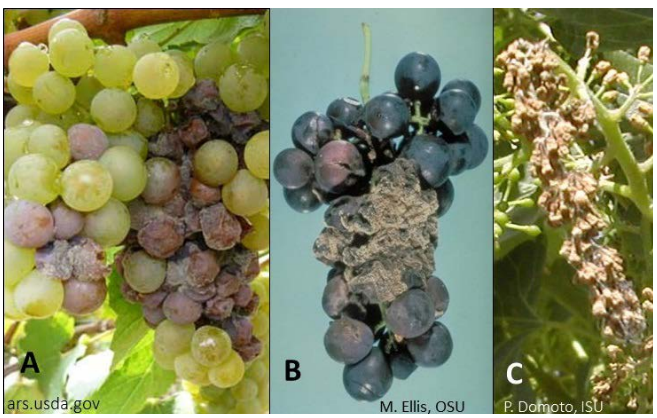


Figure 60. Botrytis bunch rot.

Figure 61. Ripe rot.

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Figure 62. Bitter rot.

Figure 63. Sour rot.

Crown Gall

Crown gall is caused by the bacterium *Agrobacterium tumefaciens*. The bacteria will induce galls or tumors on the roots, crowns, trunks and canes of infected plants. These galls will interfere with water and nutrient flow in the plants causing seriously infected plants to become weakened, stunted and unproductive. Their leaves may turn yellow or red (**Figure 64**). The disease first appears as small overgrowths or galls on the roots, crown, trunk or canes. Galls usually develop on the crown or trunk of the plant near the soil line or underground on the roots. They usually form in late spring or early summer and can be formed each season. As galls age they become dark brown to black, hard, rough, and woody (**Figure 65**) (Ellis, 2008a).

The crown gall bacterium is soil-borne and persists for long periods of time in the soil in plant debris. It requires a fresh wound in order to infect and initiate gall formation. Wounds that commonly serve as infection sites are those made during pruning, machinery operations, freezing injury, growth cracks, soil insects and any other factor that causes injury to plant tissues. The bacteria over winter inside the plant (systemically) in galls, or in the soil. When they come in contact with wounded tissue of a susceptible host, they enter the plant and induce gall formation, thus completing the disease cycle. The bacteria are most commonly introduced into a planting site on or in planting material (Ellis, 2008a). There is a risk of spreading Agrobacterium if sanitation practices aren't maintained on pruning equipment.

In the upper Midwest, crown gall symptoms most commonly appear following a stressful winter on cultivars that are marginally adapted to the region. Therefore, planting cultivars adapted to the region is the most effective measure for controlling crown gall.

Figure 64. Early symptom of a vine with crown gall.

Figure 65. Crown gall on trunks.

Cultivar Sensitivity to Fungicides

Some fungicides can be phytotoxic to grapevine foliage either because of cultivar sensitivity or the environmental conditions at the time of application. Therefore, it is important to read the pesticide label before applying any fungicide.

Sulfur is an inexpensive fungicide that is very effective for controlling powdery mildew and is also approved for use in organic vineyards (**Table 37**). However, some cultivars are very sensitive to sulfur and on those cultivars, it can cause significant injury to the foliage and possible defoliation (**Figure 66A**). Even on non-sensitive cultivars, sulfur sprays can cause some foliar injury if applied when temperatures are above 85^{o} F (**Figure 66B**).

Copper sprays (copper sulfate, Bordeaux mixture, fixed coppers) are some of the oldest fungicides for controlling grape diseases and is very effective for controlling downy mildew (**Table 37**). It is also approved for use in organic vineyards. However, some cultivars are sensitive to copper sprays (**Figure 67A**). During the early stages of shoot development, injury can occur even on non-sensitive cultivars when copper is applied under conditions of prolonged cool, cloudy, wet conditions that are promote slow drying and greater absorption of the copper into the leaves (**Figure 67B**). Therefore, it is best to avoid using sprays containing copper early in the growing season. The **Midwest Small Fruit and Grape Spray Guide** (Bordelon, *et al*. *annual publ*) lists additional safety measures when using copper sprays.

Strobilurin fungicides are a relatively new class of fungicides that provide control for a broad spectrum of common grape diseases (**Table 37**). However, Flint and Pristine will cause severe injury when applied on Concord grapevines and other related cultivars (**Figure 68**). For grape growers that also grow apples, Abound is very phytotoxic to McIntosh and related cultivars to the extent that separate sprayers should be used on the two crops.

Under specific conditions, various grape cultivars can exhibit some sensitivity to other fungicides, so it is important to fully read the product labels when using fungicides.

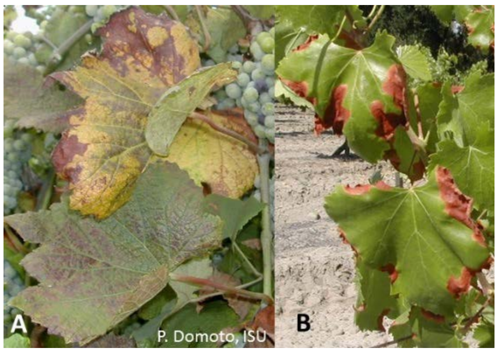

Figure 66. Sulfur injury on a sulfur-sensitive grapevine (A), and injury on a non-sensitive grapevine when applied when temperatures were above 85° F (B).

Figure 67. Copper injury on a copper-sensitive grapevine (A), and injury on a non-sensitive grapevine when applied when early spring under cool, wet, cloudy conditions (B).

Figure 68. Strobiluin injury on a Concord grape leaf.

Scouting and monitoring grape diseases

A good disease management program includes learning to recognize the various diseases of grapes and this knowledge should be put to use by scouting the vineyard on a regular basis to determine if a problem exists. **A Pocket Guide for Grape IPM Scouting in North Central and Easter U.S.** (Isaacs, *et al*., 2003) is a very useful tool to aid in identifying the various diseases. Another approach to scouting is the use of weather-based electronic monitoring systems that are now commercially available. These systems that monitor temperature, rainfall, humidity and drying time and input the data into a modeling program. Programs are available for black rot, downy mildew, powdery mildew, Phomopsis cane and leaf spot, and Botrytis bunch rot.

Fungicide Resistance Management

Plant diseases have been known to develop resistance to fungicides after repeated exposures. This is particularly true for those fungicides that exhibit inhibitor properties. To reduce the risk of a disease developing resistance to a fungicide, the Fungicide Resistance Action Committee (FRAC) developed a code to identify the various fungicide modes-of-action groups (**Table 36**). When using fungicides, avoid successive applications of fungicide or fungicides having the same FRAC mode-of-action code, follow recommendations on combining fungicides, and any restrictions on the number of applications or total material that can be applied during a growing season (**Table 37**).

Table 36. Fungicide Resistance Action Committee (FRAC©) mode-of-action code for grape fungicides.[z]

FRAC Code	Mode-of-Action
M	Multi-site contact activity (*Protectant fungicides, not considered at risk for resistance development)*
1, 43	Inhibits mitosis and cell division
1, 12, 13	Inhibits signal transduction
3, 17	Inhibits sterol biosynthesis in membranes
4	Inhibits nucleic acid synthesis
7, 11, 21, 45	Inhibits respiration (*Strobilurin fungicides*)
9	Inhibits amino acid and protein synthesis
40	Inhibits cell wall biosynthesis
33, U6, U8	Unknown mode-of-action
NC	Not classified

[z] *From*: FRAC Code List© 2015 (www.frac.info)

Additional information on spray schedules for grape disease control can be found in **Midwest Small Fruit and Grape Spray Guide** (Bordelon, *et al. annual publ*). The spray guide is an annual publication that is available from most State Cooperative Extension Publication Distribution Centers in the North Central Region. A pdf version is posted at: https://ag.purdue.edu/hla/Hort/Documents/ID-169.pdf

Table 37. Characteristics of fungicides registered for use on grapes.

Fungicide	Effectiveness in Controlling Disease [z]							FRAC Code [y]	Restrictions [x]		
	Anthracnose	Phomopsis	Black rot	Downy mildew	Powdery mildew	Botrytis fruit rot	Bitter rot		REI	PHI	Max. Product, ai or Apl / Season
Organic-approved fungicides:											
Copper, Bordeaux mix	0	+	+	+++	++	+	+	M	24 h	0 d	
Liquid lime sulfur	+++							M	48 h	n/a	
Sulfur	+	+	0	0	+++	0	0	M	24 h	0 d	
Phosphorous acid	?	0	0	+++	0	0	0	33	4 h	0 d	
Potassium salts	?	0	0	0	++	0	0	NC	4 h	1 d	
JMS Stylet oil	?	0	0	0	+++	+	0	NC	4 h	0 d	
Protectant fungicides:											
Captan	++	+++	+	+++	0	+	++	M	72 h	0 d	12 lb ai
Ferbam	?	+	+++	+++	0	0	0	M	24 h	7 d	
Mancozeb	+++	+++	+++	+++	0	0	0	M	24 h	66 d	19.2 lb ai
Ziram	++	++	+++	++	0	0	0	M	48 h	10 d	28 lb
Ridomil Gold MZ	+++	+	++	+++	0	0	++	4, M	48 h	66 d	10 lb
Ridomil Gold Copper	++	+	+	+++	++	+	+	4, M	48 h	42 d	4 Apl
Broad-spectrum inhibitor fungicides: (Should be used in combination with a FRAC code M fungicide)											
Topsin M	+++	++	+	0	+++	++	++	1	7 d	14 d	4.2 lb ai
Bayleton	?	0	+++	0	+++(FRP)	0	0	3	12 h	14 d	18 oz
Mettle	++	0	+++	0	+++(FRP)	0	0	3	12h,7d[w]	14 d	
Procure	?	0	++	0	+++(FRP)	0	0	3	24 h	7 d	32 oz
Rally	++	0	+++	0	+++(FRP)	0	0	3	24 h	14 d	1.5 lb
Inspire Super	+++	0	+++	0	+++	?	?	3, 9	12 h	14 d	80 oz
Revus Top	++	0	++	+++	+++	0	0	3, 40	12 h	14 d	28 oz
Endura	+++	0	0	0	+++	++	0	7	12 h	14 d	3 or 5 Apl
Luna Privilege	?	?	0	0	+++	++	?	7	12 h	7 d	13.7 oz
Narrow-spectrum inhibitor fungicides: (DO NOT apply more than 2 sequential sprays using one of these products or products with same FRAC code)											
Quintec	0	0	0	0	+++	0	0	13	12 h	14 d	33 oz, 5 Apl
Torino	0	0	0	0	+++	0	0	U6	4 h	3 d	6.8 oz, 2Apl
Vivando	0	0	0	0	+++	0	0	U8	12 h	14 d	42.6 oz
Forum	0	0	0	+++	0	0	0	40	12 h	14 d	24 oz, 4Apl
Zampro	0	0	0	+++	0	0	0	40, 45	12 h	14 d	56 oz
Presidio	0	0	0	+++	0	0	0	43	12 h	21 d	
Ranman	0	0	0	+++	0	0	0	21	12 h	30 d	16.5oz, 6Apl
Revus	0	0	0	+++	0	0	0	40	4 h	14 d	32 oz
Botrytis control fungicides: (DO NOT apply more than 2 sequential sprays using one of these products or products with same FRAC code)											
Elevate	?	0	0	0	0	+++	0	17	12 h	0 d	3 lb
Rovral	?	0	0	0	0	+++	0	2	48 h	7 d	4 Apl
Scala	?	0	0	0	0	+++	0	9	12 h	7 d	36 oz
Switch	0	0	0	0	0	+++	?	9, 12	12 h	7 d	56 oz
Vangard	?	0	0	0	0	+++	0	9	12 h	7 d	30 oz
Strobilurin fungicides: (DO NOT apply more than 2 sequential sprays using one of these products or products with same FRAC code)											
Abound	+++	+	+++	+++(FRP)	+++(FRP)	++	?	11	12 h	14 d	92.3 oz
Adament	?	+	+++	+	+++(FRP)	++	?	3, 11	24 h	14 d	48 oz, 6Apl
Flint	?	+	+++	+++(FRP)	+++(FRP)	++	0	11	12 h	14 d	24 oz, 6Apl
Pristine	+++	++	+++	+++(FRP)	+++	++	?	7, 11	12h,5d[w]	14 d	69 oz, 5Apl
Quadris Top	+++	+	+++	+++	+++(FRP)	?	?	3, 11	12 h	14 d	56 oz
Sovran	+++	+	+++	+++(FRP)	+++(FRP)	++	?	11	12 h	14 d	25.6oz,4Apl

[z] Effectiveness: +++ = highly effective; ++ = moderately effective; + = slightly effective; 0 = not effective; ?= effectiveness unknown; FRP= fungicide resistance possible.

[y] Fungicide Resistance Action Committee code.

[x] Restrictions: REI = re-entry interval; PHI = pre-harvest interval; Maximum units of product, active ingredient (ai) or number of applications per season.

[w] REI when shoot positioning or cane girdling.

* From different sections of the Midwest Small Fruit and Grape Spray Guide 2015, and pesticide labels. Registration for use on grapes and restrictions can change from year to year.

Vineyard Best Management Practices – Vineyard Pest Management

Rate your vineyard pest management practices:

Management Area: **Grape diseases**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Identification	Learned to identify the common grape diseases, their life cycles & when infection can occur, and scout weekly.	Learned to identify the common grape diseases & when infection can occur, and scout regularly.	Learned to identify some of the common grape diseases, and scout periodically.	Can only identify a few common grape diseases, and seldom scout.
Cultural control	Site & cultural practices to promote good air circulation & fast vine drying, and pruning out infected canes & mummies.	Site & cultural practices to promote good air circulation & fast drying.	Pruning out infected canes & mummies.	No emphasis to prune out infected canes & mummies or practices to promote good air circulation & fast vine drying.
Fungicides	Selected fungicides or combinations that effectively control the specific diseases or disease combinations when infections can occur, & considered cost effectiveness.	Selected fungicides or combinations that effectively control the specific diseases or disease combinations when infections can occur.	Relied on someone else to develop my disease control program.	Use the same fungicides throughout the growing season.
Fungicide resistance management	Avoid successive applications of a fungicide or fungicides with same FRAC code; follow recommendations on combining fungicides, & any restrictions on number of applications or total material applied during a season.	Follow recommendations on combining fungicides, & any restrictions on number of applications or total material applied during a season.	Follow any restrictions on number of applications or total material applied during a growing season.	Use the same fungicides throughout the growing season.
Fungicide usage restrictions	Follow restrictions on re-entry interval (REI) and pre-harvest interval (PHI) when applying fungicides.			Lax on follow restrictions on re-entry interval (REI) and pre-harvest interval (PHI) when applying fungicides.

Insect Pests of Grapes

Grape Berry Moth

The grape berry moth (*Paralobesia viteana* Clemens) can be found wherever wild and cultivated grapes are grown. They have mostly been a problem in the northeastern United States, but there is concern that they may be moving towards the west. They often bore into ripening berries later in the season and significantly damage the crop. If left uncontrolled populations can develop and significantly damage the crop.

The grape berry moth overwinters as pupae in leaf litter in and around vineyards. Around bloom, the first generation adults emerge from the pupae. The adult is a mottled brown-colored moth with some bluish-gray on the inner halves of the front wings (**Figure 69**). The females lay circular flat eggs directly unto the cluster. The eggs can be difficult to find because of their small size (approximately 1 mm diameter). Their shiny exterior can be used to detect them, especially with a hand lens. Larvae hatch from the eggs and feed on young grape clusters, sometimes removing sections of clusters, and leaving webbing on the rachis (**Figure 70**). When the berries are formed, the young larvae burrow into the fruit. Webbing and larvae are visible in the small clusters during and after bloom (Isaacs, 2014).

There are two or more generations of larvae per year. Second generation larvae feed on the expanding berries, and feeding sites are visible as holes. Larvae may web together multiple berries. Larvae of the third generation feed inside berries before and after veraison (**Figure 71**). Berries may be hollowed out by feeding, and larvae at this time may contaminate harvested fruit. Damage by grape berry moth after veraison predisposes berries to infection by Botrytis and sour rots and can attract fruit flies, wasps and ants (Isaacs, 2014).

In areas where grape berry moths are suspected to be a concern, it is important to scout in mid- to late-July for eggs and larvae. Infestation is often greater on the border than the interior of vineyards, particularly near woods or hedgerows. Detecting egg laying and egg hatch helps accurately time insecticide controls (Isaacs, 2014). Pheromone traps can be used to monitor grape berry moth adult activity. Pheromones can also be used as mating disruption strategy to control grape berry moth using Isomate®-GBM a twist-tie product impregnated with the pheromone (Bordelon, Foster and Gautier, *annual publ*). Insecticides that that provide good control of grape berry moths are listed in **Table 38**.

Figure 69. Grape berry moth adult.

Figure 70. Grape berry moth damage on a young grape cluster.

Figure 71. Grape berry moth larva feeding on a grape berry.

Grape Flea Beetle

Grape flea beetles (*Altica chalybea*) emerge early in the spring, boring into the swelling buds by chewing holes in the ends and sides of the buds, damaging primary and occasionally secondary and tertiary buds, causing the internode to be non-productive for that year (**Figures 72, 73**). Once the buds begin to open, the threat diminishes. Female beetles lay eggs mainly under loose bark and larvae begin feeding on developing leaves. The damage from larvae and adults feeding on the young leaves is usually spotty and not severe. The beetle is about 3/16th of an inch long and is metallic steel blue or greenish blue in color. Adults can be seen on canes and buds on warm sunny days in April and May. Flea beetle damage is often concentrated in vineyard borders and near wooded or brushy areas. Spot treatment may be all that is needed to control this pest. The threshold used to determine if there is need for intervention with a spray is at 5% bud damage, when the buds are just beginning to swell (Williams, *et al*.). Insecticides that provide good control of grape flea beetles are listed in **Table 38**.

Figure 72. Grape flea beetle adult.

Figure 73. Grape flea beetle injury.

Multicolored Asian Lady Beetle (MALB)

Lady beetles are normally considered beneficial insects that feed on smaller insects such as aphids and mites. However, the multicolored Asian lady beetle (*Harmonia axyridis)*, has become an economically significant contaminant pest in the winemaking process throughout the Midwest, and Northeastern U.S. They were first detected in Minnesota in 1994 (Wold-Burkness, *et al*., 2012) and their rapid population explosion has been attributed to the sudden arrival of the Chinese soybean aphid (Dami, *et al*., 2005). Some MALB can be found in vineyards throughout the growing season, but as soybeans mature and dry later in the growing season, they disperse and begin seeking a sugary food source that grapes offer (Dami, *et al*., 2005), and tend to aggregate on and within grape clusters just before harvest (**Figure 74**). Some beetles may be crushed along with the grapes during the wine pressing, releasing their foul smelling hemolymph (insect blood). This MALB "residue" taints the flavor and aroma of the resulting wine. Research has shown that 10% of wine consumers can detect MALB taint when the grapes are contaminated with 0.3 MALB per cluster (Wold-Burkness, *et al*. 2012). Control measures are not justified until 1-2 weeks before harvest. There are three reasons why grape growers should not control MALB earlier in the season.

1. This insect cannot directly damage, or penetrate grape skins. To date, MALB have only fed on berries that have been previously damaged by other insects, birds, diseases, or "splitting." Although berries can be damaged as early as the berry set stage, damage increases dramatically as the sugar content rises over the last few weeks of ripening.
2. MALB is a contaminant pest and its presence in the vineyard throughout the growing season does not affect grape yield.
3. MALB is one the most abundant predators of several insect pests, including pests of grapes, and in several other crops (e.g., soybeans, sweet corn), where they may further contribute to reducing insect pest populations.

Monitoring and Sampling Options: Since MALB cannot cause initial damage on berries, preventing or minimizing physiological splitting damage to berries should decrease MALB infestations on grapes. Sampling can be done using yellow sticky cards, as an "early warning" indicator of the potential presence of MALB in clusters. However, within 10-14 days of harvest, growers should sample the clusters directly for beetles. Only 26 clusters selected randomly throughout each one-acre block need to be sampled. A cluster is considered infested if one or more beetles are found. You do not have to count all the beetles in each cluster. Instead, add up the number of clusters infested out of 25. Current research indicates that if 18% or more of the clusters are infested within 10-14 days of harvest, the planting is at high risk for MALB contamination, and an insecticide spray is warranted (Wold-Burkness, *et al.*, 2012).

Chemical Control Options: Insecticide trials conducted at the University of Minnesota (Galvan, *et al*., 2006) have shown that Sevin® is one of the most effective insecticides available, based on a cost benefit analysis. However, Sevin® has a 7 day pre-harvest interval (PHI) that allows time for MALB to re-infest the clusters. **Table 38** lists insecticides that are effective in controlling MALB that have shorter re-entry (REI) and PHI intervals. Aza-Direct® and Neemix® do not kill the adult stage of MALB, but act as repellants to drive them out of the grapevines.

If MALB continues to be present at harvest, beetles must be removed by shaking clusters and covering bins where clusters are held. Growers may also float clusters in buckets of water or vacuum clusters to remove beetles. However, each method has resulted in significant increases in time and labor, and increased the costs of harvest.

Figure 74. Multicolored Asian lady beetle (MALB) feeding on grapes.

Figure 75. Grape phylloxera galls on the underside of a mature leaf.

Figure 76. Grape phylloxera galls on a shoot tip and emerging leaves.

Figure 77. Grape phylloxera leaf damage on a Frontenac grapevine exposing the clusters to better light exposure.

Grape Phylloxera

In the U.S. east of the Rocky Mountains, the grape phylloxera louse (*Daktulosphaira vitifoliae*) is endemic and has been here, evidently for centuries. This tiny insect forms galls on leaves (**Figure 75**) and roots of grapevines. It is believed that this insect originated in the Eastern United States, where damage is now most prevalent on leaves of French-American hybrid grapevines. While a few galls are not harmful, repeated hatchings throughout the summer can result in markedly deformed leaves which can result in premature defoliation, reduced shoot growth, and reduced yield and quality of the crop.

In most wine producing regions of the world where grape phylloxera has become established, including California, *V. vinifera* cultivars are killed by the root galls and must be planted on resistant rootstock. Even though most grapes common in Minnesota and the upper Midwest are immune to phylloxera root damage and do not need a resistant rootstock, the foliar form of phylloxera is still common resulting in some cultivars getting leaf galls from this pest. This aphid-like insect is very small and difficult to see with the unaided eye. Galls formed by phylloxera are more readily identified than the insects. The damage appears as bumpy, felty galls on the underside of leaves (Dami, *et al*., 2005).

Grape phylloxera overwinter either as a winter egg under the bark of older canes or trunks or as nymphs on grapevine roots. The winter egg gives rise to the stem mother, which moves to a nearby shoot tip and begins feeding. Feeding by the phylloxera elicits gall formation, and the female becomes enclosed within a small, spherical gall on the underside of the grape leaves. The female is capable of producing several hundred eggs asexually. First instar nymphs, or crawlers, emerge and move out of galls to nearby shoot tips where they begin feeding and thereby initiate formation of new galls (**Figure 76**). Throughout the summer a certain portion of the foliar crawlers move actively or passively to the soil surface. These crawlers may move through cracks in the soil and eventually reach grapevine roots. Feeding by phylloxera on grapevine roots results in two types of galls. Nodosities are galls formed on small, apical rootlets and generally thought to result in little damage to the vine. Tuberosities are galls formed on larger, older portions of the root which, if sufficiently abundant, may eventually result in death of the vine (Williams, *et al*.).

Phylloxera Control

Phylloxera crawlers can be spread on vineyard equipment. Therefore, when mechanical operations are performed, equipment should not be moved from an infested block to a non-infested block. Infestations may also originate from wild grapevines near the vineyard, so these areas should be monitored carefully. Wild grapevines near the borders of vineyards should be destroyed if possible. (Williams, *et al*.).

Grape cultivars differ in their susceptibility to leaf-feeding form of phylloxera. Frontenac along with its color mutations, La Crescent and to some extent Marquette are particularly susceptible to phylloxera, while cultivars with a strong *V. labrusca* lineage are seldom affected. **Table 38** lists insecticides that are effective in controlling grape phylloxera. They should be applied just before bloom and most of them should be followed by a repeat application 10-14 days later. Therefore, it is important to scout the vineyard blocks before bloom to determine if there is a need for phylloxera control. If a cultivar had a high incidence of phylloxera galls the previous season and numerous galls are present on the young leaves, phylloxera control may be warranted. However, if there are only a few to moderate number of galls present, and at least 15 leaves on the primary shoots are gall-free, a moderate phylloxera infestation can be beneficial later in the growing season in opening up the canopy for better light exposure for the clusters (**Figure 77**).

Japanese beetle

Japanese beetles (*Popillia japonica*) have been spreading westward since they were first detected in New Jersey in 1916, and have recently spread west of the Mississippi River in some areas. The adult feeds on foliage, fruits and flowers of more than 250 kinds of plants, of which grapevines are one of their preferred hosts. The larvae are grubs that live in the soil and feed on grass roots. The adult beetles have a shiny, metallic-green head and thorax, coppery wing covers, and tufts of white hairs along the sides of their body (**Figure 78**). The adults emerge from the ground in late June through July and sometimes into August, and begin feeding. Damaged leaves have a laced, skeletonized pattern. Cultivars with thin, smooth leaves are preferred over cultivars with thick, pubescent leaves (Dami, *et al.*, 2005). Damage is often worse on the edges of the vineyard on sun-exposed leaves (**Figure 79**).

There are no economic thresholds on the number of beetles or amount of damage that warrants control measures. When Japanese beetles begin to emerge, vineyards should be frequently scouted for the number of beetles and damage. There are Japanese beetle traps available, but they are not recommended because they can attract more beetles into the vineyard (Wold-Burkness, 2011b). A Virginia study found that Japanese beetle feeding prior to veraison did not significantly reduce fruit quality, yield or vine growth with up to a 6.5% loss of foliage. After veraison, an accumulated leaf loss of 11% reduced fruit quality (Wolf, *editor*, 2008). Growers need to assess the Japanese beetle damage relative stage of fruit development when determining if treatment is required. Additional treatments may be needed as more beetles emerge to keep the damage under control. Insecticides that that provide good control of Japanese beetles are listed in **Table 38**.

Figure 78. Adult Japanese beetles feeding on grape leaves.

Figure 79. Japanese beetle damage on sun exposed leaves of grapevines.

Other Insects that can be a problem in vineyards:

There are a number of other insects that can be a problem in vineyards or are relatively new pests to the upper Midwest and have the potential to cause significant economic damage. **Table 38** lists insecticides that are effective in controlling some of the important pests listed below. Additional information on all the pests covered and other pests can be found in several publications:

- Midwest Small Fruit Pest Management Handbook
- Midwest Grape Production Guide
- Wine Grape Production Guide for Eastern North America
- Grape IPM Guide for Minnesota Producers
- Pocket Guide for Grape IPM Scouting in the North Central and Eastern U.S.

Climbing cutworms (Figure 80) are an early spring pest that emerge from the soil and climb up the grapevines to feed on the young buds at night (Rufus, *et al*., 2001). They are mainly a pest in vineyards on sandy soils and in vineyards with weeds under the vines. Injury is often worse in years when cool temperatures slow bud development.

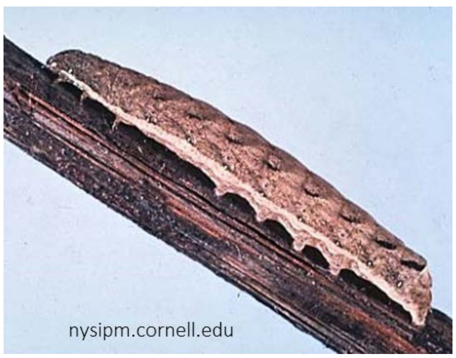

Figure 80. Climbing cutworm

Figure 81. Leaf rolled by redbanded leafroller larva.

Figure 82. Redbanded leafroller larva.

Redbanded leafroller adult moths emerge at about the 3 to 5 inch shoot growth and females lay their eggs on the shoots. First generation larvae feed new foliage and fruit clusters. Two more generations usually occur with the last generation being the most damaging. Larvae will roll leaves (**Figure 81**) and may be seen in the clusters (**Figure 82**). They eat holes in the sides of berries but not enter (Wolf, *editor*, 2008). .

Wasps and yellow jackets can be a vineyard pest (**Figure 83**). In the fall, they seek sugars in their diet and seek out ripening fruit such as grapes. They usually gather after some other pest such as birds have damaged the berries and the smell of broken berries will attract them. They can damage additional fruit and are often a detriment to pickers at harvest. Wasp traps, baited with a sugar solution, situated around the vineyard can help reduce moderate infestations. In addition, if pickers are being stung or fear stinging, inexpensive latex gloves, available at any drug store, effectively protects pickers' hands from being stung (Wold-Burkness, 2011c).

Figure 83. Wasp feeding on grapes.

Figure 84. Honey bees feeding on grapes.

Honey bees will also feed on grapes as they ripen (**Figure 84**). They can pierce the skin and can be a problem on thin skinned cultivars such as St. Croix and La Crosse. This often occurs where honey bees are being maintained to pollinate other crops. Since they are a beneficial, domesticated insect, it is best to move the hives away from vineyards as harvest approaches. Honey bees will travel up to two miles to a source of food.

Mites. Both European red mites (*Panonychus ulmi*) and two-spotted spider mites (*Tetranychus urticae*) can cause injury to grape leaves (**Figure 85**). Both feed on the undersides of the leaves, and when populations are high, they will cause "bronzing" of the foliage (**Figure 86**). The European red mite overwinters as eggs laid around the cane nodes, while the two-spotted spider mite female adults overwinter under the bark of grapevines (Wolf, *editor,* 2008).

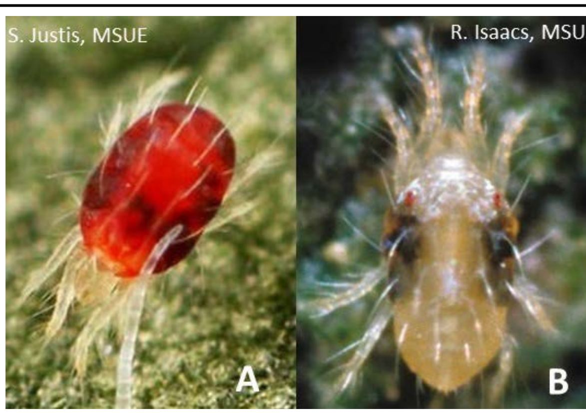

Figure 85. European red mite (A) and two-spotted spider mite (B).

Figure 86. Leaf "bronzing" caused by European red mites or two-spotted spider mites.

Leafhoppers are small insects with piercing-sucking mouthparts that feed on a wide range of plants including grapes.

Potato leafhoppers (PLH, *Empoasca fabae*) are the most common in Minnesota (Wold-Burkness, 2011a) and the upper Midwest (**Figure 87**). The PLH does not over-winter in the upper Midwest, and migrates from the southern US on wind currents and state arriving in mid- to late-May. Large populations continue to migrate through June and July. Female PLH lay eggs on grape stems and the nymphs feed on the underside of the leaves. As the PLH nymphs feed on the leaves, they inject saliva that causes physical damage by plugging the vascular tissue. First symptoms of feeding are pale leaf veins and curling or crinkling leaves (**Figure 88**) (Wold-Burkness, 2011a).

Grape leafhoppers (*Errythroneura* sp.) are also present in the upper Midwest. They can be identified by their orange-yellow color and high activity of the nymphs and adults. The adults jump or fly away as you pass or brush the vines. When disturbed, the nymphs very quickly move sideways while PLH move forward (Wold-Burkness, 2011a). Symptoms of grape leafhopper feeding show up as whitish blotches on the leaves (**Figure 89**).

Management tools for controlling leafhoppers include: 1) Using cover crops between the rows to reduce populations in the vines. 2). Scouting to monitor the population of nymphs. Grapevines can tolerate up to 15 leafhoppers per leaf with little economic damage. 3) Chemical control when populations exceed 15 leafhoppers per leaf (Wold-Burkness, 2011a).

Figure 87. Potato leafhopper nymphs and an adult.

Figure 88. Potato leafhopper damage.

Figure 89. Grape leafhopper damage.

Brown marmorated stink bug (BMSB) (*Halyomorpha halys*) is native to china, Japan and surrounding countries (**Figures 90, 91**). It was first found in the eastern U.S. in the mid-1990's (Adamczyk, *et al*., 2013), and has been moving westward and was recently detected in the upper Midwest (Cira and Hutchison, 2013). It feeds on over 300 plant species, including grapes. In harvested wine grapes, 5 to 10 BMSB per lug can lead to foul aromas that may reduce varietal character (Adamczyk, *et al*., 2013). So far, BMSB has only been detected in Minnesota, Iowa, Nebraska, and Wisconsin, and is a nuisance problem in Michigan, Indiana and Ontario (Cira and Hutchison, 2013). Grape growers should learn to identify this insect and be prepared to implement control measures if the pest becomes a problem.

Figure 90. Brown marmorated stink bug adult.

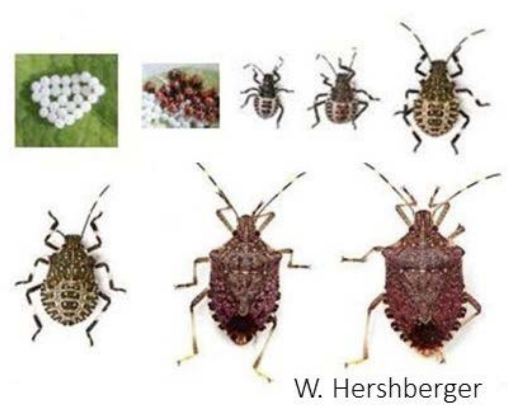

Figure 91. Developmental stages of the brown marmorated stink bug.

Spotted wing drosophila (SWD) (*Drosophila suzukii*) is another recent insect pest to the U.S. that was first detected in California in 2008, and in Minnesota in 2012 (Burkness, *et al*., 2012). It belongs to the group of tiny flies commonly referred to as small fruit flies. The SWD feed on about two dozen cultivated plant species worldwide and has the greatest potential to severely damage thin-skinned berry crops, including grapes (Sampson, *et al*., 2014).

Spotted wing drosophila flies are small (2-3 mm) with rounded abdomens and rather large orange-colored eyes. The male SWD has distinctive dark dot near the end of its wings, while the female does not have the dots (**Figure 92, 93**). The female SWD uses its saw-like ovipositor to pierce the skin of fruit and lay its eggs. The eggs hatch in about 3 days, feed within the fruit and causing brown, sunken areas (**Figure 94**) (Burkness, *et al*., 2012).

Vineyards should be monitored for SWD during the fruit ripening period. This can be done with a trap baited with apple cider vinegar and an optional yellow sticky card (**Figure 95**). Traps should be checked 1-2 times per week with fresh vinegar added each time the traps are checked (Burkness, *et al*., 2012). Because SWD is new to Minnesota and the upper Midwest, its economic impact on grapes grown in the region is still unknown, but grape growers should learn to identify this insect and be prepared to implement control measures if the pest becomes a problem. Additional information of the SWD, suggested control measures and current information can be found on the University of Minnesota's **FruitingEdge Fruit IPM Resource for new and emerging pests of the Midwest – Spotted Wing Drosophila** web site: www.fruitedge.umn.edu/spotted-wing-drosophila/.

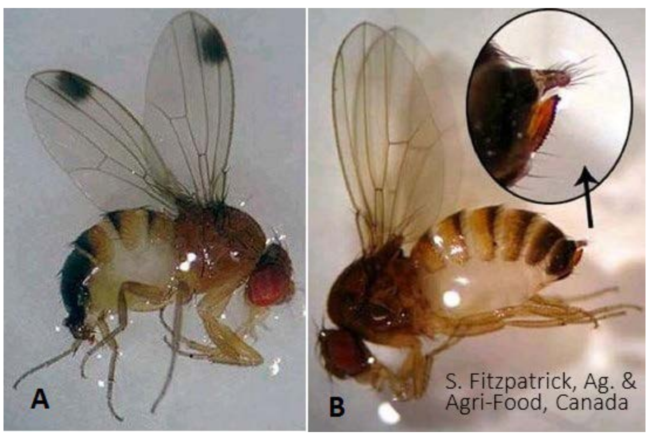

Figure 92. Spotted wing drosophila male (A) and female (B) flies, and insert of the female ovipositor.

Figure 93. Spotted wing drosophila fly showing the distinctive eye.

Figure 94. Grape berry showing a spotted wing drosophila oviposite wound, and sunken area associated with larvae feeding.

Figure 95. Spotted wing drosophila trap baited with apple cider vinegar and optional yellow stick card.

Insecticide Resistance Management

Insects have been known to develop resistance to insecticides after repeated exposure. For insecticide resistance management, avoid successive applications of an insecticide or insecticides with the same mode-of-action or type of chemistry. The Insecticide Resistance Action Committee (IRAC, www.irac-online.org) has coded insecticides by mode-of-action groups (number) and type of chemistry (letter) where it applies. Rotating insecticides with a different IRAC Code should help avoid the development of insects that are resistant to an insecticide. IRAC Codes for the insecticides registered for use on grapes are included in **Table 38**. Growers should also follow the restrictions on the amount of material that can be used per season.

Integrated Pest Management (IPM) Practices

Rather than spraying an insecticide at the first sighting of an insect pest or the first sign of damage on the vine, the grower should follow a few basic principles of IPM.

1. Attempt to accurately identify the pest, and the damage symptoms on the vine.
2. Scout the vineyard to determine the extent of damage or size of the pest population present. Monitoring over a period of days or a week may be necessary to determine accurately whether the pest population is relatively static or is increasing.
3. Decide whether the amount of damage anticipated is significant in economic terms or in terms of the effect on vine health. If a decision is made to apply an insecticide, chose the one that most specifically targets the problem pest.
4. If possible, avoid broad-spectrum insecticides. Growers should be aware that use of a broad spectrum insecticide such as Sevin® or Danitol® kill not only the target pest, but also does significant damage to the vineyard population of beneficial insects. Once this population is reduced, the balance between harmful and beneficial insects is upset. During the time it takes for the balance to recover, the vineyard may experience serious outbreaks of insect pests due to the lack of natural predators.
5. Finally, through research and vineyard experience it is becoming more apparent that cover crop management in the vineyard can have a significant effect on insect pest problems. The objective is to grow various cover crops, including flowering crops, between the rows of vines. The grass crops provide a sanctuary for beneficial and predatory insects. The flowering crops foster reproduction of beneficial insects by making available a good supply of the pollen and nectar essential to their reproduction. The entire vineyard is never mowed all at once. Rather, rows are mowed alternately, so some are always left to harbor beneficial. The net effect of this system is an increase in natural controls of pests and a reduction in vineyard pest problems.

Table 38. Characteristics of insecticides and miticides registered for use on grapes.

	Effectiveness in Controlling Grape Insects and Mites [z]											Restrictions [w]		
Insecticides:	Climbing cutworm	Grape flea Beetle	Redbanded leafroller	Grape berry moth	Leaf hoppers	Grape Phylloxera (foliar)	Japanese beetle	Multicolored Asian lady beetle	Spider mites	Signal word [y]	IRAC Code [x]	REI	PHI	Max./A/ season
Actara	-	-	-	-	++	-	++	-	-	C	4A	12h	5d	7 oz
Admire Pro	-	-	-	-	++	++	-	++	-	C	4A	12h	0d	2.8oz
Altacor	++	-	+++	+++	-	-	-	-	-	C	28	4h	14d	9 oz, 4 Apl
Applaud	-	-	-	-	++	-	-	-	-	C	16	12h	7d	24 oz, 2 Apl
Assail	-	-	-	-	+++	++	++	-	-	C	4A	12h	3d	.2 lb ai, 2 Apl
Avaunt	-	-	-	++	-	-	++	-	-	C	22	12h	7d	12 oz, 2 Apl
Aza-Direct [v]	-	-	-	-	-	-	+	++	-	C	UN	4h	0d	
Baythroid [rup]	++	++	++	+++	++	++	+++	++	-	W	3	12h	3d	12.8 oz
Belay	-	-	-	+	+++	-	+	+++	-	C	4A	12h	0d	.2 lb
Brigade [rup]	-	-	-	++	++	++	++	-	-	W	3A	12h	30d	.1 lb ai
Brigadier [rup]	-	-	-	++	++	-	++	-	-	W	3A,4A	12h	30d	12.8 oz
Bt *(B. thuringiensis)* [v]	+	-	+	++	-	-	-	-	-	C	11A	4h	0d	
Danitol [rup]	+++	+++	++	+++	++	+++	+++	-	++	W	3	24h	21d	.8 lb ai, 2 Apl
Delegate	++	-	+++	+++	-	-	-	-	-	C	5	4h	7d	19.5 oz, 5 Apl
Entrust [v]	-	-	++	++	-	-	-	-	-	C	5	4h	7d	.36 lb ai, 5 Apl
Imidan	-	-	++	++	++	-	++	-	-	W	1B	14d	14d	4.55 lb ai
Intrepid	-	-	++	+++	-	-	-	-	-	C	18	4h	30d	.75 lb ai
JMS Stylet Oil [w]	-	-	-	-	+	-	-	-	++	C	-	4h	0d	
Lorsban [rup]	+++	-	-	-	-	-	-	-	-	W	1B	24h	35d	1 lb ai, 1 Apl
Malathion	-	-	-	+	++	-	++	-	-	C	1B	24h,72h[u]	3d	1.88 lb ai,2 Apl
Movento	-	-	-	-	-	+++	-	-	-	C	23	24h	7d	12.5 oz
Mustang Maxx [rup]	++	-	-	++	++	-	++	++	-	W	UN	12h	1d	.15 lb ai
Neemix [v]	-	-	-	-	-	-	++	++	-	C	UN	4h	0d	
Platinum	-	-	-	-	++	-	++	-	-	C	4A	12h	60d	17 oz
Provado	-	-	-	-	++	-	++	-	-	C	4A	12h	0d	.1 lb ai
PyGanic [v]	-	-	-	-	++	-	++	-	-	C	3A	12h	0d	
Renounce [rup]	++	++	-	++	++	-	-	-	-	C	3	12h	3d	16 oz
Sevin	+++	+++	++	+++	+++	-	+++	++	-	C	1A	2d, 6d[u]	7d	10 lb ai, 5 Apl
SpinTor [v]	-	-	++	++	-	-	-	-	-	C	5	4h	7d	.36 lb ai
Superior oil	-	-	-	-	-	-	-	-	+++	C	-	12h	-	
Surround [v]	-	-	+	-	-	-	+	-	-	C	UN	4h	0d	
Venom	-	-	++	-	-	-	-	+++	-	C	4A	12h	1d	.264 lb ai
Voliam Flexi				+++	++	++				C	4A, 28	12h	14d	9 oz, 2 Apl
Miticides:														
Acramite									+++	C	UN	12h,5d[u]	14d	1 Apl
Agri-Mek [rup]					+				+++	W	6	12h	28d	.038 lb ai, 2 Apl
Apollo									+++	C	10A	12h	21d	1 Apl
Envidor									+++	C	23	12h	14d	34 oz, 1 Apl
Kanemite									+	C	20B	12h	7d	62 oz, 2 Apl
Nexter					++				++	W	21A	12h	7d	2 Apl
Onager									+++	C	10A	12h	7d	24 oz, 1 Apl
Portal					+				+++	W	21A	12h	14d	2 pt, 2 Apl
Vendex [rup]									+	D	12B	48h	28d	4 lb, 2 Apl
Zeal									+++	C	10B	12h	14d	.135 lb ai, 1 Apl

z Key to rating: +++ = highly effective; ++ = moderately effective; + = slightly effective; - = ineffective or not sufficient data. *Adapted from*: Midwest Small Fruit and Grape Spray Guide.

y Signal Word: C = Caution; W = Warning; D = Danger.

x Insecticide Resistance Action Committee Mode of Action Classification. www.irac-online.org/

w From the 2015 Midwest Small Fruit and Grape Spray Guide, and pesticide labels

v Listed by the Organic Materials Review Institute (OMRI) for use in organic production.

u REI when shoot positioning or cane girdling.

rup Restricted Use Pesticide. A certified pesticide applicator's license is required to purchase and apply the pesticide.

Vineyard Best Management Practices – Vineyard Pest Management

Rate your vineyard pest management practices:

Management Area: **Insect pest of grapes**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Identification	Learned to identify the common grape insects, their life cycles & when they are present, & scout weekly.	Learned to identify the common grape insects & when they are present, & scout regularly.	Learned to identify some of the common grape insects, & scout periodically.	Can only identify a few common grape diseases, & seldom scout.
Cultural control	Take measures to reduce alternative hosts in the area that pest may feed on, and undertake practices that will promote natural predators of the pest.	Undertake practices that will promote natural predators of the pest.	No measures taken to promote natural predators or reducing alternative hosts of the pest in the area.	
Insecticides	Apply insecticides that effectively control the specific insects when they reach threshold levels, & considered cost effectiveness. Or use alternative strategies to insecticides.	Apply insecticides that effectively control the specific insects when they reach threshold levels.	Apply broad spectrum insecticides to control the most insects when they are present.	Include a broad spectrum insecticide in spray every 2nd or 3rd spray.
Insecticide resistance management	Avoid successive applications of an insecticide or insecticides with same FRAC code; follow restrictions on number of applications or total material applied during a season.	Follow restrictions on number of applications or total material applied during a season.		Use the same insecticides throughout the growing season.
Insecticide usage restrictions	Follow restrictions on re-entry interval (REI) and pre-harvest interval (PHI) when applying insecticides.			Lax on follow restrictions on re-entry interval (REI) and pre-harvest interval (PHI) when applying insecticides.

Wildlife Pests of Grapes

Birds

Birds are the most common wildlife pest in Minnesota vineyards during the pre-harvest and harvest season. Early ripening, black fruited cultivars such as Severnyi, Maréchal Foch, and Leon Millot are particularly vulnerable to bird attack, but they will also feed on white cultivars as well. Later ripening cultivars have also experienced significant damage as well. Grapes do not necessarily have to be fully ripe to be attacked. Starlings have been known to feed on grapes during early maturation when they have reached 10^{o}Brix (10% soluble solids, (SS)). Invariably, grapes will be "sampled" by birds before they are fully mature. Birds typically peck at the berries and leaving the skins on the rachis (**Figure 96**). Besides the loss of crop from bird feeding, damages berries are prone to infection by fruit rots, and invasion by multicolored Asian lady beetles, wasps and bees.

Several methods of deterring birds from vineyard feeding are available. If possible, situate your vineyard as far from trees to lessen the population of birds to begin with. An attempt can be made to completely exclude birds from the grapes by netting the vines (**Figure 97**). The initial expense of the netting is quite high, but when amortized over the life of the netting (5-10 years) it becomes much more affordable. Applying and removing the netting are labor-intensive tasks. However, a number of bird netting implements have been designed that dramatically reduce the time and labor required to making bird netting more feasible. If the netting is just draped over the grapevines, birds have a knack for finding ways to get under the netting to feed. Therefore, it may be necessary to pin the ends of the netting together under the vines.

Some alternatives to netting have been recently tried with good success. Some growers have used multiple layers of hay bale net wrap as an alternative to the expensive bird netting (**Figure 98**). It is inexpensive and can be replaced each season, but it is not strong enough to withstand entry by raccoons. Another approach being used in Germany, the bird netting is attached to the end posts and allowed to hang like a curtain, blocking access to the vineyard aisles. This technique disrupts birds attempting to enter the vineyard from the periphery at low altitudes.

The propane cannon can be effective, especially when combined with occasional shotgun blasts (**Figure 99A**). Unfortunately, use of both the cannon and shotguns have been found to alienate nearby neighbors and are only recommended for rural growers. To be most effective, propane cannons should be moved to different locations in and around the vineyard every few days.

An approach, being used in Oregon, Michigan and Minnesota with some success, is to stretch long strips of bi-colored plastic or Mylar ribbon between the end posts and between line posts over the vineyard (**Figure 99B**). Small extender poles must first be attached to the trellis posts to elevate the tape a foot or so above the vines. As the wind blows, the ribbon flashes and vibrates, making a sound resembling that of a flock of pigeons. The noise is quite disruptive to feeding birds. Birdscare Flash Tape® is a Mylar ribbon being imported from Japan. It is metallic red on one side and silver on the other and relies on its intense visual impact to deter birds.

Other visual tactics have been used to scare birds away with mixed success. Common visual devices include predator kites (**Figure 99C**) or figures, and eye balloons (**Figure 99D**). A novel approach that has recently gained attention in New York is the dancing tube man (**Figure 99E**).

Another method to deter birds is the use of electronic destress call generators such as Bird Gard® (**Figure 99F**). The Bird Gard® uses computer chips programmed with specific bird distress cries, predator calls, and harassment sounds. Birds will hear their particular distress call and stay away. It has been quite effective in several Minnesota vineyards. In addition, a tape with the call of the Sharp Shinned Hawk which preys upon other birds has been effective.

For birds, a combination of several deterrents is more effective than relying on just one, even with netting.

Figure 96. Injury on grapes from bird pecking.

Figure 97. Protecting grapes with bird netting.

Figure 98. Applying multiple layers of hay bale net wrap to protect grapes from bird damage.

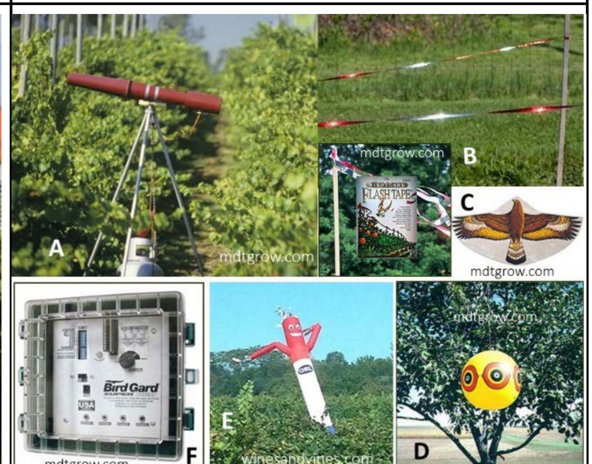

Figure 99. Bird scare tactics: propane cannon (A), Mylar ribbon (B), predator kite (C), eye balloon (D), dancing tube man (E), and distress call generator (F).

Raccoons

Raccoons are common around Minnesota and other upper Midwest vineyards located near woodlands, ponds, and lakes. They are extremely fond of ripe grapes and can do heavy damage to the crop. In a replicated cultivar trial at Iowa State University (ISU), raccoons selectively sought out Frontenac grapes among 15 other cultivars. In addition, raccoon feeding is usually associated with at least some damage to the vines, as the animals will climb up into them to feed on the grapes. Raccoons typically clean the cluster when feeding and there will be no skins remaining as occurs with bird feeding (**Figure 100A**), and the damage will often be closer to the trunk and cordons (**Figure 100B**).

Bird netting may slow down raccoons, but it will not prevent them from feeding on the grapes. The only reliable method for preventing raccoon damage is to exclude them from the vineyard by means of an electrified fence. At least two weeks before harvest, a 12-18" strip should be tilled clean or sprayed with glyphosate around the entire perimeter of the vineyard. A low fence then can be set up using 3 wires placed at 8 inch intervals above the ground (**Figure 101A**). Polytape wire works well because it is more visible. One of the wires should be a ground wire, the other two "hot". An alternative to the three-wire electrified system is the use of VersaNet® Garden/Wildlife netting (**Figure 101B**). With either system, corners should be rigged with wire standoffs so that a raccoons cannot simply climb the corner post and avoid the wires. The fence line should be policed daily to ensure that no debris has fallen across the wires and that the raccoons have not broken through. Use of a voltage meter makes it easy to detect shorts or battery failure when they occur. In the absence of an electric fence, the next best solution may be to leave a portable radio set to a "talk station" on all night in the vineyard. The sound of human voices has quite a deterrent effect on raccoons.

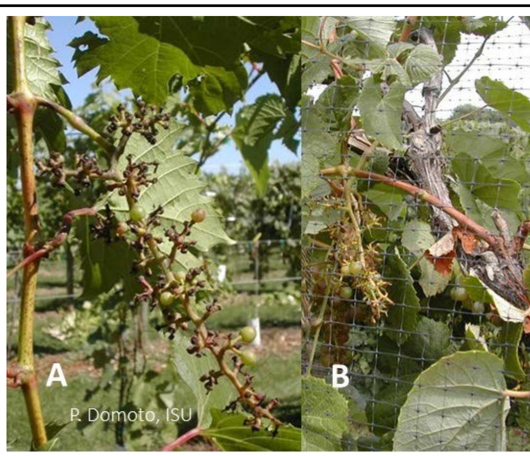

Figure 100 Raccoon feeding on grapes leaving an almost clean rachis (A), with feeding typically occurring near the trunk and cordon (B).

Figure 101. Three-strand electrified polytape fence (A), and electrified VersaNet® garden/ wildlife netting.

Deer

Deer are a problem primarily in new vineyard plantings during the first month or two after vines are set out (**Figure 102**), and in established vineyards trained to a mid-wire system (**Figure 103**). The new shoots are quite attractive to deer, but as they grow and toughen, begin to lose their appeal. Several reliable methods are available for protecting new and established vineyards where deer populations are very high. These options include permanent wire fencing, permanent and temporary electrified fencing, repellants, scare devices and dog restraint systems. Permanent, 8 ft woven-wire perimeter fencing is the most effective system, but also the most expensive (**Figure 104**). Temporary electrified fences have proven to be effective in keeping deer out of new plantings. A 4 ft high two-wire fence built with polytape is usually sufficient to redirect deer browsing habits away from the vineyard.

Commercial repellents such as Hinder® or Plantskydd®, and home-made repellants can be effective for short periods, but have to be re-applied as shoots grow and/or the scent fades away. A very inexpensive deer repellent can be made at home quite easily by combining a couple of eggs with water in an electric blender. This mixture is added to a gallon of water and applied to the vines as a spray. Strained through fine mesh prior to use in order to remove any large egg particles that might clog the sprayer. Again this spray must be reapplied regularly to be effective. Also, some Minnesota growers have repelled deer by hanging bars of soap throughout the vineyard. However, this method along with other materials that are associated with human scent as a deterrent, may work for a while and their effectiveness tends to be inversely associated with the density of the human population in the area.

Scare tactics such as propane cannons and dog restraint invisible fences have also been used. Deer population management is another option in rural areas. This includes habitat management, encouraging hunting, and shooting permits under high damages situations. Minnesota has a wildlife damage management materials assistance program (http://www.dnr.state.mn.us/livingwith_wildlife/wildlife_damage.html). For other states or provinces, growers should check with their departments of Natural Resources.

More detailed information on deer control is available in the following publications:

- Deer Barriers – fencing, repellents, dog restrain systems, scare devices. MSU Ext. Bul. E-2672. www.oak.gov.com/msu/Documents/publications/e2672_deer20barriers.pdf
- Controlling Deer Damage in Missouri. Univ. Missouri Ext. MP685. www.extension.missouri.edu/p/MP685

Figure 102. Deer browsing on young grape shoots.

Figure 103. Deer browsing on mid-wire cordon shoots.

Figure 104. Permanent woven-wire deer barrier.

Voles

As mentioned in the section on winter protection, voles (commonly called mice) sometimes find shelter under vegetation used for winter cover, and gnaw at the vines over the winter (**Figure 105A**). Meadow voles (**Figure 105B**) and prairie voles are common to Minnesota and the upper Midwest. Both leave surface trails in the sod under snow cover (**Figure 105C**). If the vine is completely girdled, it will die. The best policy for growers is to control the vole population before any damage occurs. This is done simply by placing poison bait feeding stations around the vineyard. Zinc phosphide treated oats are now available in paraffin coated form, which improves the longevity of the bait. Pieces of plastic pipe, pop cans, or tin cans all suffice for bait stations. Initial baiting of the stations should be done in mid-October to coincide with the increase in vole shelter-seeking activities. A significant reduction in the vole population can be made at this time of year, just prior to winter. Combined with the natural mortality caused by winter, the vole population should be greatly reduced by spring. Re-baiting the stations in spring helps keep the population from building up again. If this is repeated every year, voles should not be a significant problem. Encouraging predators, and keeping a vegetation-free area around the grapevine trunks also reduces the incidence of vole damage.

Figure 105. Vole damage on the base of a grapevine trunk (A), a meadow vole (B), and vole tunneling in a vineyard alley way (C).

Figure 106. Rabbit damage on the shoots of a newly planted grapevine (A), and winter damage on the trunk of an established grapevine (B).

Figure 107. Grapevine killed by pocket gopher feeding on the roots.

Rabbits

Rabbits can also be a problem in vineyards. They will feed on the young shoots of newly planted vines (**Figure 106A**), and on the trunks of established grapevines in the winter (**Figure 106B**). For newly planted vines, commercial repellents such as Hinder® or Plantskydd® can be sprayed on the shoots, but must be re-applied as the vines grow. Using grow tubes will provide protection form rabbits, but need to be removed in August to allow the shoots to properly mature. Once the grapevine is dormant, the grow tubes can be re-installed for winter protection form rabbits. For older grapevines, hardware cloth trunk guards can be installed to provide protection from rabbits and voles. Often good habitat management and encouraging predators will provide good protection from rabbits.

Pocket Gophers

Pocket gophers can also be a problem in vineyards, particularly on sandier soils which they prefer. They burrow and feed on the grapevine roots. If there are gopher mounds present in the vineyard and grapevines suddenly collapse and die during the growing season, it is probably because a gopher has eaten the roots (**Figure 107**). Vineyards planted with a tree planter can be particularly susceptible to pocket gophers because they will follow the softer soil made by planter. Pocket gophers can be controlled by trapping, the use of poison baits and fumigants. A novel approach for controlling gophers are devices that disperse a mixture of propane and oxygen down the burrow and ignite it. Encouraging predators will aid in controlling pocket gopher populations (White, 2015).

Vineyard Best Management Practices – Vineyard Pest Management

Rate your vineyard pest management practices:

Management Area: **Animal pest control**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Identification	Can identify damage caused by all wildlife pests that attack grapes.	Can identify damage caused by most wildlife pests that attack grapes.	Can identify damage caused by some wildlife pests that attack grapes.	Unable to identify damage caused by most wildlife pests that attack grapes.
Habitat	Measures taken to reduce nearby areas that harbor various wildlife pest.		No measures taken to reduce nearby areas that harbor various wildlife pest.	
Birds	In addition to netting, undertake an addition measure to control birds.	Rely on netting to control birds.	Rely on measures other than netting to control birds.	No measures undertake to control birds.
Raccoons	Use electrified fencing to keep raccoons out of the vineyard.	Population low, no measure is taken to keep raccoons out.	Population moderate, no measure is taken to keep raccoons out.	Population is high, no measure is taken to keep raccoons out.
Deer feeding in a new vineyard	Use electrified or permanent fencing to keep deer out of the vineyard.	Use repellants to keep deer out of the vineyard.	Use scare tactics to protect the vineyard.	No measures are taken to protect the vineyard.
Deer feeding in an established vineyard	Use 8-ft permanent fencing or electrified fencing to keep deer out of the vineyard.	Population low, no measures are taken to keep deer out.	Population moderate, no measures are taken to keep deer out.	Populations are high, no measures are taken to keep deer out.
Voles	Use bait stations, keep vegetation away from the trunks and encourage predators.	Population low, keep vegetation away from the trunks and encourage predators.	Population moderate, keep vegetation away from the trunks and encourage predators.	Populations high, no measures are taken to control voles.
Rabbits	Apply repellants on young vines; reduce habitat and encourage predator for established vineyard.	Apply repellants on young vines; population low, no measures taken in established vineyard.	Apply repellants on young vines; population moderate, no measures taken in established vineyard.	No repellants applied on young vines; population high, no measures taken in established vineyard
Pocket gophers	Practice one or more control measure and encourage predators.	Population low, no control measure undertaken.	Population moderate, no control measure undertaken.	Population high, no control measure undertaken.

Grape Maturation and Ripening

Changes occurring during the ripening process:

Following bloom and fruit set, grape berries undergo a rapid phase of growth by cell division that transitions to growth by cell enlargement. As the berries begin to touch, growth slows that is referred to as the lag phase, and the process of maturation begins at veraison (**Figure 108**). Several changes occur during veraison:

- Skin color of colored cultivars changes from green to red, blue or black (**Figure 109A**).
- Berries begin to soften, with white cultivars becoming more translucent (**Figure 109C**).
- Sugars (*measured as* °Brix or %SS) begin to increase (**Figure 110**).
- Acids [measures as titratable acidity (TA)] begin to decrease (**Figure 110**).
- Juice pH begins to increase and becomes less acidic (**Figure 110**).

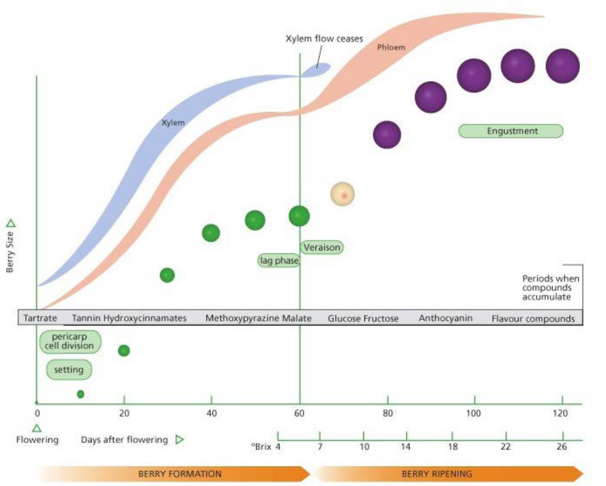

Figure 108. Grape berry development & maturation. (Illustration by J. Koutroumanidis, Winetitles)

Figure 109. Veraison in a red wine cultivar (A). Lag phase (B) and veraison (C) in a white wine cultivar.

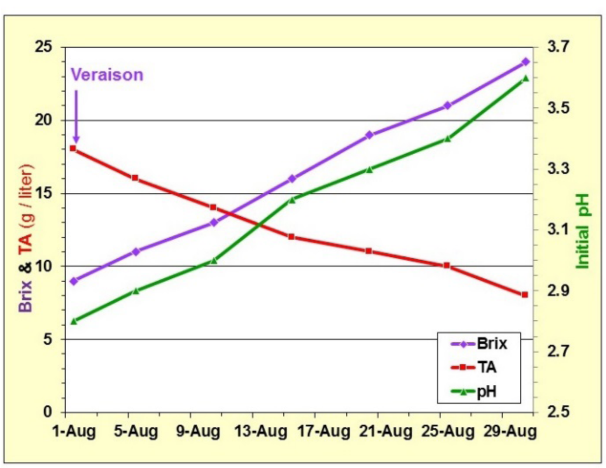

Figure 110. Changes in °Brix, titratable acidity (TA) and initial pH following veraison.

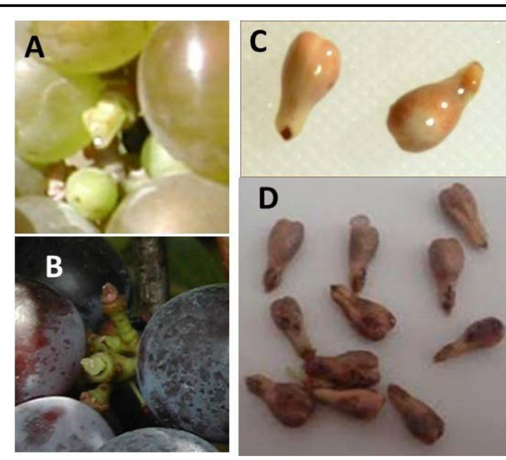

Figure 111. Pedicel/berry abscission zone: immature (A), mature (B). Seed maturity: immature (C), mature (D).

- Juice color begins to change. Whites – greenish to whitish. Reds – begin to take on some skin pigment.
- Skin tannins begin to polymerize to become more desirable.

- Seed tannins (undesirable) begin to become less extractable.
- Varietal flavor components begin to increase.
- The rachis begins to mature.
- An abscission zone between the pedicel (berry stem) and berry begins to develop (**Figure 111A, B**).
- Seeds begin to mature (**Figure 111C, D**).

As these changes occur, the transport system to the berries changes from xylem transport of mostly water associated with berry enlargement to phloem transport of mostly sugars as the berries enter the engustment (ripening) phase.

Testing grape maturity

Following veraison, you should begin testing the maturity of the grapes to determine when to harvest, and there are several tests that can be used to monitor the changes that occur during the maturation process.

Sugars: The concentration of sugars, expressed as either °Brix or % SS, increases during maturation and can be measured with a refractometer or a hydrometer. The Brix refractometer measures the degree sugar molecules bend light as it passes through a prism with the degree of bending being associated with the concentration of sugars. The hydrometer measures the specific gravity of the sugars (soluble solids) in the grape juice. The refractometer is easy to use and can be taken into the field to sample berries, while the hydrometer requires enough juice to be floated. Sugars are important for wine making because to 1% sugar converts to 0.55% alcohol (% SS x .55 = % alcohol).

Sugars are easy to measure and are a common measurement in the wine industry, but it is not a good measure of maturity when used alone. This is particularly true for some of the Northern hybrids such as Frontenac, La Crescent and Marquette that are high in acids and can have high concentrations of sugar shortly after veraison. In addition, there is a poor relationship between sugar levels and accumulated berry flavors (Wolf, *editor*, 2008).

Initial Juice pH: During maturation, juice pH increases and is measurable with a pH meter. Juice pH is important because wine balance or the perception of sourness or tartness, aroma, microbial stability, and physiochemical stability of the wine. When grapes harvested at a below optimal juice pH, the wines tend to be sour, herbaceous and lack character. At a pH above 3.5 to 3.6, wines may be “flat” in character, more prone to microbial infection, more oxidized and have less color, and have less desirable flavors (Wolf, *editor*, 2008).

Titratable acidity (TA): During maturation the organic acids in the juice decline, and this can be measured as titratable acidity. It requires a pH meter to measure the amount of a strong base [0.1 N sodium hydroxide (NaOH)] to neutralize the juice to an end-point of 8.2 pH for tartaric acid. Titratable acidity is expressed as either the percentage acidity (% TA) or grams of acid per liter where 1 % TA is equivalent to 10 g/liter TA. Titratable acidity serves as a measure for developing a sugar/acid balance of the juice and determines how sweet a wine needs to be finished to maintain a good balance (Wolf, *editor*, 2008).

The °Brix, initial juice pH and TA are measurable indicators of maturity and when used together, provide good guidance in determining when to harvest, and optimum maturity indices have been developed for different styles of wine (**Table 39**). These measurements should be taken at intervals post veraison to make a harvest decision.

Table 39. Optimal juice °Brix, initial pH and titratable acidity (TA) for different styles of wine.

Wine Style	°Brix (% SS)	Initial pH	TA (g / liter)
White table wine [z]	21 - 22	3.2 – 3.4	7 – 9
Red table wine [z]	22 - 24	3.3 – 3.5	6 – 8
Sparkling wine [y]	17 - 20	2.8 – 3.2	7.0 – 9.0
White table wine [y]	19 - 23	3.0 – 3.3	7.0 – 8.0
Red table wine [y]	20 – 24	3.2 – 3.4	6.0 – 7.5
Sweet table wine [y]	22 – 25	3.2 – 3.4	6.5 -8.0
Dessert wine [y]	23 – 26	3.3 – 3.7	5.0 – 7.5

[z] Dharmadhikari and Wilker. 2001. **Micro Vinification**, a practical guide to small-scale wine production.

[y] Wolf, *editor,* 2008. **Wine Production Guide for Eastern North America**.

These are optimal indices, but for Northern hybrids that are characteristically high in acids, grapes are typically harvested before the TA drops into the optimal range. Often the initial pH is allowed to approach the upper end of its optimal range to allow the TA to come down to a reasonable level.

Other tests for measuring changes that occur during the grape maturation process are available and can aid in determining when to harvest. However, they are subjective measurements, and often require several years of experience to master. These measures include:

Skin tannins: As grapes mature the skin tannins polymerize from short chain to long chain molecules. With practice, this change can be detected on the tongue, particularly with red cultivars. Un-polymerized "unripe" tannins cause friction in the mouth when they bind with salivary proteins, while polymerized "mature" tannins cause less binding with the salivary proteins. To test for skin tannins, separate the skins from the berry pulp and chew it to release the tannins. Then press and move your tongue against the roof of your mouth (palate). If the tongue sticks or binds against the palate, the tannins are "green" or gripping and less mature. If the moves freely and "slides", the tannins are judged smooth or "silky" and more mature (Wolf, *editor*, 2008)

Berry detachment: As grapes mature an abscission zone begins to form between the pedicle and berry, and ease of berry detachment can serve as an indicator of maturity. When detaching a berry from a cluster, observe where the pulp and skin detach cleanly from the pedicel. If some pulp and/or skin remain attached to the pedicel (**Figure 112A**), the berry is considered un-ripe. If the no pulp remains attached to the pedicel (**Figure 112B**), the berry is judged to be ripe (Wolf, *editor*, 2008). Once the abscission zone is formed, the berries will not mature any further, but can become sweeter from of dehydration. For cultivars such as La Crescent that are prone to shelling, checking for the beginning of berry detachment is an important procedure for determining when to harvest.

Seed maturity: As grape seeds mature, their color changes from green to brown to dark brown. This color change is associated with oxidative reactions and corresponds with the decrease in extractable seed tannins. Seed color has been used as an indicator or maturity, but uniform and complete brown seed color is seldom achieved in Eastern and Midwestern vineyards (Wolf, *editor*, 2008).

Aroma and Flavor: Both aroma and flavor can be used as indicators of grape maturity. With training human sensory skills can be developed to recognize flavor, aroma, sweetness and acidity development that characterize the maturation of a particular grape cul tivar. However, it takes years of experience to develop these skills. It is one of the few ways to assess "balance" (Wolf, *editor*, 2008).

Table 40 summarizes these maturity tests that can be conducted for determining when to harvest and provides guidance regarding their use.

Table 40. Harvest parameters that can be performed to determine when to harvest wine grapes.

Harvest parameter	Run the test?	Comments
°Brix	Yes	Conducted together with initial pH and TA.
Initial juice pH	Yes	Conducted together with °Brix and TA.
Titratable acidity	Yes	Conducted together with °Brix and initial pH.
Skin tannins	Check	Use along with °Brix, initial pH and TA.
Berry detachment	Check	Use along with °Brix, initial pH and TA as an indicator.
Aroma	Maybe	Along with °Brix, initial pH and TA, learn to develop the skill to detect changes for each cultivar.
Flavor	Maybe	Along with °Brix, initial pH and TA, learn to develop the skill to detect changes for each cultivar.
Seed color	Maybe	Use along with °Brix, initial pH and TA as an indicator.

Collecting a sampling to test for maturity:

Sampling to test for maturity should begin following veraison. Initially it can be done in the vineyard with a refractometer to determine when to begin collecting a larger sample to run a more through test for °Brix, juice pH and TA. When collecting a sample, it is very important to collect a sample that is representative of the crop. Grape maturity is not uniform between vines, within vines and within grape clusters. Differences in maturity between clusters on a shoot and berries within a cluster exists because they bloom at different times (**Figure 112A**). Berries near the top of the cluster will be more mature than those near the end (tail) of the cluster (**Figure 112B**). In addition, differences will exist between sun-exposed berries and those in the shade.

A sample can consist of whole clusters or berries. Collecting clusters overcomes the variability within clusters and is often necessary if a hydrometer is used to determine °Brix. At least 10 clusters representative of the vineyard should be collected. When berries are collected a sample should consist of 100-200 or more berries collected over the vineyard with no more than two berries collected from a vine. Because berries on a cluster vary in their maturity, the sample should consist of berries collected from the top, middle and bottom of the clusters as well as being collected from the sun-exposed and shaded sides of the clusters. An alternative procedure is to collect berries from the mid-portion of the clusters. If green berries are present, they should be included in the sample in proportion to their presence in vineyard, unless they will be separated out before or during the crush.

Figure 112. Difference in bloom between clusters on a shoot and within clusters (A), and maturity of berries on a cluster (B).

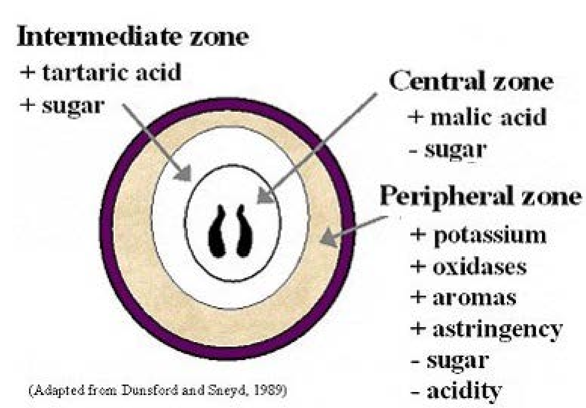

Figure 113. Location of juice components within a grape berry (Zoecklein, 2001).

When preparing the sample for testing, it is important to thoroughly crush the berries because the components in the juice are located in different regions of the berry (**Figure 113**). Samples can be either crushed or blended. Crushing is quick and easy, and gives a good estimate of maturity. It is better suited for white wine cultivars because it can miss skin tannins in red wine cultivars, but this not a critical issue when determining when to harvest. When using a blender, the berries are blended for six seconds. The procedure is more time consuming but gives a better estimate of maturity. It is best suited for red wine cultivars and is probably overkill for white wine cultivars.

Calculating TA:

A pH meter is needed to determine the initial juice pH and TA. Other items needed include: pH 4 & 7 buffer solutions, 0.1 N sodium hydroxide (NaOH), buret & buret stand, beakers, 10 ml & 100 ml graduated cylinders, magnetic stirrer & stir bars. To determine the TA, 5 ml of grape juice (diluted with distilled or de-ionized water is titrated with 0.1 N NaOH to a pH of 8.2. Using the buret, the milliliters (ml) of 0.1 N NaOH needed can be accurately measured and the TA can be calculated (**Table 41**). Because tartaric and malic acids in the juice are organic acids and exhibit a buffering capacity, the change in pH is not directly proportional to the amount of NaOH added (**Figure 114**).

Table 41. The basic formula for calculating the Titratable Acidity (TA).

Basic formula	_____ml NaOH x ___normality of NaOH x .075* %TA = --x 100 ____ ml of grape juice
Using 0.1 N NaOH & 5 ml grape juice	_____ml NaOH x **0.1** N NaOH x .075* %TA = --x 100 **5** ml of grape juice
Example: used 8 ml 0.1 N Na OH to titrate to pH of 8.2	**8** ml NaOH x **0.1** N NaOH x .075* %TA = --x 100 = **1.2% TA** **5** ml of grape juice
Convert %TA to g/liter TA	**1.2** %TA x 10 = **12** g / liter TA
Short cut when using 0.1 N NaOH & 5 ml grape juice	g / liter TA = ___ml 0.1 N NaOH x 1.5 g / liter TA = **8** ml 0.1 N NaOH x 1.5 = **12** g / liter TA

* Conversion factor for tartaric acid

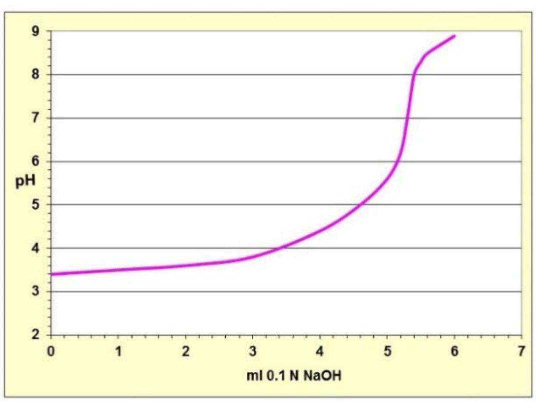

Figure 114. Typical titration curve for grape juice.

Grape Maturity

Cultivar:				Year:			
Date	Total berry wt. (g)	No. of berries	Avg. berry wt. (g)	°Brix (% SS)	Initial pH	TA (g/liter)	Comment

Figure 115. An example of a recording sheet that can be used to monitor changes in grape maturity during the season and from year to year.

Maturity testing results should be recorded for the growing season and maintained from year to year (**Figure 115**). By maintaining such a record, changes in maturity can be plotted (**Figure 110**) and aid in predicting when to harvest. Wolf (2008) presents an example of a maturity evaluation sheet that includes the subjective maturity indicators.

Vineyard Best Management Practices – Grape Maturation and Ripening

Rate your pre-harvest vineyard practices:

Management Area: **Evaluating when to harvest**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Maturity testing	Evaluate juice °Brix, initial pH and TA, on a weekly basis following veraison; and develop skills to use one or more of the subjective measures of maturity.	Evaluate juice °Brix, initial pH and TA on a weekly basis following veraison.	Begin evaluating juice °Brix, initial pH and TA about a week before you think it is time to harvest.	Evaluate juice °Brix to determine when to harvest.
Record keeping	Maintain annual records of maturity test results.			Do not maintain annual records of maturity test results.

Making Wine from Minnesota Grown Grapes*

As early fall harvest season approaches, many grape growers become interested in and enthusiastic about making wine from part or all of their harvest. At this point, it's important to remember that different grapes are suited for different uses; fruit that can be delightful for jelly production or eating out-of-hand is often unsuitable for wine making. Table and juice grapes often have lower sugar, lower acid, lower skin-to-pulp ratio, and fewer seeds than wine grapes; making palatable table wines from these grapes may be tricky at best and impossible at worst.

In the realm of wine grapes, a differentiation should be made between French-American hybrid grapes, Swenson cultivars, and cold-hardy hybrids with *V. riparia* ancestry. French-American hybrids, like Maréchal Foch and Leon Millot, contain lower acid and sugars, have low to moderate tannins in red cultivars, and may have herbaceous notes. Swenson's varieties, which are largely based on *V. labrusca*, may have sugar low enough to require chapitalization (the addition of sugar) and acids similar to French-American hybrids. St. Croix and St. Pepin are examples of Swenson cultivars often used for quality wine production. Some, like Edelweiss, show their *labrusca* heritage in characteristic 'foxy' flavors, which will be present in the final wine; this can be an asset or a major flavor flaw, depending on personal taste. The newer UMN cold-hardy hybrids, like Frontenac and La Crescent, have enough wild *V. riparia* in their make-up that they produce much higher acids and sugars when ripe. With these cultivars, it's important to allow grapes to fully ripen before picking, and to be prepared to perform acid reduction if necessary.

The first step in successful winemaking is harvesting grapes at the appropriate ripeness, which varies from cultivar to cultivar. In this area we generally need from 6 to 8 weeks of hot, sunny weather after the grapes have changed color (veraison) before they are at the proper sugar/acid level to be picked. As the sugar in the grape increases, the acid content decreases. To a winemaker it is important that the grapes be picked only when the best balance possible is achieved; this balance can often be measured only by careful and experienced tasting. Generally, sugar concentrations in locally grown grapes will reach 18° to 24°Brix depending on cultivar and growing conditions; for low sugar varieties, it's a good idea to sweeten to 22°Brix to produce a finished wine with 11-12% alcohol. Acid concentrations in Minnesota grapes will range from 0.8% to 1.3%.

Sometimes frost arrives before the grapes are fully ripe. If this occurs, grapes must be harvested immediately, as they will no longer ripen and the vine may sustain damage that will impair its ability to survive winter. Harvest in the Minneapolis/St. Paul area usually occurs between the last week in August and the first week in October, depending on grape cultivar. You should not schedule any spraying within 10 days of harvest as the residue may get into the wine and either inhibit fermentation or lead to the formation of off odors in the wine.

Once you have harvested the grapes it is essential to cull diseased and damaged grapes prior to crushing. Do not use anything except sound, ripe fruit. Washing fruit is usually unnecessary, and water will be absorbed by the grapes, causing dilution of sugars and flavor.

At this point, specific processing methods depend on the type of grape to be fermented, whether the grape is red or white, and the desired wine style. A general method is listed at the end of this section, but a good home winemaking book or webpage will provide detailed information about processing specific varieties and styles. Developing a good relationship with your local amateur winemaking store is highly recommended.

The initial processing step is crushing and destemming. Crushing involves simply breaking open the grape skins, so that the grape juice can begin to leak out. Grapes may be removed from the stems by hand prior to crushing, or whole clusters may be run though a crusher and the stems removed afterwards. Stems will leach bitter tannins into the wine, so removing as many as possible is key to fine wine production. Once the stems are separated from the must (the crushed grapes in their juice) grapes may be pressed to remove the juice for white wine production, or fermented on the skins (maceration) to produce red wine. For white wine production, the must is pressed, and the juice settled for 24 hours with the aid of pectic enzyme to allow the gross lees (suspended pieces of pulp and other field trash) to settle to the bottom. The clear juice can then be racked off, and fermentation started. For red wine production, yeast is added to the must and the juice is fermented on the skins for 3-5 days to extract color and flavor, then pressed and allowed to finish fermentation off the skins.

After fermentation is complete, wines must be racked into a full container, as air contact results in oxidation and conversion to vinegar. At this point, adjustments to acid can be made, and additional racking and fining, if necessary, can be performed to obtain a clean, bright finished product. Clearing and aging may take from 3 months to 3 years, depending on the wine. It is important to emphasize that cleaning and sanitizing all equipment is a must. Spoilage organisms occur naturally on both the fruit and in the atmosphere, and must be dutifully battled to prevent wine loss.

A note on additives: most Minnesota grapes contain high acids, so addition of tartaric or acid blends are generally unnecessary. Adding appropriate enological tannins may be desired for some wine styles, but their use is tricky and not recommended for the beginner.

For most home winemakers, the easiest way to make a sweet wine is to first ferment the original wine to dryness, then back sweeten with table sugar. This method allows small-scale sweetening trials, so exactly the right acid/sugar balance can be achieved. When sweetening a wine, it is necessary to add the stabilizer potassium sorbate at the same time as the sugar to prevent further fermentation. Potassium sorbate must be added in the correct dose and all at once, so careful reading of product directions is essential. Adding additional sugar at the start of fermentation will not produce a sweet wine- rather, the sugar will be converted to alcohol, making a dry wine with higher alcohol content.

Basic Ingredients for One Gallon of Grape Wine

15# ripe wine grapes, culled to remove diseased fruit

Sugar (if needed, recommended if harvest Brix is less than 22°) 1 tablespoon wine yeast, rehydrated prior to use

1 tablespoon yeast nutrient

1 oz pectic enzyme (added to white juice prior to fermentation; not used in reds) 1 campden tablet (SO2)

* Rewritten by Anna Katharine Mansfield. 2006. University of Minnesota

Resources

Sources for Grapevines

Aberfoyle Vineyards & Nursery
58143 111th Street
Mapleton, MN 56065
Phone: 612-481-8115
Email: order@aberfoyle.org
www.aberfoyle.org

Bevens Creek Vineyard & Nursery
9350 Foxford Road
Chanhassen, MN 55317
Phone: 952-496-2213
Email: dellsss@yahoo.com
Bunchgrapes.com

(Lon J. Rombough)
PO Box 365
Aurora, OR 97002
Phone: 503-678-1410
Email: lonrom@bunchgrapes.com
www.bunchgrapes.com

Double A Vineyards
10277 Christy Road
Fredonia, NY 14063
Phone: 716-672-8493
Fax: 716-679-3442
Email: suerak@rakgrape.com
www.doubleavineyards.com

Grafted Grapevines Nursery, LLC
2399 Wheat Road
Clifton Springs, NY 14432
Phone: 315-462-3288
Email: Ute@graftedgrapevines.com
www.graftedgrapevines.com

Great River Vineyard & Nursery
35680 Hwy. 61 Blvd.
Lake City, MN 55041
Phone: 877-345-3531 (toll-free)
Email: grv@mchsi.com
www.greatrivervineyard.com

Northeastern Vine Supply
1428 River Rd.
West Pawlet, VT 05775 Phone:
802-287-9311
Email: andy@nevinesupply.com
www.nevinesupply.com

Red Dog Vineyards and Nursery
213 NE 15th St.
Ankeny, IA 50021
Phone: 515-577-4192
Email: jerry@reddogvineyards.com
www.reddogvineyards.com

Seaway Coldhardy Grapevines
9250 Route 11
Evans Mills, NY 13637
Phone: 315-629-8728
Email: cautote@twcny.com
www.seawaycoldhardygrapes.com

St. Francois Vineyards
1669 Pine Ridge Trail
Park Hills, MO 63601
Phone: 573-431-4294
Email:
contact@stfrancoisvineyard.com
www.stfrancoisvineyard.com/

Winterhaven Vineyard & Nursery
18103 - 628th Ave.
Janesville, MN 56048
Phone: 507-234-5469
Cell: 507-317-7914
Email:
order@winterhavengrapevines.com
www.winterhavengrapevines.com

Minnesota & MGGA Member Wineries

Alexis Bailly Vineyard
18200 Kirby Ave
Hastings, MN 55033
(651) 437-1413
www.abvwines.com

Aspelund Winery
9204 425th St.
Kenyon, MN 55946
(507) 824-2935
www.aspelundwinery.com

Buffalo Rock Winery
4527 23rd St., SE
Buffalo, MN 55313
(763) 682-WINE
www.buffalorockwinery.com

Cannon River Winery
421 Mill St. W
Cannon Falls, MN 55009
(517) 263-7400
www.cannonriverfwinery.com

Carlos Creek Winery
6693 Cty. Rd. 34, NW
Alexandria, MN 5638
(320) 846-5443
www.carloscreekwinery.com

Chankaska Creek Ranch Winery
1179 E. Pearl St.
Kasota, MN 56050
(507) 931-0089
www.chankaskawines.com

Chateau St. Croix Winery
1998 State Road 87
St. Croix Falls WI 54024
(715) 483-2556
www.chateaustcroix.com

Crow River Winery
14848 Hwy 7 E
Hutchinson, MN 55350
(612) 598-6800
www.crowriverwinery.com

Dancing Dragonfly Winery
2013 120th Ave
St. Croix Falls, WI 54024
(715) 483-9463
www.dancingdragonflywinery.com

Danzinger Vineyards
S2015 Grapeview Lane
Alma, WI 54610
(608) 685-6000
www.danzingervineyard.com.com

Elmaro Vineyard
N14756 Delaney Rd.
Trempealeau, WI 54661
(608) 534-6456
www.elmarovineyard.com

Falconer Vineyards Winery
3572 Old Tyler Rd.
Red Wing, MN 55066
(651) 388-8849
www.falconervineyards.com

Flower Valley Vineyard
29212 Orchard Rd.
Red Wing, MN 55066
(651) 388-1770
www.flowervalleyvineyard.com

Forestedge Winery
35295 State 64
Laporte, MN 56461
(218) 224-3535
www.forestedgewinery.com

Four Daughters Vineyard & Winery
78757 US Hwy 63
Spring Valley, MN 55975
(507) 346-7300
www.fourdaughtersvineyard.com

Garvin Heights Vineyards, LLC
2255 Garvin Heights Rd.
Winona, MN 55987
(507) 454-9463
www.ghvwine.com

Glacial Ridge Winery, Inc.
15455 Old Mill Rd.
Spicer, MN 56288
(320) 796-WINE
www.glacialridgewinery.com

Grape Mill Vineyard & Winery
18696 430th Ave, SW
East Grand Forks, MN 56721
(218) 499-WINE
www.thegrapemill.com

Hinterland Vineyards
3060 120th Ave SE
Clara City, MN
(320) 847-3060
www.hinderlandvineyards.com

Hoch Orchard
32553 Forster Rd.
La Crescent, MN 55947
(507) 643-6329
www.hochorchard.com

Indian Island Winery
18018 631st Ave
Janesville, MN 56048
(507) 234-6222
www.indianislandwinery.com

James Perry Vineyards
4790 480th Street
Rush City, MN 55069
(651) 528-2858
www.jamesperryvineyards.com

Lake Pepin Winery
35680 Hwy 61 Blvd.
Lake City, MN 55041
(651) 345-4004
www.greatrivervineyard.com

Maiden Rock Winery & Cidery
W12266 King Lane
Stockholm, WI 54769
(715) 448-3502
www.maidenrockwinerycidery.com

Millner Heritage Vineyard & Winery
32025 State Hwy 15
Kimball, MN 55353
(320) 398-2081
www.millnerheritage.com

Minnestalgia Winery
41640 State Hwy 65
McGregor, MN 55760
(866) 768-2533
www.minnestalgia.com

Morgan Creek Vineyards
23707 478th Ave
New Ulm, MN 56073
(507) 947-3547
www.morgancreekvineyards.com

Next Chapter Winery
16945 320th St.
New Prague, MN 56071
(612) 756-3012
www.nextchapterwinery.com

Northern Hollow Winery
6916 Canary Rd.
Grasston, MN 55030
(320) 266-8691
www.NorthernHollowWinery.com

Northern Vineyards Winery
223 North Main St.
Stillwater, MN 55082
(651) 430-1032
www.northernvineyards.com

North Folk Winery
43150 Blackhawk Rd.
Harris, MN 55032
(612) 674-7548
www.northfolkwinery.com

North Shore Winery
202 Ski Hill Road
Lutsen, MN 55612
(218) 481-9280
www.northshorewinery.us

Painted Prairie Vineyard
1575 250th Ave.
Currie MN 56123
(507) 626.5203
www.paintedprairiewine.com/

Parley Lake Winery
8350 Parley Lake Rd.
Waconia, MN 55387
(952) 442-2290
www.parleylakewinery.com

Post Town Vineyard & Winery
Rochester, MN
(507) 251-1946
www.posttownwinery.com

Red Barn Vineyard
20775 Putting Ave
Hastings, MN 55033
(651) 245-1193

Richwood Winery
27799 Cty Rd. 34
Callaway, MN 56521
(281) 844-5990
www.richwoodwinery.com

Round Lake Vineyards & Winery
20124 State Hwy 264
Round Lake, MN 56167
(507) 945-1100
www.roundlakevineyards.com

Saint Croix Vineyards
6428 Manning Ave, N
Stillwater, MN 55082
(651) 430-3310
www.scvwines.com

Salem Glen Vineyard & Winey
5211 60th Ave. SW
Rochester, MN 55902
(507) 365-8758
www.salemglenvineyard.com

Seven Hawks Vineyards
17 North Street
Fountain City, WI 54629
(608) 687-9463
www.sevenhawksvineyards.com

Sovereign Estate Wine
9950 North Shore Rd.
Waconia, MN 55387
(952) 446-9957
www.sovereignestatewine.com

Tassel Ridge Winery
1681 220th St.
Leeighton, IA 50143
(641) 672-9463
www.tasselridge.com

Two Fools Vineyard & Winery
12501 240th Ave, SE
Plummer, MN 56748
(218) 465-4655
www.twofoolsvineyard.com

Two Rivers Vineyard & Winery
6111 US Hwy 10, #200
Ramsey, MN 55303
(763) 439-4748
www.tworiversvineyardandwinery.com

Villa Bellezza Winery & Vineyard
1420 3rd Street
St. Pepin, WI 54759
(715) 442-2424
www.villabellezza.com

Vinmark Estates
13310 80th Street Court
Hastings, MN 55033
(651) 436-8401
www.vinmarkestates.com

Warehouse Winery
6415 Cambridge Street
Minneapolis, MN 55426
(612) 867-8998
www.warehousewinery.com

Whitewater Wines, LLC
10832 Fischer Hill Dr.
Plainview, MN 55964
(507) 534-1262
www.whitewaterwines.com

Wild Mountain Winery
16906 Wild Mountain Rd.
Taylors Falls, MN 55084
(651) 583-3583
www.wildmountainwinery.com

Willow Tree Vineyard & Winery
828 Constance Blvd, NE
Ham Lake, MN 55304
(763) 229-8824
www.willowtreewinery.com

Winehaven Winery & Vineyard
9757 22nd St.
Chisago City, MN 55013
(651) 257-1017
www.winehaven.com

Winneshiek Wildberry Winery, LLC
1966 292nd Street
Decorah, IA 52101
(563) 735-5809
www.wwwinery.com

Woodland Hill Winery
731 Cty Rd 30 SE
Delano, MN 55328
763-972-4000
www.woodlandhillwinery.com

Winemaking Supplies

Midwest Supplies
5825 Excelsior Blvd
St Louis Park, MN 55416
(888) 449-2739
midwestsupplies.com

Northern Brewer
1150 Grand Avenue
St Paul MN 55105
Ph: (800) 681-2739
northernbrewer.com

Presque Isle Wine Cellars
9440 West Main Road
North East, PA 16428
Ph: (814) 725-1314
piwine.com

Von Klopp Brew Shop
1137 6th St. NW
Barlow Plaza
Rochester, MN 55901
Ph: (507) 252-WINE
makewineandbeer.com

The Wine & Hop Shop
1931 Monroe St
Madison, WI 53711
Ph: (800) 657-5199
www.wineandhop.com

Soil and Plant Analysis Laboratories

MINNESOTA

AGVISE Laboratories
902 13th Street
P.O. Box 187
Benson, MN 56215
Ph: (302) 843-4109
http://agvise.com/

International Ag Labs
800 W. Lake Avenue
Fairmont, MN 56031
Ph: (507) 235-6909
http://www.aglabs.com/

Minnesota Valley Testing Laboratories
1126 N. Front Street
New Ulm, MN 56073
Ph: (800) 782-3557
http://www.mvtl.com/

U of MN Research Analytical Lab
135 Crops Research Bldg
1902 Dudley Avenue
St. Paul, MN 55108
Ph:(612) 625-3101
http://ral.cfans.umn.edu/

IOWA

AgSource Laboratories-Ellsworth
1532 DeWitt
PO Box 247
Ellsworth, IA 50075
Ph: (515) 836-4444
http://agsource.crinet.com/page3775/EllsworthIowa

Minnesota Valley Testing Laboratories
35 L Avenue
Nevada, IA 50201
Ph: (800) 362-0855
http://www.mvtl.com/

ISU Soil & Plant Analysis Lab
G 501 Agronomy Hall
Ames, IA 50011
Ph: (515) 294-3076
http://soiltesting.agron.iastate.edu/

Waypoint Analytical, Inc.
111 Linn Street
Atlantic, IA 50022
Ph: (712) 243-6933
http://waypointanalytical.com

NEBRASKA

AgSource
Harris Laboratories
624 Peach Street
P.O. Box 80837
Lincoln, NE 68501
Ph: (402) 476-2811
http://agsource.crinet.com/page2286/AgSourceHarrisLaboratories

Midwest Laboratories
13611 B Street
Omaha, NE 68114-3693
Ph: (402) 334-7770
https://www.midwestlabs.com

Ward Laboratories, Inc.
4007 Cherry Avenue
P.O. Box 788
Kearney, NE 68848
Ph: 800-887-7645
http://producers.wardlab.com/default.aspx

NORTH DAKOTA

AGVISE Laboratories
604 Highway 15 W
P.O. Box 510
Northwood, ND 58267
Ph : (701) 587-6010
http://www.agvise.com/

SOUTH DAKOTA

Soil Testing Laboratory
South Dakota State Univ.
Box 2207A, AGH 219
Brookings, SD 57007-1096
Ph: (605)688-4766
http://plantsci.sdstate.edu/soiltest/

WISCONSIN

AgSource Laboratories - Bonduel
106 N. Cecil Street
Bonduel, WI 54107
Ph: (715) 758-2178
http://agsource.crinet.com/page3774/BonduelWis

Dairyland Laboratories
217 E. Main Street
Arcadia, WI 54612
Ph: (608) 323-2123
https://www.dairylandlabs.net/

U of WI Soil & Plant Analysis Lab
5711 Mineral Point Rd.
Madison, WI 53705
Ph: (608) 262-4634
http://uwlab.soils.wisc.edu/ madison

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Grape breeding & enology

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mobile: (515) 681-7286
Email: mlwhite@iastate.edu

Vineyard Supply Sources

Agro-K Corporation
8030 Main Street NE
Minneapolis, MN 55432
Ph: (763)780-4116
www.agro-k.com

foliar and soil nutrients

Clements Lumber, Inc.
P.O. Box 218
Morgan, MN 56266-0218
Ph: (507) 249-3122
www.clementslumber.com

trellising supplies

Kfence Inc.
62411 386th Ave.
Zumbro Falls, MN 55991
Ph: (507) 753-2943
www.kfence.com fencing materials

MDT & Associates
3319 York Ave. No.
Minneapolis, MN 55422
Ph: (763) 529-4355,
(888) 530-7082
Fax: (763) 522-5843
Email: MaryJo@MDTgrow.com
www.mdtgrow.com

vineyard supplies

Brian Nelson UAP Distribution
N15721 Schubert Rd.
Galesville, WI 54630
Ph: (608) 539-2090
ag chemicals & supplies

Midwest Grower Supply
606 West 4th Street
Stanberry, MO 64489
Ph: (866) 802-3431
http://mwgsupply.com/

ag chemicals & equipment

Pliny Post and Pole
20110 220th St.
McGrath, MN 56350
Ph: (320) 592-3700
treated posts

Weed Badger Division
5673 95th Ave. SE
Marion, ND 58466-9718
Ph: (701) 778-7511
www.weedbadger.com

Recommended Reading

Dami, I., B. Bordelon, D.C. Ferree, M. Brown, M.A. Ellis, R.N. Williams, and D. Deehan. 2005. ***Midwest Grape Production Guide***. Ohio State Univ. Ext., Bull. 919.

P*rinted version available at:* http://estore.osu-extension.org/Midwest-Grape-Production-Guide-P224.aspx.

PDF version: http://www.oardc.ohio-state.edu/fruitpathology/Bulletins/mw_grape_12aug05%20S.pdf

Funt, R.C., M.A. Ellis, and C. Welty, *editors*. 2004. ***Midwest Small Fruit Pest Management Handbook***. Ohio St. Univ. Ext. Bulletin 861.

P*rinted version available at*: http://estore.osu-extension.org/Midwest-Small-Fruit-Pest-Management-Handbook-P115.aspx .

PDF version: http://pested.osu.edu/documents/CommStudy/2b%20Midwest%20Small%20Fruit%20Pest%20Mgmt..pdf

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Web Resources

Cornell University, Dept. of Horticulture **Cornell Fruit - Grapes** http://www.fruit.cornell.edu/grape/index.html

FruitEdge Fruit IPM Resources for new and emerging pests of the Midwest. UMN Extension. http://www.fruitedge.umn.edu/

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