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Growing Grapes in Missouri

State Fruit Experiment Station Missouri State University-Mountain Grove

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The viticulture advisory program at the Missouri State University, Mid-America Viticulture and Enology Center offers a wide range of services to Missouri grape growers. For further information or to arrange a consultation, contact the Viticulture Advisor at the Mid-America Viticulture and Enology Center, 9740 Red Spring Road, Mountain Grove, Missouri 65711-2999; telephone 417.547.7508; or email the Mid-America Viticulture and Enology Center at AndyAllen@mvec-usa.org. Information is also available at the website http://www.mvec-usa.org

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Chapter 1
Introduction

The Grape

The grape is a woody perennial vine of the genus *Vitis.* Missouri has at least eight native *Vitis* species. The important cultivated varieties, or cultivars, of grape grown in Missouri are divided into three general groups, the **American cultivars**, the **French hybrid cultivars**, and the **American hybrid cultivars**. The American cultivars are derived from native North American grape species and include cultivars derived from *Vitis labrusca* (Concord, Niagara, Catawba, Delaware), *V. aestivalis* (Norton/ Cynthiana), and other grape species. The French hybrid grapes were derived from native American species and *Vitis vinifera*, the classic grape of Europe. French hybrid grapes include cultivars such as Seyval Blanc, Vidal Blanc, Vignoles, Chambourcin, and many others. The American hybrid cultivars have a complex parentage that includes North American, French hybrid, and *V. vinifera* cultivars. Examples include Cayuga White, Reliance, Chardonel, and many others. Two groups of grapes, vinifera and muscadine, lack sufficient hardiness for consistent production in Missouri.

Missouri's Grape Industry

Missouri has a long and interesting history of grape production. The earliest viticultural efforts were by French settlers in the St. Louis and St. Genevieve areas of eastern Missouri, and date to the late eighteenth and early nineteenth centuries. Grape production increased tremendously in the early 1800s through the efforts of German settlers in the "Little Rhine" region of central Missouri near the Missouri River. By 1900 Missouri was a leading producer of grapes and award-winning wines. Production continued to increase statewide until the advent of Prohibition in 1920 outlawed the production of wine and other alcoholic beverages. Smaller scale grape production, primarily of the cultivar Concord for unfermented juice, continued through Prohibition and in the years following repeal in 1933. Missouri's wine industry experienced a rebirth in the 1960s, and growth of both grape and wine production continues today. At present (2002) Missouri has 41 bonded wineries and approximately 1200 acres of vineyard (Anderson, 2001; Saenz, 2002). Wine production (2002) approaches 500,000 gallons. Production of grapes is primarily for wine, although a small part of the crop is used for unfermented juice or sold for fresh table use.

Missouri's grape and wine industry is based on production of a number of grape cultivars of the American, French Hybrid, and American Hybrid groups. While small plantings of vinifera cultivars are found in Missouri, extreme winter cold limits the potential of this group. In addition, Missouri's range of geographies, soil types, precipitation patterns, and climates can limit production at specific sites and for specific cultivars.

Missouri was a leader in developing the concept of viticultural areas. Designated viticultural areas, which are regulated by the U.S. Bureau of Alcohol, Tobacco, and Firearms (BATF), have helped Missouri wines develop a regional identity. Portions of Missouri are currently included in four viticultural areas: Augusta (the first viticultural area established in the U.S.), Hermann, Ozark Mountain, and Ozark Highlands. Figure 1-1 illustrates these areas. For a detailed description of each viticultural area, consult the appropriate sections of the US Code of Federal Regulations (CFR, 2001).

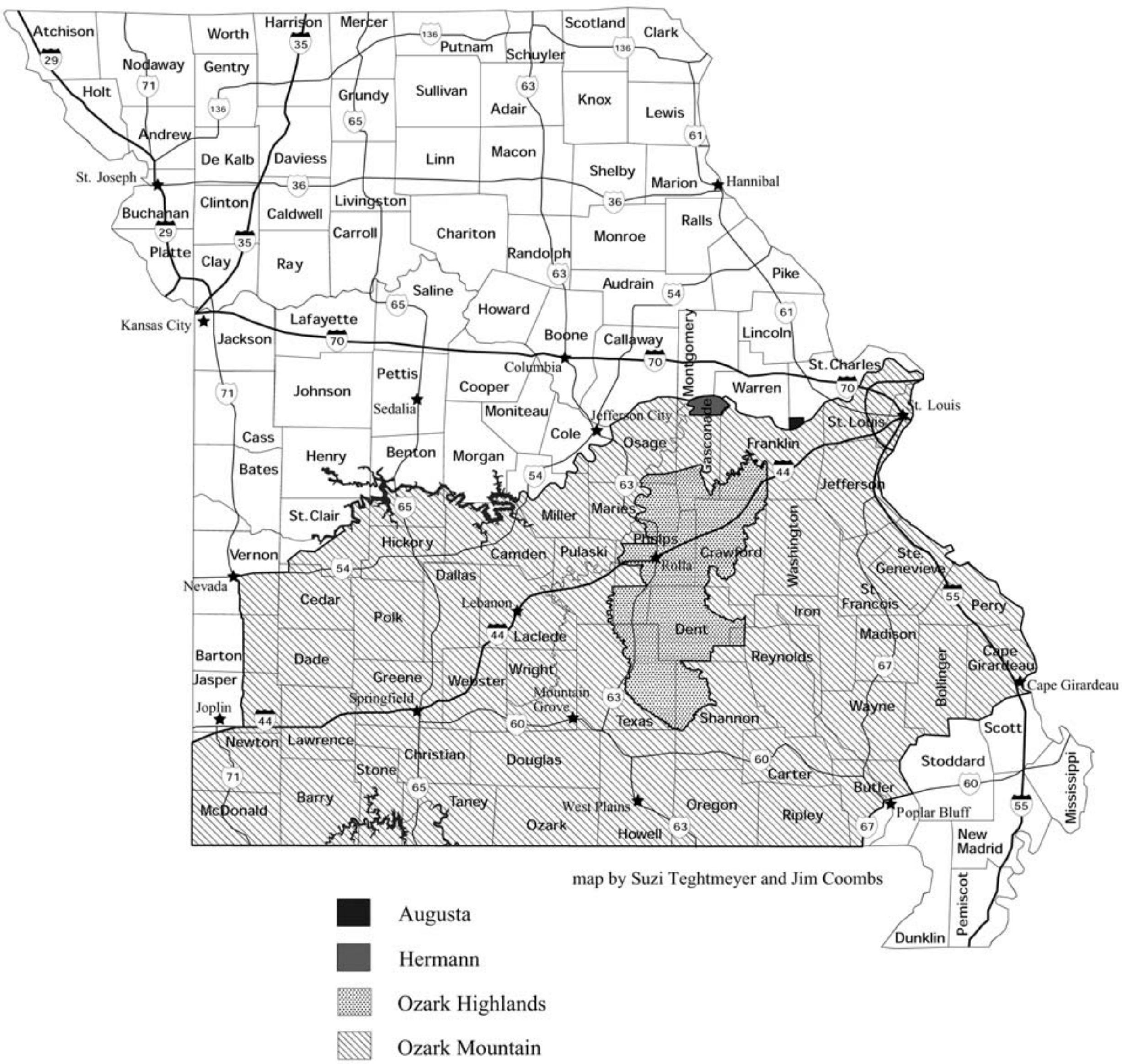


Fig. 1-1. Viticultural regions of Missouri

Chapter 2 Considerations in Planning a Vineyard

Many factors must be considered before establishing a vineyard. First of all you must be sure the grape cultivars you choose to plant will be marketable when they bear fruit. Planting cultivars that are marketable and adapted to your site is key. You must consider the nature of the site you have to work with, the vineyard operations you need to perform, and the best architecture for the vines.

Select cultivars. Contact wineries and other vineyards to see what cultivars are in short supply or popular at the moment. What cultivars will be popular or in short supply in the next 5 years? 10 years?

Site considerations include water availability, slope, depth and fertility of the soil, and prevailing winds.

Vineyard operations include irrigation, mowing, spraying, harvesting, and pruning. The vineyard should be designed so that operations can proceed efficiently and effectively.

The architecture of the vineyard is the training system, the between-row spacing, and the in-row vine spacing. You want to build a vineyard that will best expose the canopy to sunlight. The grower needs to have an idea of how much vigor a given cultivar will exhibit on a particular site before row and plant spacing and training system decisions are made. If you spread the buds too far apart, you will lose productivity. If you place them too close together, you will lose quality.

The row orientation depends on several factors. It is better to orient rows across hillsides or slope than to orient rows up and down to prevent erosion and for more efficient irrigation design. Many areas of Missouri are windy and it is best to orient the rows so the prevailing winds blow down the row and not against it (Patterson, 1996a). Often it is mentioned that rows should be oriented north and south to better intercept the sunlight, but this is not as important a consideration in Missouri as slope and prevailing winds.

The design of the vineyard should also take into consideration the economics of establishment. If two designs will take into account the slope and prevailing wind, choose the one with fewer end post assemblies. Of course the most economical may be one with very long rows but these may be depressing to workers who are hand harvesting or pruning. Remember that you have to efficiently harvest and transport the grape to the winery when you are designing the vineyard. Rows longer than 600 feet long may be interrupted by alleys (Wolf and Poling, 1995).

Between the row spacing most often is determined by the width of the vineyard machinery and the training system. Narrow vineyard equipment is available, but the rows should never be closer together than the trellis is high (Smart and Robinson, 1991). In Missouri, the most common between row spacing is 10 feet. Wider spacing may be used if planting on a steeper slope or where vigorous cultivars are planted to a horizontally divided training system like the Geneva Double Curtain.

Within the row spacing depends on the vigor and hardiness of the cultivar selected, how vigorous the cultivar will grow on the site with or without irrigation, and the training system selected. In Missouri, spacing between vines in the row commonly varies from 6 to 8 feet. Vigorous cultivars such as Norton/Cynthiana may be planted more than 8 feet apart, particularly if a divided canopy training system is not used, vines are planted on a deep and fertile soil, and/or irrigation is used.

Decisions made at vineyard establishment will have long-term effects on the profitability of your vineyard operation. You can avoid many problems down the road such as erosion, irrigation design problems, vines that are out of balance, and wasting fuel and time if you consider your vineyard establishment carefully.

Chapter 3
Cost of Establishing a Vineyard

The cost of establishing a vineyard can vary greatly in Missouri because of differences in the cost of real estate, labor, machinery, materials, site characteristics, grape cultivars, vineyard and trellis design, training system, pest management strategies, and other cultural practices. The following budget for vineyard site preparation and first year management is based on standard viticultural practices in Missouri. All costs were current at the time of publication. Alternative materials and practices are available that may reduce costs in specific situations. Several references detail the cost of establishing a vineyard (Bordelon, 1997; Cross and Casteel, 1992; Vaden and Wolf, 1994; Wolf et al., 1995).

Initial planning of all aspects of a vineyard is critical. Substantial capital is required to establish a vineyard, and the recovery time on this capital will be spread over several years. As is the case with any agricultural enterprise, risk is present and the potential for loss is real. A grape grower must recognize that establishment and production costs can vary greatly. Refer to Wolf et al. (1995) for grape production costs.

The economic viability of a specific vineyard depends on many factors. Several of these factors should be addressed during the planning phase of establishing a vineyard. These factors include a careful evaluation of the strong and weak points of a prospective site, selection of cultivars that are both profitable and in demand, selection of the trellis design and the training system, pest management and cultural practices, and harvest requirements.

Vineyard establishment costs are both fixed and variable. Fixed costs are usually specific to a given site, and include equipment costs and overhead, irrigation water sources, interest on land and money investments, and taxes. Because these costs are site specific, this budget will not consider fixed costs.

Variable costs include land, site preparation, vine and planting costs, trellis materials and installation, pest and weed management costs, fertilization costs, canopy management costs, irrigation system costs, labor for vineyard management, and debt on the loan of capital. This budget will not include land costs and fixed costs associated with land ownership, cost of a water supply, major site preparation costs, fixed ownership costs for machinery and equipment, and management fees.

The figures in this budget are based on site preparation and first year management for a 10-acre vineyard of own-rooted French hybrid or American winegrapes. Budget amounts are based on costs associated with one acre of vineyard. This one-acre vineyard has 11 rows, each 400 feet long. Rows are spaced 10 feet apart, and vines are spaced 8 feet apart in the row. The trellis is a two-wire trellis, and the vines are trained to a high wire bilateral cordon

system. Labor costs are figured at $7.50 per hour, and the finance rate for capital is 8%. Only operating costs are included for machinery.

This vineyard site is assumed to be clear of vegetation. A soil test will help guide applications of lime and nutrients. For this example, 3 tons of lime are applied to modify soil pH. A between-row cover crop of grass is seeded. Labor for site preparation is also included.

Table 3-1. Soil Preparation for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Soil test	$8	_______
Lime ($6/ton, 3 ton)	$18	_______
Cover crop (0.68/lb, 50 lb.)	$34	_______
Labor (14 hours)	$105	_______
Total	**$165**	_______

Planting costs include 1 year rooted cuttings, sleeves or grow tubes, and labor for planting.

Table 3-2. Planting for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Vines (545/acre, $2/vine)	$1090	_______
Sleeves (545 @ 0.30)	$163	_______
Labor (72.7 hours)	$545	_______
Total	**$1798**	_______

The trellis is a two-wire system using CCA pressure treated wooden posts and galvanized high tensile wire. Posts are spaced 24 feet apart in the row. End post assemblies are secured using helical screw-in anchors. This category also includes hardware and labor.

Table 3-3. Trellis for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
3.5” x 8’ CCA posts (187)	$808	_______
6” x 8’ CCA posts (22)	$219	_______
12.5 ga HT wire (10,000 ft)	$180	_______
Anchors (22)	$88	_______
Strainers, sleeves, staples	$70	_______
Labor (50 hours)	$375	_______
Total	**$1740**	_______

This vineyard is irrigated with a trickle system, with 6mm drip tube laterals with 3′ inline emitters. The tubes are attached to a trellis wire that is 18″ high. A backhoe is used to bury the irrigation manifold line. This budget does not include the cost of a water source, pump, filters, distribution lines, manifold lines, and controls.

Table 3-4. Irrigation for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Backhoe operations (2 hr @ $50/hour)	$100	______
Drip tube (3' inline, 4400 feet)	$506	______
Irrigation wire	$66	______
Tube attachers	$14	______
Labor (11.5 hours)	$86	______
Total	**$662**	______

Canopy management during the establishment year includes trunk training and removal of excess side shoots. The trunk is trained to a 6′ bamboo stake.

Table 3-5. Canopy Management for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Training stakes (545 @ 0.25)	$136	______
Tie materials	$5	______
Labor (22 hours)	$165	______
Total	**$306**	______

A single application of ammonium nitrate will supply the vine's nitrogen needs during the establishment year.

Table 3-6. Nitrogen for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Ammonium nitrate (0.25 lb./vine)	$19	______
Labor (2 hours)	$15	______
Total	**$34**	______

Pest management during the establishment year includes the use of herbicides for weed management and application of insecticides and fungicides.

Table 3-7. Pest Management for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Herbicides	$28	______
Fungicides/insecticides	$109	______
Labor (39 hours)	$293	______
Total	**$430**	______

Additional expenses associated with vineyard establishment include machinery operating costs and operating interest. Machinery operating costs are based on standard hourly operation costs, and include the use of a tractor, pickup, herbicide and pesticide sprayers, post driver, mower, fertilizer spreader, PTO driven auger, and a flatbed trailer. Operating interest is estimated as 8% of the total capital outlay for the vineyard for 6 months.

Table 3-8. Operating Interest for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Machinery operating costs	$578	______
Operating interest	$232	______

Annual cash expenses for vineyard site preparation and first year establishment are summarized below.

Table 3-9. Summary Budget for One Acre Vineyard

Budget Item	Estimated Cost	Your Estimate
Site preparation	$165	______
Planting	$1798	______
Trellis construction	$1740	______
Pest management, fertilizer	$464	______
Canopy management	$306	______
Irrigation	$772	______
Machinery operating cost	$578	______
Operating interest	$232	______
Total	**$6046**	______

Chapter 4
Site Selection

The first consideration for successful investment in a new vineyard is the selection of an outstanding site. This strategic and critical step will condition all the future performance of the vineyard, not only in the years of establishment, but also for the rest of the more than thirty years of expected vineyard life. The selection of the site is of such paramount importance that it is a major factor controlling the success or failure of vineyards in Missouri. For all these reasons and given the abundance of land for expansion of the viticulture industry in Missouri, emphasis has to be placed on choosing only superior sites. Superior sites optimize yield, grape quality for winemaking, and costs of production.

Site selection is not a new topic in viticulture. Since ancient times experience has shown that selecting the right site was a key for success. For example, Romans developed the proverb, "Bacchus loves the hills", probably to emphasize that hills provide a better environment for grape ripening, avoidance of diseases, and reduced risk of frost injury.

Poor site selection could present an increase in future maintenance cost because of an increased need for fungicide sprays, increased cost for replacing missing plants, a need for construction of drainage systems, and a need to use frost protection systems.

The important factors to be considered for site selection under Missouri conditions include:

- Topography: elevation, slope, aspect and relative position
- Climate: rain and temperature
- Soil: depth of top soil, internal drainage, texture, pH, etc.
- Neighboring land: wildlife, cereal crops (herbicides), densely forested (tall, thick trees)

Other factors that are not horticultural but also could be of relevance are the reputation of the region, and the proximity to markets, labor force availability, and services.

Topographic factors

Elevation is a factor known to dramatically influence the climate of a site, primarily because with every 150 feet gain in elevation the average temperature decreases 1 ^{o}F. Given that Missouri viticulture areas range from 300 feet (100 meters) to 1300 feet (400 meters) in elevation, it is expected that elevation could be an influential factor on temperature.

Aspect is another prominent factor influencing the mesoclimate. For Missouri conditions with the high risk of frost and freeze, a southern exposure could be a negative factor because of an early induction to budbreak. During ripening, a southern exposure could be a negative factor because of increased temperatures that decrease fruit quality. Practically speaking, however, aspect is generally not the primary factor in selecting a vineyard site.

Slope has a big influence on cold air drainage. Given that cold air is heavier than warm air, cold air tends to move downhill and pool in valleys, analogous to the flow of water. When the temperature of the grape tissues is below the dew point, free water starts forming on it and the dew provides the optimum condition for disease infection. Planting a vineyard in a "cold spot" not only will make it more susceptible to frost and freeze, but also will create conditions for increased fungal infections. In addition, steep slopes always increase the risk of erosion, especially slopes above 10%, but the use of contour rows and other practices can help to reduce this risk.

Climatic Factors

Low temperature is the single most important limiting factor for grape growing in the state of Missouri. The total number of days with temperatures below the freezing point fluctuates from approximately 40 days in the Northwest to 10 days in the Southeast. In a parallel fashion, the length of the growing season is shorter in the Northwest (approximately 150 days) compared to the Southeast (approximately 210 days) (Fig. 4-1). In general, the major viticulture areas located in central and south Missouri have enough season to adequately ripen the fruit of the common varieties before the first killing frost. On rare occasions fall cold temperatures can reduce quality of late ripening cultivars such as Norton.

Average minimum temperatures for January range from -12 ºF in the Northwest to + 20 ºF in the extreme Southeast. This provides an idea of the big differences in cold hardiness limits on varieties growth in the NW compare to the SE. Also, it indicates that winter minimum temperature is one of the most important limiting factors for selecting a superior site.

Rain provides needed water for grape growth. On average, annual rainfall increases from the NW corner of the state with approximately 34 inches (800 mm) to the SE part of the state, with an average of 50 inches (1200 mm) (Fig. 4-2). Erratic rainfall distribution, often coupled with soils of low water infiltration rates and/or shallow soils with low water holding capacity, can lead to water stress for

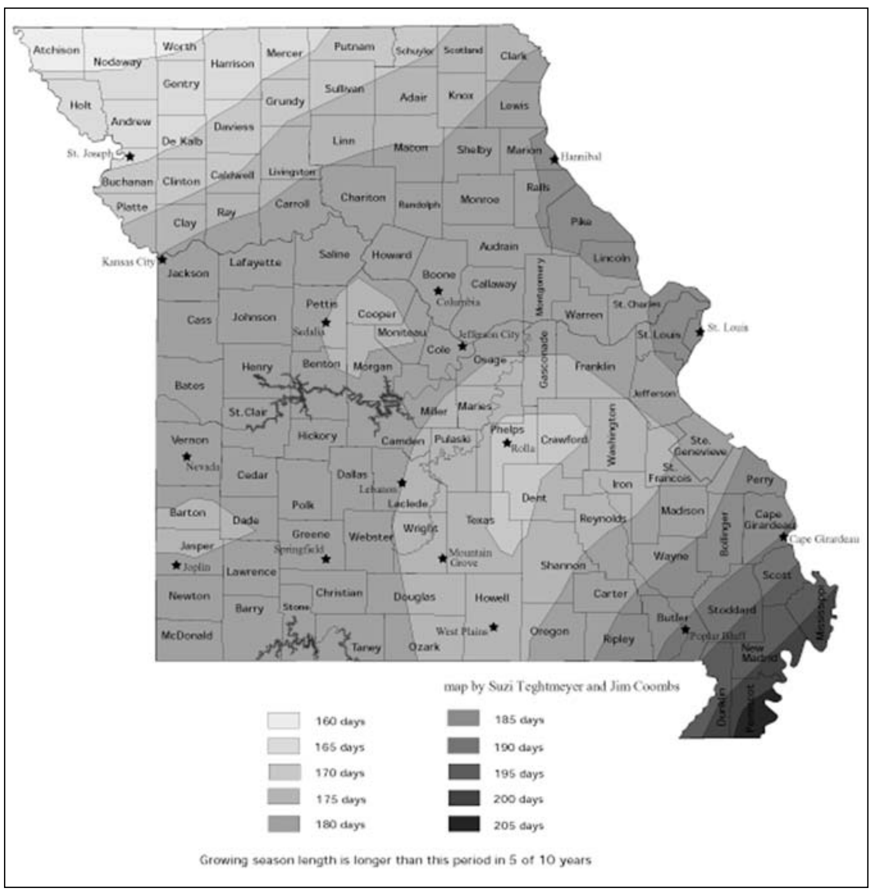


Fig. 4-1. Length of growing season in Missouri

grapes. Supplemental irrigation is a useful tool for optimizing yields and quality.

Soil

Adequate internal soil drainage that prevents waterlogging is an important element. Deep soils, capable of providing adequate water storage and fertility, are a big advantage. Nevertheless, shallow soils like the ones in the Ozarks provide a suitable environment but these soils require supplemental irrigation and careful and continuous fertility management. Soil pH tends to be acidic and generally demands correction by liming to reach desirable values above 6.

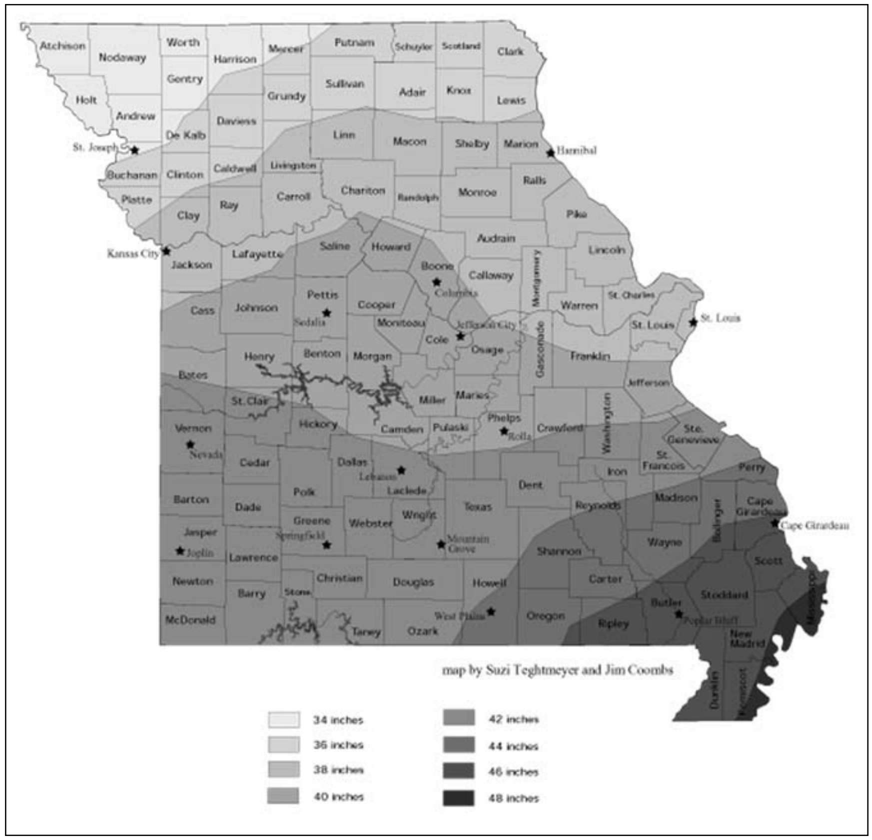


Fig. 4-2. Annual average precipitation in Missouri

Corrective measures, like soil ripping or drainage installation, are efficient and cost effective if adopted before planting.

Wildlife

Missouri vineyards are often surrounded by woodlands or open areas devoted to livestock grazing. Wildlife is particularly abundant. Isolated vineyards can be devastated by wildlife damage, commonly the case in Missouri, if care is not taken. Deer and birds are the most conspicuous examples of vertebrates preying on grapes and/or grapevines. Deer are a huge problem almost everywhere in the state. Establishment is the most critical period for deer damage, but deer can also be a limiting factor later. Bird (including wild turkey) damage is another serious problem particularly in small vineyards.

Phenoxy Herbicides

The use of broadleaf weed herbicides is widespread in field crops like corn. The herbicides of the phenoxy group, such as 2,4-D, will cause dramatic injury on grapes. The poisoning effects of these herbicides can occur miles away from the area where the herbicides have been sprayed. Grape production can be severely impacted in regions where phenoxy type herbicides are widely applied.

How to Get Information

Many Missouri counties have an office of the Natural Resources Conservation Service of the U.S.D.A. This office can provide you with reliable, detailed soil studies and soil survey maps, and also with topographic maps and aerial photography. There is also a University

of Missouri Extension and Outreach office in many counties where you can send soil samples for analysis.

Chapter 5
Cultivar Selection

The selection of grape cultivars is a very important decision. Select cultivars based on their intended use as fresh fruit (table), jam, juice, or wine. Color, taste, aroma, sugar and acidity content, seedless condition, and vine growth will vary widely depending on cultivar. Grape species and cultivar adaptation to winter cold temperature is as important to Midwestern viticulturists as fruit and vine characteristics.

Over 90 percent of world viticulture is represented by the grape species *Vitis vinifera.* It is grown in geographic locations in the U.S. where weather patterns and large bodies of water moderate winter temperatures, such as the eastern seaboard, west coast states, and eastern and southern shores along the Great Lakes. This species is not hardy in the Midwestern U.S. temperate climate. A few viticulturists successfully grow *Vitis vinifera* vines in cold climates by mounding soil over vines trained low or bent-over to ground level. For most viticulturists this is not practical or economical for any more than a few vines. Because of this cultivars of *Vitis vinifera* are not recommended.

Grape cultivars recommended for the Midwestern U.S. are selected native American species, some French-American hybrids, and a few more recent American hybrids. The native American species used for fruiting are primarily *Vitis labrusca* and *Vitis aestivalis.* Most older cultivars of *Vitis labrusca* and *V. aestivalis* were selections from the wild and are not considered to be pure species but natural hybrids. A number of these cultivars have been grown for well over a hundred years. The French-American hybrids are an important group of cultivars for wine. These were a result of late nineteenth and early twentieth century French breeders' efforts to obtain direct producing (ungrafted) grapes that combined good fruit quality with adequate disease and insect resistance. Both native American species and *Vitis vinifera* were used in breeding. The geneology of these cultivars is often complex and sometimes unknown. The French-American hybrids are usually grown on their own roots without grafting, and they retain much of the fruit quality of their *Vitis vinifera* parents. More recently, state or Canadian provincial breeding programs have developed cultivars for regional climates, some of which are adapted to the midwestern U.S. These hybrid crosses often include native American grape species, *Vitis vinifera,* and French-American hybrids in their geneology, and are called American hybrids. Tradition plays an important role in grape cultivar selection and culture in world viticulture. Tradition plays much less a role in Midwestern U.S. viticulture. New cultivars of grapes continue to be evaluated.

Grape cultivar recommendations are based on their productivity in southern Missouri at Mountain Grove. A cultivar trial was initiated in 1985 and continued through 1994. Twenty-seven wine grape and ten table grape cultivars were evaluated. The more productive cultivars from this trial have gained acceptance by the Missouri grape and wine industry and are listed below. Exceptions to this are Chardonel, Marquis and Traminette; their recommendations are based on later trials at Mountain Grove and grower experience. All the recommended cultivars require a spray program for control of insect and disease problems. Refer to Table 11-1 for relative disease susceptibility ratings.

American Species

Vitis labrusca

Catawba is a red grape for table fruit, juice and wine with large berry size and small, loose clusters. It has high vigor and a high degree of winter hardiness. The fruit matures late season. Dormant pruning adequately controls cropping. Yield is moderate to high. The vine trains well to a cordon system with spur pruning. High vigor sites will allow for divided canopy training. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease with Black Rot and Downy Mildew being the major problems. Table fruit quality is very good but berries are seeded. Juice quality is very good. Labrusca 'foxy' character is strong. It is typically made into a sweet, blush wine or used in blending.

Concord is a blue-black grape for table fruit, juice and wine with large berry size and small, loose clusters. It has high vigor and a high degree of winter hardiness. The fruit matures late season. Dormant pruning adequately controls cropping. Yield is high. The vine trains well to a cordon system with spur pruning. High vigor sites will allow for divided canopy training. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease with Black Rot being a major problem. Table fruit quality is very good but berries are seeded. Juice quality is very good. Labrusca 'foxy' character is strong. It is typically made into a sweet, red wine or used in blending. **Sunbelt** is a 1993 Arkansas release that has vine and fruit characteristics that are very similar to Concord. Fruit of Concord can ripen unevenly during warm maturing seasons; Sunbelt is less prone to this.

Delaware is a red grape for wine with small berry size and small, compact clusters. It has moderate vigor and moderate winter hardiness. The fruit matures midseason. Dormant pruning adequately controls cropping. Yield is moderate to high. The vine trains well to a cordon system with spur pruning. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease with Black Rot and Downy Mildew being the major problems. Juice quality is very good. Labrusca 'foxy' character is mild. It is typically made into a sweet, blush wine or used in blending. It is also used in sparkling wine production.

Niagara is a white grape for table use, juice and wine with large berry size and medium, loose clusters. It has high vigor and a high degree of winter hardiness. The fruit matures midseason. Dormant pruning adequately controls cropping. Yield is high. The vine trains well to a cordon system with spur pruning. High vigor sites will allow for divided canopy training. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease with Black Rot being a major problem. Table fruit quality is very good but berries are seeded. Juice quality is very good. Labrusca 'foxy' character is strong. It is typically made into a sweet, white wine, or used in blending.

Vitis aestivalis

Cynthiana and Norton cultivars are genetically the same. It is a blue-black grape for red wine with small berry size and small, loose clusters. It has high vigor and a high degree of winter hardiness. The fruit matures late season. Dormant pruning adequately controls cropping. Yield is low. On any site other than very low vigor, the vine should be trained to a divided canopy system with spur pruning to improve yield. Shoot positioning is recommended several times during the growing season. Foliage and fruit are much less susceptible to the major grape diseases but some spray program will be needed. Wine quality is excellent. It is typically made into a dry, red varietal wine.

American Hybrids

Cayuga White is a 1972 New York release. It is a white grape for wine with large berry size and large, compact clusters. It has high vigor and moderate winter hardiness. The fruit matures midseason. Dormant pruning usually controls cropping but cluster thinning may be needed to prevent overbearing. Yield is high. The vine trains well to a cordon system with spur pruning. High vigor sites will allow for divided canopy training. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease with Black Rot and Anthracnose being the major problems. Wine quality is excellent. Labrusca 'foxy' character is mild. It is typically made into a semi-dry to dry, white, varietal wine.

Chardonel is a 1990 New York release. It is a white grape for wine with medium berry size and medium to large, compact clusters. It has moderate vigor and low to moderate winter hardiness. The fruit matures late season. Dormant pruning usually controls cropping but cluster thinning may be required in some years. Yield is moderate. The vine trains well to a cordon system with spur pruning. It should be planted on a vineyard site with good water drainage because of its susceptibility to winter trunk injury. A good spray program is necessary to control disease. Clusters are less susceptible to bunch rot. Wine quality is excellent, having characteristics of its Chardonnay and Seyval blanc parents. It is typically made into a dry, white, varietal wine. This cultivar is only adapted to better sites in Missouri. In areas where its hardiness has not been determined, it should be planted on a trial basis.

Mars is a 1985 Arkansas release. It is a blue-black, seedless table grape with medium berry size and small, loose clusters. It has high vigor and a high degree of winter hardiness. The fruit matures early season. Cluster thinning may be needed in years of high production to prevent overbearing. Yield is moderate to high. The vine trains well to a cordon system with spur pruning. High vigor sites will allow for divided canopy training. Shoot positioning is recommended several times during the growing season. Foliage and fruit are less susceptible to the major grape diseases but some spray program will be needed. Table fruit quality is very good. Berries may have occasional soft seeds. Skin is somewhat tough. Labrusca 'foxy' character is strong and similar to Concord.

Marquis is a 1996 New York release. It is a greenish-white, seedless table grape with large berry size and medium, loose clusters. It has moderate vigor and moderate hardiness. The fruit matures midseason. Cluster thinning may be needed in years of high production to prevent overbearing. Yield is high. The vine trains well to a cordon system with spur pruning. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease. Table fruit quality is excellent. Labrusca 'foxy' character is mild.

Reliance is a 1982 Arkansas release. It is a red, seedless table grape with medium berry size and medium to large, loose clusters. It has high vigor and a high degree of winter hardiness. The fruit matures early season. Cluster thinning may be needed in years of high production to prevent overbearing. Yield is moderate to high. The vine trains well to a cordon system with spur pruning. High vigor sites will allow for divided canopy training. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease with Black Rot and Anthracnose being the major problems. Table fruit quality is excellent. Berry skin is thin which leads to fruit 'cracking' and rot in some years. A large crop maturing in warm weather leads to poor red color development. Labrusca 'foxy' character is mild.

Traminette is a 1996 New York release. It is a white grape for wine with medium berry size and small, loose clusters. It has low to moderate vigor and low winter hardiness. The fruit matures late season. Cluster thinning is not required. Yield is low to moderate. The vine trains well to a cordon system with spur pruning. It should be planted on a vineyard site with good water drainage because of its susceptibility to winter trunk injury. A good spray program is necessary to control disease with Black Rot, and Downy and Powdery Mildews being the major problems. Clusters are less susceptible to bunch rot. Wine quality is excellent, having characteristics of its Gerwurztraminer parent. It is typically made into a semi-dry to dry, white, varietal wine. This cultivar is only adapted to better sites in Missouri. In areas where its hardiness has not been determined, it should be planted on a trial basis.

Vanessa is a 1983 Ontario, Canada release. It is a red, seedless table grape with medium berry size and medium, loose clusters. It has moderate vigor and moderate winter hardiness. The fruit matures midseason. Cluster thinning is usually not required. Yield is moderate. The vine trains well to a cordon system with spur pruning. Shoot positioning is recommended several times during the growing season. A good spray program is necessary to control disease. Table fruit quality is excellent. Berries are non- slipskin, similar to vinifera table grapes. Berries may have occasional soft seeds. Labrusca 'foxy' character is mild.

Vivant is a 1983 Ontario, Canada release. It is a white grape for wine with small berry size and medium, compact clusters. It has low to moderate vigor and moderate winter hardiness. The fruit matures late season. Yield is low to moderate. The vine trains well to a cordon system with spur pruning. A good spray program is needed to control diseases with Black Rot, Downy and Powdery Mildews and Anthracnose being the major problems. Clusters are less susceptible to bunch rot. Wine quality is excellent. It is typically made into a dry, white, varietal wine.

French-American Hybrids

Chambourcin is a red grape for wine with medium to large berry size and large, loose clusters. It has low to moderate vigor. It has low to moderate winter hardiness. The fruit matures late season. It does not require cluster thinning. Yield is moderate. The vine trains well to a cordon system with spur pruning. Spacing should be closer than eight feet between vines on lower fertility sites. It grows better when planted on a vineyard site with good water drainage and higher soil fertility. A good spray program is needed to control diseases with Powdery Mildew being a major problem. Loose clusters make it not susceptible to bunch rot. Wine quality is excellent. It is typically made into a dry, red wine.

Seyval blanc is a white grape for wine with medium berry size and large, compact clusters. It has moderate vigor and moderate winter hardiness when managed to a moderate cropping level. The fruit matures midseason. Cluster thinning is required in most years. Yield is high. The vine trains well to a cordon system with spur pruning. A good spray program is needed to control diseases with Black Rot and Powdery Mildew being the major problems. Bunch rot can be a problem in some years. Wine quality is good. It is typically made into a dry, white, varietal wine.

St. Vincent is considered to be a chance hybrid of a French-American hybrid cultivar with an unknown parent. It is a red grape for wine with large berry size and small, loose clusters. It has high vigor and moderate to high degree of winter hardiness. The fruit matures late season. It does not require cluster thinning. Yield is high. The vine trains well to a cordon system with spur pruning. A good spray program is needed to control diseases. Loose clusters make it not susceptible to bunch rot. Wine quality is good. It is typically made into a dry, red wine, or used in blending.

Vidal blanc is a white grape for wine with medium berry size and large, elongated, compact clusters. It has high vigor and moderate winter hardiness when managed to a moderate cropping level. The fruit matures late season. Cluster thinning is required in most years to prevent over cropping. Yield is moderate to high. The vine trains well to a cordon system with spur pruning. It should be planted on well drained vineyard sites because of its susceptibility to winter trunk injury. A good spray program is needed to control diseases with Powdery Mildew and Anthracnose being the major problems. Berries have thicker skins and clusters are less compact than Seyval which makes it more resistant to bunch rot. Wine quality is excellent. It is typically made into a dry, white, varietal wine.

Vignoles is a white wine grape with small berry size and small, compact clusters. It has low to moderate vigor depending on planting site fertility. It has moderate to a high degree of winter hardiness. The fruit matures early season. It does not require cluster thinning because of low bud fruitfulness. Yield is low to moderate. The vine trains well to a cordon system with spur pruning. Spacing should be closer than eight feet between vines on lower fertility sites. It should not be cropped the first three years to promote good vine establishment. A good spray program is needed to control diseases with Black Rot and Anthracnose being the major problems. Compact clusters make it very susceptible to bunch rot. Frequently, this can not be adequately controlled by protective sprays. Wine quality is excellent. It is typically made into a semi-dry to semi-sweet, white, varietal wine.

Chapter 6 Selecting and Constructing a Trellis System

Key Planning Points Checklist

- Get professional assistance. Consider contacting advisers from the Missouri State University Department of Fruit Science, UMC Extension Service, Missouri Department of Agriculture Grape and Wine Program, established vineyard growers, an irrigation specialist, and sales reps for the products you will need for trellis construction, i.e., post, wire, and hardware. This should be the first item on your list of things to do!
- Check your soils. Sands, loam, clay or mixture. Deep soils or shallow. Clay, chert, or rock subsoil layer. Get a soil test for pH and nutrients and get advice on interpreting the results, if needed. Make needed adjustments before the vines go in the ground.
- Locate water, electrical, gas, telephone lines.
- Check topography. Level land or rolling terrain. Are there rises or dips?
- Consider your needs. Will you hand harvest? Or will you machine harvest? Do you need access aisles?
- Plan ahead. Is there expansion in the future?
- Focus on vineyard location. How far is it to public gravel road or paved road?
- Sketch the vineyard. Draw a simple map of topography; locate hazards, roads, water resources, note prevailing winds, general location and orientation of vineyard.
- Choose a trellis system. These are all questions that need to be answered when deciding on the trellis system to utilize with a new vineyard: What cultivars will be grown? What is the vigor of the cultivars? How deep is the soil? Will the vineyard be irrigated? What are the yield goals for the vineyard? Will grapes be machine harvested or hand harvested?
- Bracing assemblies (end post). Decide what kinds of end post assembly you want to use for the vineyard. What is the trellis system being constructed? What are your soil types, the terrain of your land, and the length of the rows?

Training Systems

High wire cordon

The high wire cordon (Fig. 6-1) is used with cultivars that tend to have a drooping growth habit. Most wine grapes in the state are grown on this system. It is easy to train and maintain vines on this system. The trellis itself is easy to maintain. Generally only two wires are needed for the trellis. The top wire is the cordon wire and the bottom wire serves as a training wire and a hanging wire for the irrigation system. It is the least expensive system to construct and readily lends itself to machine harvesting.

Low wire cordon

The low wire cordon (Fig. 6-2) was developed for low to moderate vigor cultivars, which have an extremely upright growth habit, such as Vignoles. It also keeps the

Fig. 6-1. High Wire Cordon training system

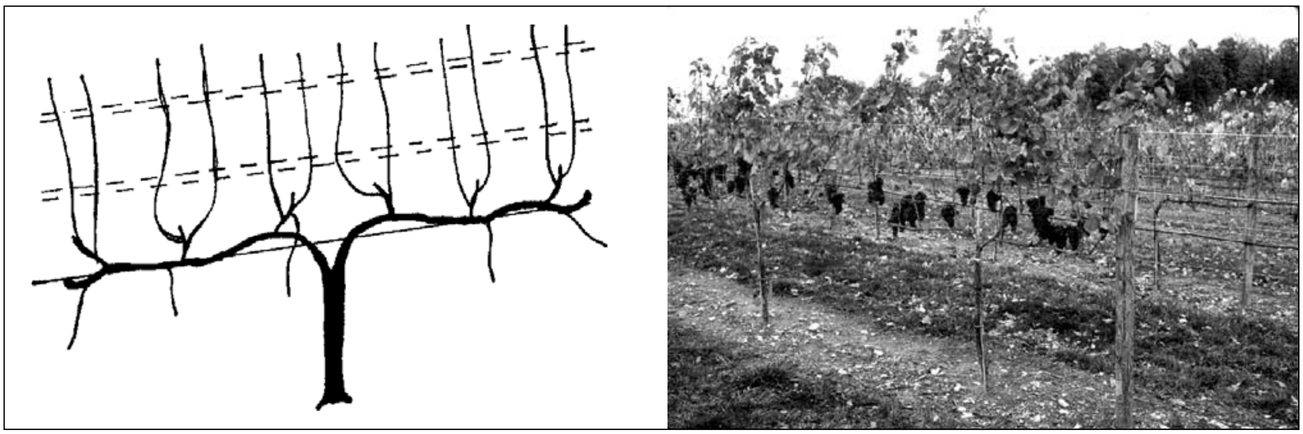


Fig. 6-2. Low Wire Cordon training system

fruiting zone exposed thus allowing for uniform spray coverage of the fruit. With disease prone cultivars it can be used to help control disease by leaf removal in the fruiting zone. The system is a little more complicated than the high wire cordon. The cordon wire is placed about 36 inches above the ground with pairs of catch wire above. Some systems utilize one pair of movable catch wires while others use two pairs of non-movable catch wires. With the low wire cordon, the grower must send workers through the vineyard two or three time during the growing season to push new shoot up and behind the catch wire. Often shoots are trimmed in the summer when they grow over the top wire of the system. In some years this may need to be done twice before growth ceases. Approximately four feet of canopy is maintained. The system does lend itself to some mechanization.

Geneva Double Curtain (GDC)

The Geneva Double Curtain (Fig. 6-3) was developed for vigorous cultivars that can fill in the trellis in a year or two. Cultivars like Concord or Cynthiana/Norton are generally too vigorous to put on a single curtain type system of training. The number of new buds needed each year would crowd a short length of cordon. With the double cordon wires, adjacent plants can be trained

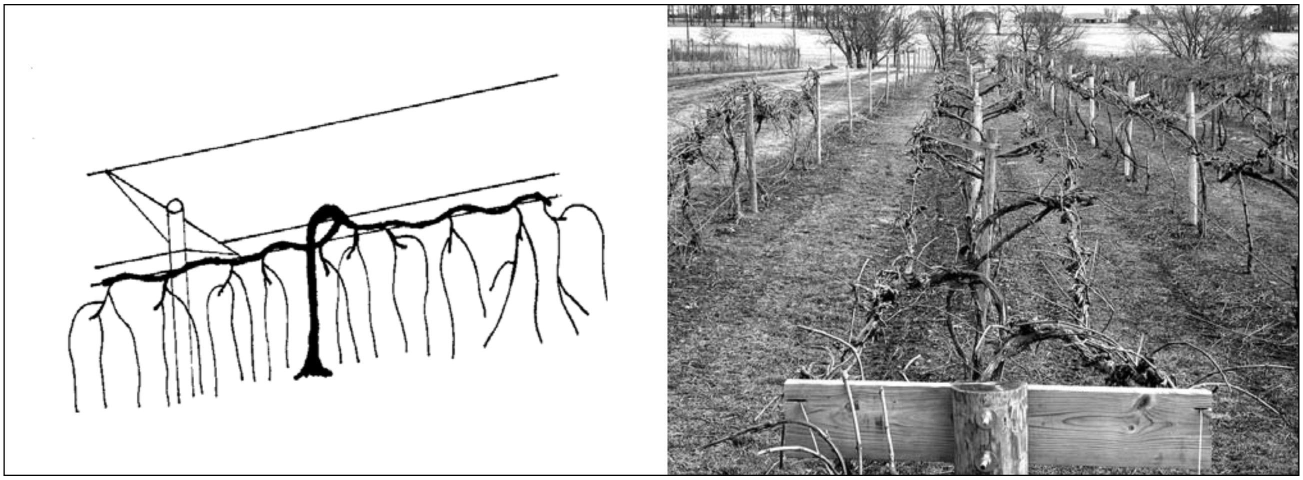


Fig. 6-3. Geneva Double Curtain training system

to opposite wires thus giving 16 feet of cordon for the bud spurs to be spread on instead of just 8 feet with the single wire trellis. Long spurs (4 to 6 buds) can be spaced 10 to 12 inches apart on the cordon thus allowing better light and airflow to the new developing shoots. This is important with vigorous cultivars that can grow canes of 15 or more feet each year. The GDC allows for the use of mechanical hedging, pruning and harvesting. It also allows for higher yields of better quality grapes than could be accomplished with a single wire system.

A number of other training systems are used to a limited extent in Missouri. These systems include various cane pruned Kniffen systems and divided canopy systems such as the Lyre, the Scott Henry, and variations of the Smart-Dyson system.

Bracing Systems

Tie back brace assembly

The tie back system (Fig. 6-4) of bracing the end of a trellis utilizes an end post that leans away from row centers at a sixty-degree angle from the perpendicular. With this system the end post is the anchor and must be in the ground a minimum of four feet. The second post should be set at a 20 to 30 degree angle from perpendicular from the row center and at least three feet in the ground. Subsequent line posts should be plumb with the ground and set two feet in the ground. This system is suited to soils that have a deep sandy or loamy structure with clay subsoil where it is relatively easy to auger holes to the proper depth. This system is not the best for shallow rocky soils with a

Fig. 6-4. Tie back brace assembly

hardpan in the subsoil layer. These soils can be difficult to auger to the required depth for setting the post.

Single Span brace assembly (H system)

The H system (Fig. 6-5) uses a brace between the first two posts in the row. The end post should be set four feet in the ground while the second post should be set three feet in the ground. Both posts should be set with a 1″ lean away from vertical from each other. The post should be notched to hold the brace in place and a brace wire should also be utilized to pull the post tight against the brace. This system can be used with any trellis system but is particularly good with the GDC system and the low wire cordon.

Fig. 6-5. Single span brace assembly

Deadman brace assembly

Deadman assembly (Fig. 6-6) uses an anchor to hold the end post. The end post is put two to three feet deep and leaning at a sixty degree angle away from vertical from the direction of pull. The anchor can be any of several types. One of the easiest to install is a screw anchor. A tractor-mounted auger can be modified to screw the anchors in. Other types of anchors are made with rebar and concrete. Old railroad ties and large rocks have been used. These anchor types will require an augered or trenched hole so the anchor can be buried. This system is good where the soil is underlain with a rocky or chert subsoil which would make it hard to set posts a full four feet deep.

Fig. 6-6. Deadman brace assembly

Site Preparation

Soils

The soils must be tested for the needs of the new planting and nutrients added as determined by the soil test. The site is prepared to reduce weed and/or grass competition for the new plants. The soil structure should also be analyzed. The type of equipment needed for construction of the trellis system as well as the brace system to utilize will be determined by soil structure. Deep sandy or loamy soils will be easier to work in than a shallow chert soil. Shallow soil underlain with a hard rocky chert layer can be difficult to dig postholes or to drive post. Deeper soils with a lot of sand or loam are easier to drill. The brace system to use will be determined by the type of soil.

Alleys and roads

The placement of roads and alleys in the vineyard needs to be carefully considered. Trellis rows should not exceed about 800 feet in length for hand harvest. An alley each 800 feet in the vineyard can be beneficial in moving the grapes, especially when vines are hand harvested. Where machine harvest is used, rows can be longer. Terrain of the field should be studied so that road and alleys are not placed in low areas that may become impassable during rainy periods.

Row spacing

Row spacing will be determined by three factors: the trellis system, vigor of the cultivar expected on the site, and the equipment to be used. Most vineyards are set up with 10 feet row spacing. This works well with single wire trellis systems (high wire, low wire, and cane systems). When a Geneva Double Curtain is to be used then 12 feet row spacing may be needed. If specialized vineyard equipment is to be used, when tractors are narrower than normal farm equipment, then 10 feet row spacing may be kept with the GDC. Where narrow vineyard equipment is going to be used and low vigor cultivars are being planted then the row spacing may be reduced to nine or even eight feet for single wire trellis systems.

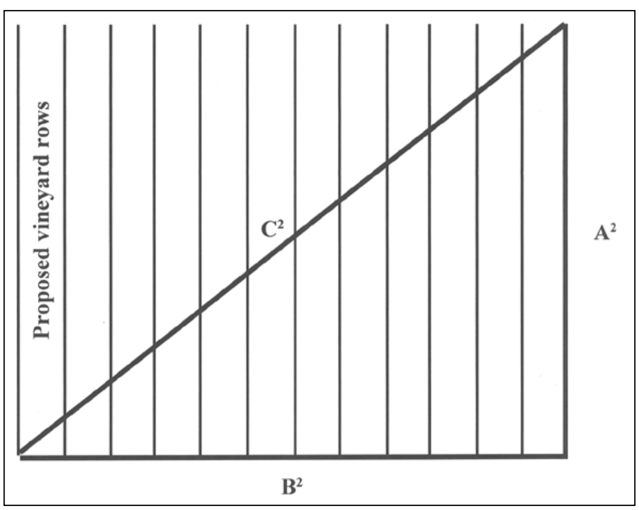


Fig. 6-7. Squaring the vineyard layout

Layout

Flag and layout the corners of the vineyard, squaring the corners of the vineyard before proceeding. Use the Pythagorean theorem ($A^2 + B^2 = C^2$) to square the vineyard (Fig. 6-7). Run rows with the terrain of the land. It is preferable to run rows across the slope of a hill than to run them up and down the hill. Any rises or dips need to be flagged so line posts can be set in the areas ahead of other line posts.

Set the four corner end posts first and then fill in with the rest of the end posts. String a guide wire down the row to aid with line post alignment. Be sure to set line posts on any rises or in any dips in the landscape. The wire should be set about 4 inches above the ground.

Last set the line posts and when finished pull the guide wires up to make the bottom training wire of the trellis.

Material

Wire, fasteners, and other hardware

Wires

Load bearing wires. There are many types of wire which can be used in trellis construction. High tensile (HT) galvanized wire has proven to be the most cost effective and longest lived of the available options. For the main load bearing (top) wire, 12.5 gauge high tensile wire with No. 3 galvanizing is preferred. It can be tightened to its load capacity and left during the winter without stretching and sagging, as soft wires will do. It is a little more expensive in the short run but will outlast soft wire by 10 to 15 years. Most high tensile wire with No. 3 galvanizing will last 40 years before rust weakens it.

Non-load bearing wires. Soft or HT wire is suitable for nonload bearing wires. The wire generally does not need to be as tight as the load bearing wires. For training and catch wires 14 gauge wire in HT or soft is sufficient.

Fasteners

Wire vises (Fig. 6-8) can be used for rows of 200 feet or less. In line strainers (Fig. 6-9) need to be used for rows of 200 feet or more. If the row length is less than 400 feet, the strainer can be placed at one end of the row. If the row is over 400 feet long, the strainer needs to be placed in the middle of the row so that both ends can be tightened at the same time.

Fig. 6-8. Wire vises

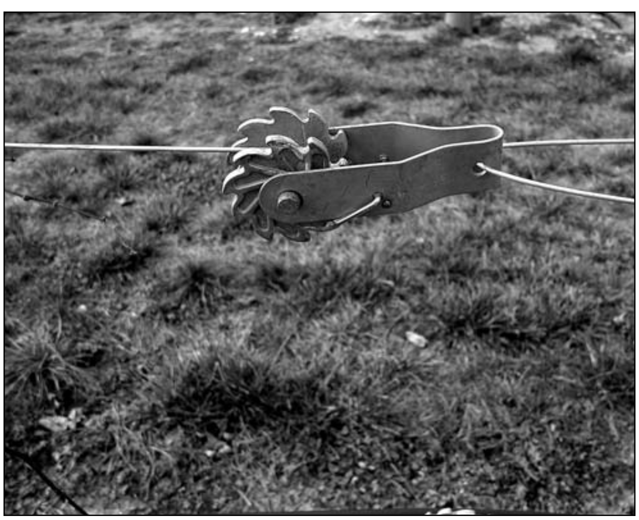


Fig. 6-9. In line strainers

Hardware

Crimp holders are needed for splicing wire at the ends of rows or at the end of a role of wire. They are readily available at local farm supply stores. Staples need to be 1¼ inch galvanized at a minimum.

Posts

Wood preservative treatments

Use **pressure treated** for maximum penetration. CCA-chromated copper arsenate will outlast penta by several years. **Do not** use dipped or sprayed posts, but buy **only pressure treated.** Pressure treated posts will last 15 to 20 years longer than dipped or sprayed posts of the same wood. Use AWPA Standard C16- 0.40 to 0.60 pcf treatment. The most common treatment for posts is the 0.40 pcf treatment but if sufficient posts are ordered the higher treatment can be requested. This may be beneficial in humid climates.

Sizing

End post: 4″ to 8″ X 8′ to 10′ wood. Line post: 3″X 8′ wooden or 8′ metal T post. Wood posts can be spaced 20 to 30 feet apart. Metal T posts should be spaced 16 feet or less with some recommendations for one post at every plant. Metal T posts may be used where mechanical harvest of the vineyard is anticipated.

Construction

If the vineyard is mechanically planted the rows will need to be flagged for the planters to follow. Trellis construction can start after the vines have been planted. When planting by hand, the trellis can be constructed before planting. Trellis should be in place as soon after planting as practical to aid in training of the young vines.

Brace assemblies must be constructed first. A guide wire is run between the end posts at about 4″ from ground.

Set line posts by driving or auguring them in the ground. They should be placed ½ inch from the guide wire and with the wire on the windward side of the post. This allows the prevailing wind to blow the foliage and wire against the post instead of away from the post. Wood line posts are spaced at 24 to 40 feet apart or between every 3 or 4 vines. Steel T posts are commonly spaced 8 to 16 feet apart.

The guide wire can then be positioned as the bottom training wire or irrigation support wire. Other wires can then be installed as per the system being built.

After all wires have been installed the cordon wires should be tensioned to 100 psi for the first year. This will give the end brace assemblies' time to settle into their location. During this first year the vines can be trained to the cordon wires. There will not be sufficient load to cause problems with sagging wire during the first year. After one year the cordon wires can be tensioned to 250 psi. Other wires in the system can be tightened sequentially from the bottom to the top to match the cordon wire.

The wires are then fastened at the proper height to the line post. With wood line posts, double staples can be used or the post notched to hold the wire. Staples should be 1¼ inch in length at a minimum. Staples should be spread so they splay outward as they are nailed in. Generally it is best to use two staples at each site on the post. The first is nailed in parallel to the wire so the wire can rest on the staple. The next staple is nailed in over the wire and first staple so that it will hold the wire to the post. The staples should be loose enough that the wire can slide as it is tightened. Notch the post at the proper locations at about a 75-degree angle and ½ to ¾ inch into the post. The wire is then laid into the notch and a nail driven in above the wire to keep it from pulling out of the notch as tension is placed on the wire. Wires are attached to steel T posts with wire connectors.

Maintenance

Maintenance of the vineyard trellis should be done each year, before new growth has started in the spring. Posts should be checked to see they are still solid. Wire should be checked for breaks and tightened as needed. End brace assemblies should be checked to make sure they are not loosened due to frost heaving. It is much easier to replace post or fix wires in the early spring than to have to try and fix a problem in the summer with full foliage and a heavy fruit load on the vines.

Additional information on trellis planning and construction is found in *How to Build Orchard and Vineyard Trellises* (United States Steel Corporation, 1982), the *Oregon Winegrape Growers Guide* (Casteel, 1997), and *Vineyard Establishment II* from Michigan State University (Zabadal, 1997).

Chapter 7 Planting the Vineyard and Care of Young Vines

Planting stock should be ordered from the nursery well in advance of the planned planting date. One year number one rooted cuttings are recommended. Popular or difficult to propagate vines like Norton/Cynthiana may have to be ordered at least two years in advance.

Planting stock should be inspected on arrival. Planting stock should be $^{3}/_{8}$ inch in diameter or about pencil thickness. Roots should be moist, not dried out and not too wet. If there is a problem contact the nursery immediately.

New plants are trimmed to one cane with 3 to 4 buds, and side shoots are removed at planting.

If plants cannot be placed in the ground immediately, store in a cool place and keep moist until planting. Cold storage should be maintained just above freezing. Plants can also be placed in a shallow trench with soil or mulch covering the roots in a shady location for planting later.

Mark the plant spacing accurately before planting.

Most planting is done by hand. An 8 to 10 inch auger works well, trenches may be dug down the row before trellis is constructed, or hand shovels can be used. It is important that the planting hole is not glazed on the sides. In clay soils you can weld a bit of metal on the edges of the auger to break up the sides. If planting with a shovel, make sure to disturb any glazed sides.

Mechanical planting is used in Missouri. Mechanical planting is done before the trellis is constructed. In general, grower experiences have been that there are more spacing discrepancies and lower percentage survival with mechanized planting, but the results will vary with planting area and type of machine used.

Plants must not dry out during the planting operation. Keep roots moist by placing them in water in buckets or by wetting them and protecting them with a tarp.

No matter what planting method you use, dig the trench or hole large enough to accommodate all of the roots so you don't have to prune any off (Zabadal, 1997b). Spread the roots out evenly, firm soil around the roots, and water the plants.

Spring planting is recommended. After vines are planted, they should be watered in. If planting by hand, it is best if the irrigation and trellis systems are installed before planting. If mechanically digging a trench or mechanically planting, water plants in by hand and install irrigation and trellising as soon as possible after planting. Make sure that a depression is not left around the vine where herbicide can pool and damage vines.

Fall planting is possible but only with very cold hardy varieties and is best handled by an experienced grower. Most nurseries do not dig in the early fall so stock may have to be specially arranged. Stock must be dormant. Plants should be mulched to help prevent frost heaving. It is not as critical to water plants in after planting in the fall as it is in the spring.

Care the first two years focuses on training (Chapter 7), fertility management (Chapter 10), providing adequate moisture (Chapter 9), weed control (Chapter 13), and protecting the vines from pests (Chapters 11-14). Read these sections for details on the care of young vines. Pest management in particular is important during the first two years. Weed control generally consists of a combination of hand hoeing, shallow cultivation, mulching, and herbicide applications.

Disease and insect control is also important. Black rot, downy mildew, anthracnose, phomopsis, and other foliar diseases can reduce vine vigor and result in winter injury to vines. Foliar feeding insects can likewise damage young vines. Monitor vines frequently during the first two years, and address any problems promptly. Deer, rabbits, and other chewing animals are also threats to young vines. Develop a management strategy before planting the vineyard (Chapter 2).

Chapter 8
Training and Pruning

Introduction

Grapes are vining plants that need support to spread out their leaves and intercept as much sunlight as possible. In a vineyard, the shape of a vine's canopy will be determined by the training system selected. In this guide, only training systems and pruning methods recommended for grape growing in Missouri are described. Specifically these are spur pruning systems for own rooted French hybrids, American hybrids, and American grapes.

In a modern vineyard, the perennial portions of the grape vine include the root system, the trunk, and cordons. Fruit is borne on current season's growth, which arises from compound buds that were formed during the previous growing season. The compound bud usually contains 3 buds. The largest bud, the primary bud, has the potential for greatest fruitfulness. If cold temperature or some other factor kills the primary bud, a secondary bud may produce a smaller crop. Grape cultivars vary in the level of fruitfulness from secondary buds. If both primary and secondary buds are killed, vegetative growth may result from a smaller bud, but these tertiary buds usually are not fruitful.

Fruit clusters are formed directly opposite a leaf on current season's growth. Environmental and genetic factors control fruitfulness in a vine. Location of clusters on the vine is also specific to cultivars. American cultivars, for instance, usually have 2 to 4 fruit clusters located at nodes 2, 3, 4, and 5 from the base of the shoot. French hybrid cultivars, on the other hand, may have four or more clusters per shoot, distributed outward from the base of the shoot. Location and number of clusters are important considerations when choosing a vine training and pruning system.

New compound buds form in the leaf axils of current season's shoots. These shoots eventually become woody and are the source of next year's fruiting wood.

Definitions

- Trunk - vertical part of the vine, trained up to the trellis wires
- Cordon - horizontal extension of the trunk, supported by trellis wires; spurs are located here
- Shoot - current season's extension growth, green in color
- Cane - shoot that has matured (hardened off), brown in color
- Spur - canes that have been pruned back to a few nodes
- Buds - swelling at nodes; after bud break, these will grow into the shoots, bearing both flower clusters and leaves
- Canopy - all shoots and their leaves make up the canopy

Training Systems

The goal in training vines is to maximize the amount of foliage exposed to sunlight by creating the concept of balance, having a large surface area without shading adjacent vines. The surface area is much larger for thin canopies than for thicker, more spherically shaped canopies. Training systems exist where the fruiting wire with the cordons is high above the ground and new growth is directed downward. Others direct shoot growth upward and the fruiting zone is closer to the ground. Both high and low training systems have variations in which two separate foliage curtains are produced, called divided canopies in contrast to the non-divided canopies.

Divided canopies are used for varieties with high vigor; since they have twice as much cordon length per plant, they make it possible to keep more buds on each vine without crowding the spurs, therefore increasing the yield from each vine, generally without reducing the fruit quality. Dividing the canopy can decrease shading of fruit and allow better air movement in the fruiting zone.

Systems with high or low cordons should be selected according to the growth habit of the variety. Most American grape varieties have trailing growth habits. Their shoots naturally hang down, and a system with a high fruiting zone is more appropriate. French hybrids can vary in their growth habits. Low cordon systems with the shoots trained upward may be selected for those with an upright growth habit.

The following systems represent possible combinations of single and double curtain systems; horizontally and vertically divided; and shoots trained upward or downward. Variations exist for several of these systems, but the pruning principles remain the same.

High Cordon (HC)

The cordon wire is about 6 to 6½ feet above ground level and cordons are trained bilaterally from the trunk. Often two trunks are grown, producing one cordon from each trunk. The shoots grow downward, so during pruning spurs that are oriented downward should be selected (Figs. 8-1a and 8-1b).

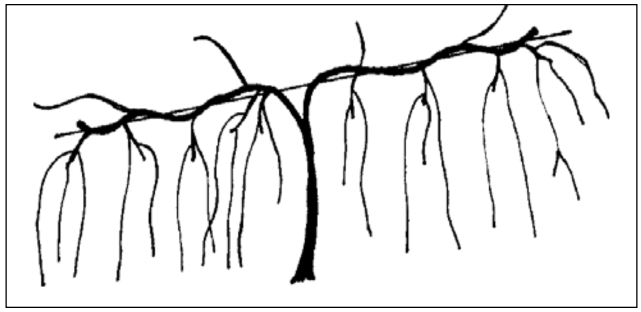


Fig. 8-1a. High cordon system. Shoots above the cordon should be removed during pruning.

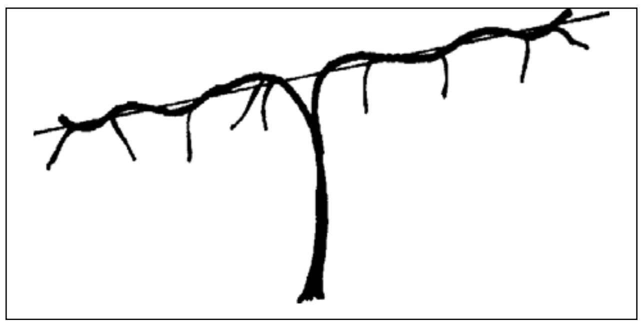


Fig. 8-1b. High cordon system after pruning.

Low Cordon (LC) or Vertical Shoot Positioning (VSP)

Contrasted with the high cordon, the fruiting wire of the LC is 36 to 44 inches above the ground, and growth is held above the cordon with sets of movable catch wires at 17 to 21 and 34 to 42 inches above the fruiting wire. Shoots are often topped after they reach the highest set of catch wires, maintaining about 4 feet of canopy. During pruning select spurs that are oriented upward. Both HC and LC systems have non-divided canopies (Fig. 8-2).

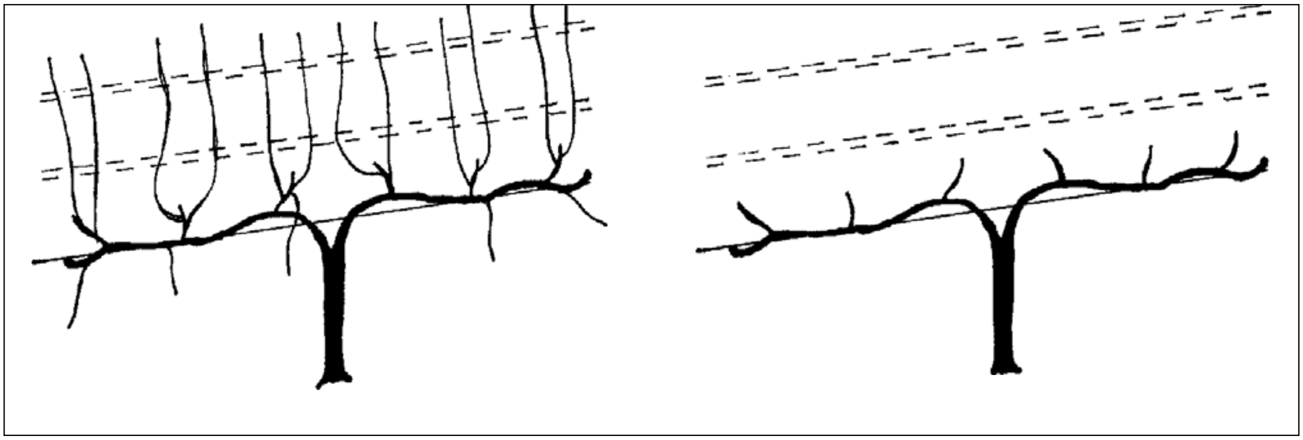


Fig. 8-2. Low cordon system. Left, shoots growing downward should be removed during pruning.
Right, Low cordon system after pruning. The two sets of two wires close together are the catch wires.

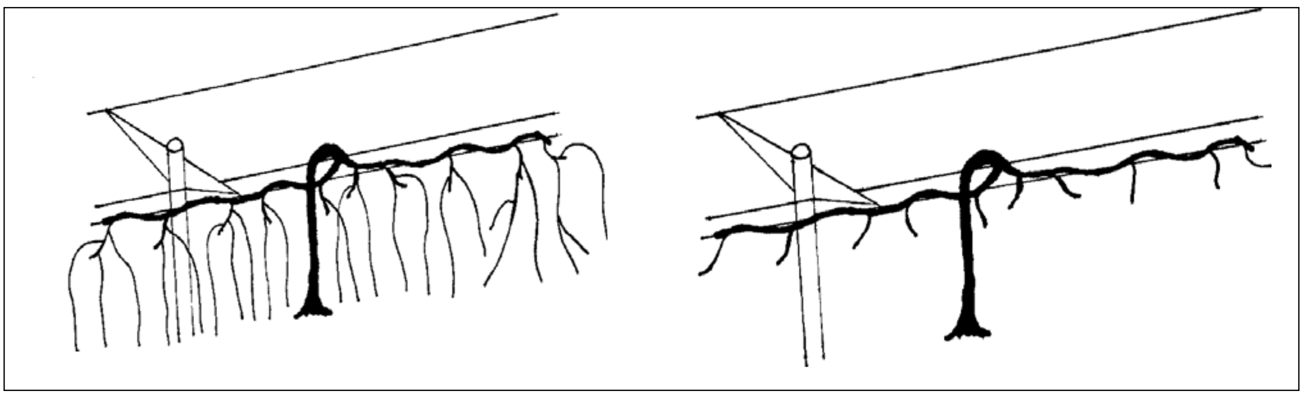


Fig. 8-3. Left, GDC system before pruning. The middle wire helps to train the vine.
Right, GDC system after pruning. The next vine would be trained to the opposite side of the trellis.

Geneva Double Curtain (GDC)

This and the following training systems have divided canopies. In the GDC system the curtains are divided vertically. When pruned and shoot positioned correctly, two canopies, side by side, should be visible. To achieve this, the curtains must be separated occasionally. The area between the two fruiting wires must be kept clear of shoots. To achieve this, shoots are postitioned or removed away from this area. Shoots and spurs grow downward; often one trunk each is trained to one set of fruiting wires, spaced 48 inches apart (Fig. 8-3).

Open Lyre or U

Contrasted with the GDC system, the Lyre system has two sets of low bilateral cordons, multiple trunks and shoots trained upwards using catch wires and topping. The canopies are vertically separated, about 30 inches apart (Fig. 8-4).

Scott Henry (SH)

In an SH system, the canopies are vertically divided and stacked on top of each other. Shoots growing from the lower set of bilateral cordons are trained downward, shoots from the upper bilateral cordon are trained upwards with catch wires and are topped (Fig. 8-5).

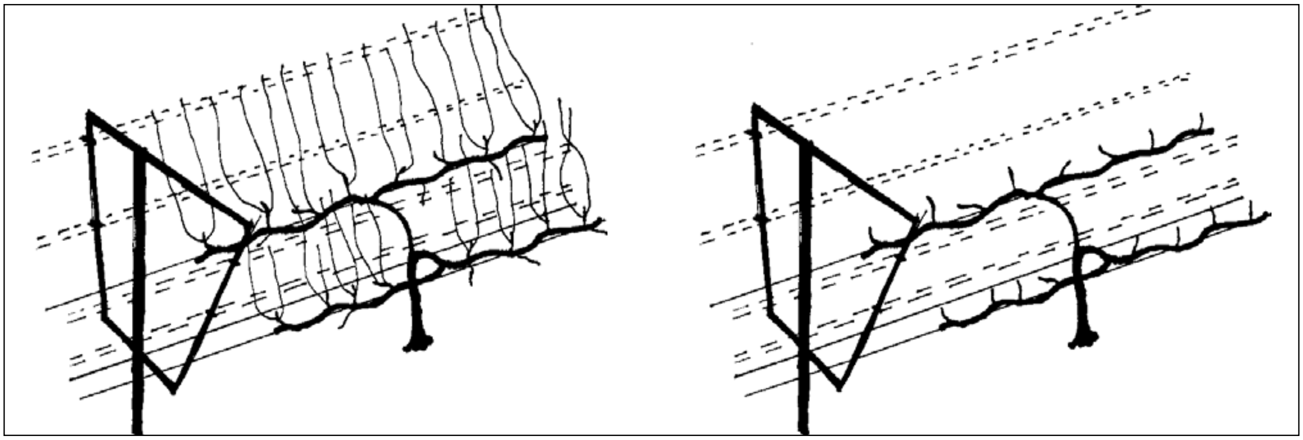


Fig. 8-4. Left, Lyre or U system before pruning. All downward growing shoots should be removed.
Right, Lyre system after pruning.

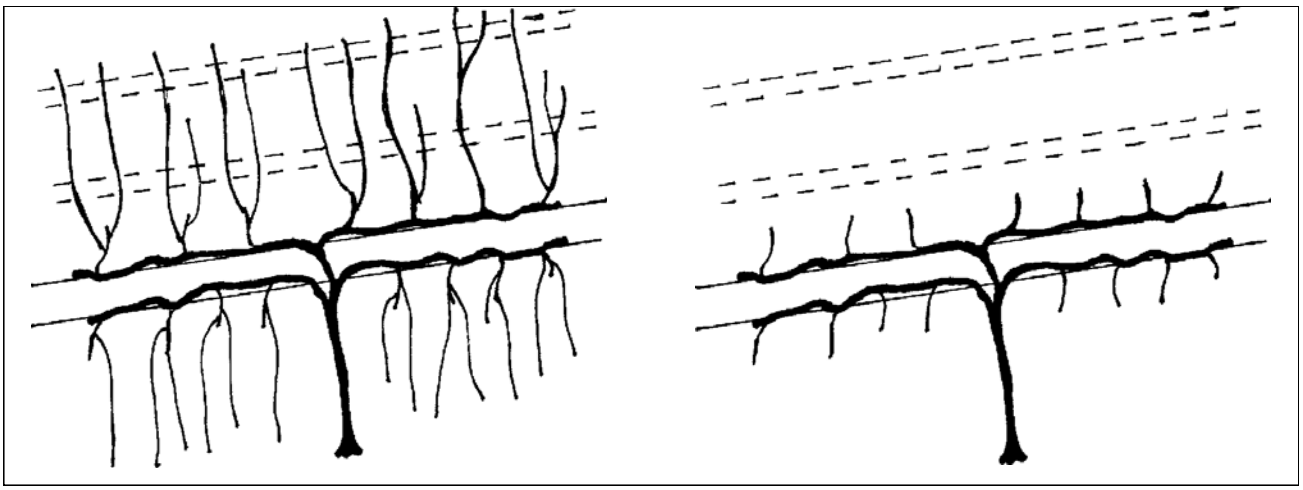


Fig. 8-5. Left, Scott Henry system before pruning.
Right, Scott Henry system after pruning. The broken lines are the catch wires.

Training

Training the vine takes place in the first 2 to 3 years after planting. The goals are to establish a strong root system, and a framework for the desired training system, including a straight trunk that will be able to support much of the vine's weight once the vine has matured.

Year One

At planting, a support system for the vine should be installed. This can be a string tied from a spur on the plant to the top trellis wire or a stake placed next to the vine and attached to the top wire with a clip. As growth occurs, the shoots are loosely fastened to their support by tying (Fig. 8-6). A tape fastener can speed this up considerably. A medium to light weight tape (4 to 6 gauge) will break as the trunks of the vines expand, eliminating the need for removal of the ties. Other ties and clip systems are available.

Vines in their first growing season should not be pruned, as all top growth is needed to establish a root system as large as possible.

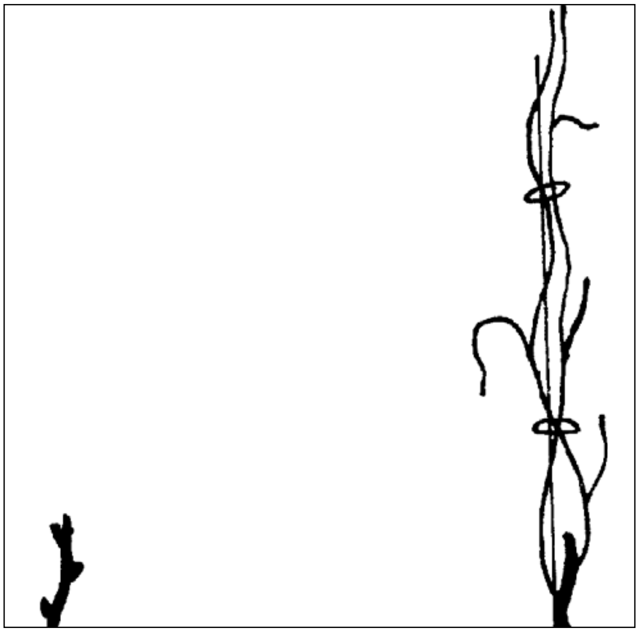


Fig. 8-6. Young vine at planting (left) and new growth tied to a stake (right).

Grow tubes can be used to protect the vines from herbicide sprays and to promote shoot growth. The narrowness of the tubes also makes it easier for the tendrils of the new growth to attach to the support, eliminating the need for tying until the shoots emerge from the top of the tubes. The tubes provide a 'greenhouse' environment, increasing temperatures and moisture levels and providing shelter from winds that could cause breakage and dry out new growth. Tubes also protect vines from mechanical injuries and damage by rabbits and deer, at least until the shoots emerge at the top. Various types of tubes have been used, and no differences in effectiveness between types have been reported. All tubes need to be removed about 4 to 6 weeks before the date on which the first freeze is expected. This gives the vines time to harden off (to be able to withstand low winter temperatures).

Year Two

After the danger of severe freezes is over, the young vines should be evaluated. Vines with very little, thin growth should be cut back to leave only 2 to 3 buds. They can then be treated as described for the first year.

If several healthy canes have grown, 2 or 3 should be selected as future trunks. If possible, the selected canes should be about pencil thickness and the nodes should not be much more than 4 to 5 inches apart. Usually no more than two trunks per vine are developed. This makes it easier and faster to replace parts of a vine that have been injured by cold temperatures or disease.

Remove any competing shoots that develop on the lower portion of the canes selected at trunks. The canes should be fastened to the support system. Any canes that reach a fruiting wire can be either bent over gently and fastened to the wire, or they can be topped just about at the height of the wire. If the latter method is used, side shoots developing from the buds at wire height will be fastened to the fruiting wire. If the shoots haven't reached the fruiting wire, continue training them up the support.

All fruit should be removed, so that the vine can put all its energy into growth of shoots and roots. An exception to this rule would be extremely vigorous vines that have already filled their space on the fruiting wire. On vines like this you can leave 3 to 4 clusters per cordon.

Year Three

Training should be completed for most vines during the third year. Canes for trunks have been selected and trained to reach the fruiting wire. The canes trained horizontally on the fruiting wires will start forming the cordons. On plants where this is not the case, treat the plants as in year two.

To form the cordons, tie and wrap canes loosely around the wires. Any side shoots on these canes should be cut back to 4 to 5 buds, spacing these spurs out on the entire length of the cordon. To encourage side shoot formation on a cane, leave the cane 3 to 4 foot longer than needed to fill the space on the fruiting wire and let this 'extra' portion droop downward. This removes inhibition of bud break due to apical dominance on the middle part of the cane (Fig. 8-7).

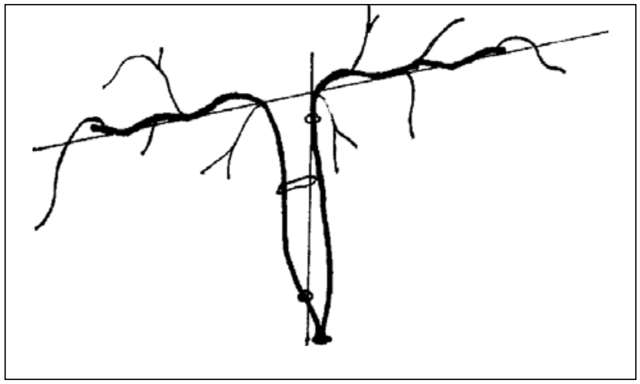


Fig. 8-7. Three year old vine, tied to a stake, bent and wrapped loosely around the fruiting wire. Trunk length will depend on training system selected.

As in year two, vines should be defruited, with the exception of very vigorous vines that have already filled their space. In the case of Vignoles vines, the crop should be thinned to about one cluster per shoot or less.

Pruning

Year Four and Older

At this point, the framework for the training system should be present. The emphasis now shifts from encouraging purely vegetative growth to maintaining a balance between cropping and vegetative growth. This is expressed in the concept of balanced pruning (Howell et al., 1987; Partridge, 1926). The goal is to produce a profitable crop every year, while maintaining enough vegetative vigor to support this crop. If the crop load is too large, vegetative growth slows down or stops and the vine will be weakened. If the crop load is too light, the vines will produce much more vegetative growth, shading the fruit, lessening quality, and shading new buds, resulting in loss of fruitfulness the following year.

When using balanced pruning, the number of buds left on the spurs of a vine is determined by pruning weight of the vine. **The pruning weight includes only the weight of previous season's shoots that are removed from the vine; do not include the weight of two year old or older wood.** The vine is 'rough pruned', leaving more spurs on the cordons than needed in the end. The removed shoots are then weighed and the number of buds is calculated as follows: A fixed number of buds is left for the first pound of pruning weight, and another fixed number of buds is added to the previous number for each additional pound of prunings. The numbers have been determined by long-term observations, confirmed by research at several locations, and vary among species and cultivars.

Table 8-1. 20 + 10 balanced pruning formulas

Pruning weight in pounds	Buds left for the first pound	Buds left for additional pounds	Total buds left on the vine
1	20	0	20
1 1/2	20	0.5 x 10 = 5	25
2	20	1 x 10 = 10	30
2 1/2	20	1.5 x 10 = 15	35
3	20	2 x 10 = 20	40

For most French-American hybrids the formula is 20 + 10. Table 8-1 contains examples on how to use this formula.

For American grape varieties, such as Norton/Cynthiana, Concord, Niagara and others, the formula changes to 30 + 10. These cultivars are generally very vigorous. The varieties Seyval Blanc (5 + 10) and Vidal Blanc (15 + 10) tend to overcrop, and the slightly lower bud numbers will help to reduce crop loads.

Low vigor vines, usually defined as vines with less than 1 pound of prunings, are often defruited to encourage vine development. Mark these vines at pruning time, and remove flowers or developing clusters in late spring.

The maximum number of buds left on a vine is usually 65-75 buds on vines spaced 8 feet apart in the row, with rows spaced 10 feet apart.

Once the number of buds has been determined, spurs of 4 to 5 buds each are selected. They should come from canes that are live (green inside when cut), healthy looking and about pencil sized. Canes with a much larger diameter and nodes that are widely spaced are called 'bull canes'; they will not be fruitful. Canes from the outside of the canopy are also more fruitful than those grown on the inside of the canopy where the light levels were lower.

Spurs should be evenly spaced across the entire cordon length and not clustered together; this will help to avoid shading during the growing season. The position of the spurs should also be selected according to the training system (upward or downward facing). Close to each of the fruiting spurs, one or two spurs with only 1 to 2 nodes should be left on the cordon. These are 'renewal' spurs, and shoots growing from these will replace, or renew, the fruiting spurs of the current year. Renewal spurs especially should be kept as close to the cordon as possible. While this also applies to fruiting spurs, it is not as crucial here, as these spurs will be removed the following year. Keeping the renewal zone close to the cordons prevents the fruiting zone from shifting slowly ever more outward (Fig. 8-8).

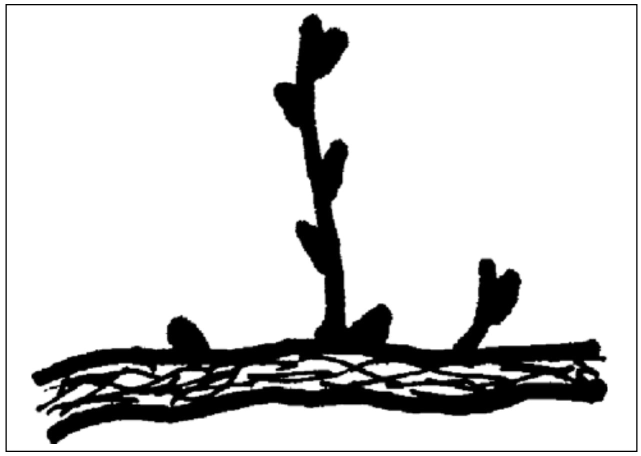


Fig. 8-8. Close-up showing part of the cordon, a fruiting spur with 4 buds, and a renewal spur with 1 bud. The two remaining buds directly on the cordon are non-count buds.

This pruning is often referred to as dormant pruning because is it carried out during the dormant, or winter, season. Often 'rough pruning' is done earlier in the winter, and adjusting the bud numbers is carried out only after the danger of severe and potentially damaging freezes is over, in late winter/early spring, up to bud break. Pruning cuts made close to bud break will 'bleed'. This does not appear to harm the vines.

Shoots forming on trunks and from the base of the vine are called "suckers" but are actually basal shoots and not suckers from roots. Unless a shoot is needed to replace a trunk or a cordon, they should be removed periodically, especially during spring and early summer. Also, any areas on the cordons where many shoots grow from buds directly on the cordon should be thinned during any time of the growing season. This thinning, as well as any hedging or topping of plants during the growing season, is often referred to as summer pruning.

Cluster Thinning

Dormant pruning is the most important means of adjusting crop levels. In some varieties, especially those where shoots arising directly on the cordons are fruitful, the crop load might need further adjusting to maintain fruit quality. This is generally done by removing some flower or berry clusters as early during the growing season as possible.

Cluster thinning is particularly important for table grapes and large clustered French American hybrids. Cluster thinning removes small and sparse clusters, increases berry size and cluster weight of remaining clusters, and brings weak vines into balance between foliage and fruit. Begin thinning clusters 2 to 3 weeks before bloom, and finish no later than one week postbloom. One or two clusters are left per shoot; the cluster thinning procedure leaves the basal cluster and sometimes the secondary cluster. The following cultivars are thinned to two clusters per shoot: Mars and Vanessa. The following cultivars are thinned to one basal cluster per shoot: Seyval, Vidal, Chambourcin, and Reliance. Remove all clusters from low vigor vines, such as those with less than one pound of prunings.

Shoot Positioning

Shoot positioning reduces shading in the upper part of the canopy, where next year's fruiting wood is developing. Developing wood that is exposed to the sun will have improved fruitfulness the following year. Shoot positioning also increases fruit exposure to sun, air movement, and pesticides, which will improve fruit quality and reduce disease problems.

Shoot positioning improves canopy microclimate, and involves separating the shoots and positioning them in a way to maximize light and air penetration into the fruiting zone. With high cordon systems, such as the bilateral cordon and the Geneva Double Curtain, the shoots are positioned in an outward and downward position. With low cordon systems, such as the VSP or the Lyre, the shoots are positioned in an upward position, usually with the aid of pairs of catch wires. With divided canopy systems (GDC or Lyre), shoots are not allowed to grow into the zone between the canopies. Positioning is done manually or mechanically with specialized equipment. The best time to position shoots is one to two weeks post-bloom, when the tendrils are still soft enough to easily separate and the shoots are strong enough to resist excessive breakage.

Mechanization

Pruning, canopy manipulations such as shoot positioning, and harvesting are labor intensive. Besides making these processes expensive, labor is often insufficient or not available when needed. To address these problems, systems have been, and are still, being developed to mechanize pruning, canopy management and harvesting.
Single curtain, spur pruned cordon systems are the easiest to mechanically prune and position because the shoots are evenly distributed. Some hand labor is still needed to 'clean up' after the machines have gone through, but the time involved is significantly reduced. Similarly, cordon systems are easier to mechanically harvest.

Chapter 9
Irrigation Systems

The Midwest is fortunate to have a reasonably consistent rainfall pattern throughout the year. However, there is enough inconsistency in the pattern, especially in the summer months, to make it economical to irrigate a vineyard. Young vines are susceptible to drought conditions. During the first two years after planting irrigation can pay for itself in vine survival and in vine growth. Even in years with adequate rainfall for mature vines, there can be extended periods without rain, which can hurt newly planted vines. Thus systems should be sized to take care of new vineyards, that is, the first 3 or 4 years, and then to help with older vineyards in those years when extended dry periods occur. Always look into the future at plans for expansion and design the system with expansion in mind.

Irrigation design is a broad topic that cannot be covered in a few pages. Use the services of an irrigation specialist from the beginning. It's easier and less expensive to correct a problem on paper than one in the field.

This chapter will help you develop questions that need to be answered by a specialist, thoughts to help in your discussion with the specialist, and information on irrigation basics.

Water source

There are several questions that must be answered first before planning your irrigation system. What is the source of irrigation water? Do you have a well? Will you dig a well? What is the expected output of your well? Generally, the deeper the well, the higher the output that will be obtained. But, the deeper the well the higher the cost to drill and the more expensive the pumping equipment needed.

Will you use a pond, a creek, or a river for your irrigation water? Ponds are expensive to build but can provide a source of water. There must be a suitable site for pond construction near the vineyard. The pond must be sized to provide the needed water for the proposed vineyard and any future expansion. If a stream or river is to be used, is there sufficient flow for irrigation, particularly during extended droughts? In some cases government permits must be obtained to withdraw water from the source. Will the government allow sufficient water removal to meet expected needs? When using open water sources the water must be filtered to remove contaminants, which would plug emitters. Filter systems can be expensive and require constant upkeep.

Sizing the System

The size of the system will depend on the answers to a few questions. What is the size of the vineyard or proposed vineyard? Is the vineyard an older established planting or a new vineyard? What is the expected output of the water supply? What funds are available to obtain a water source? All of these questions are interrelated. If a well is available, what is the output? If an open water source is available, such as a pond, how much water can be withdrawn from the pond? How fast will the pond refill?

Components

The basic component of an irrigation system is the emitter, where the water meets the plant. There are many styles with varying outputs to consider. There are the drip emitters and then there are the micro-sprinkle emitters that spray a relative large area under the plant. Generally the drip emitters are used in grapes. Drip emitters include plug-in types and in-line types. With in-line emitters there are differences in spacing in addition to different water outputs. Output is given in gallons per hour or liters per hour. Spacing can vary from 1 foot to 10 feet between emitters.

Generally, for grapes use one or two gallons per hour output and a spacing which allows two emitters per plant. For example, if vines were spaced at 8 feet then emitters would be spaced at three to four feet to give two emitters per vine. The output of the emitter would be selected based on the total output of the water supply and the size of vineyard to be irrigated. Another consideration would be the number of zones the vineyard can or might be divided into. Zones are areas that can or must be irrigated separately.

The next component is the black polyethylene tubing that carries water down the row. These lines are referred to as laterals. The emitters are either inserted into the tubing or built into the tubing when manufactured. The size of tubing is dependent upon the emitter output and the number of emitters the line must support. Generally, 16-mm tubing is standard for row lengths of 400 to 800 feet. An irrigation specialist can help with sizing the lateral lines.

Definitions

The following definitions will aid in your understanding of irrigation systems and when talking with irrigation designers or sales representatives. The design of an irrigation system can be complicated and a design engineer or specialist should be used for your needs.

Air vents - Devices that release air from the irrigation system. The two basic types are continuous and non-continuous. The non-continuous type releases large volumes of air as the system is being pressurized and is sealed when the system is fully pressurized. The continuous vents release air while the system is pressurized and functioning.

Check valves - Devices that prevent water from flowing back in the direction from which it came. Check valves are needed where fertilizer/chemical injectors may be used. Also, they are needed at the wellhead to keep water from flowing back down the well and allowing air back in the system.

Emitters - the point where water is released from the lateral to the soil. Emitters release water at low pressures and low flow rates. Emitters may be molded into lateral lines, or can be mechanically inserted into the lateral line.

Lateral lines - Water lines that move water down individual rows of the planting and generally contain the emitters.

Mainline - The main water line that carries water from pump to the field and distribution lines.

Manifold - The manifold water line connects the lateral lines to the mainline.

Output - The amount of water released in units per time at the reference point. Example: an emitter has an output of 1 gallon per hour or a well has an output of 100 gallons per minute at the head.

Pressure relief valve - Device that drains off excess pressure at any place the pressure might exceed the system design capability.

Pumps - Device that provides a prescribed amount of water at a given pressure. There are many types of pumps. The right one for you will depend on the water source, the irrigation system needs, and the amount available to spend on the pump.

Sub-mainline - Water lines that break the system down at various points and distributes water to individual plantings.

Valves - Devices that control the flow of water from one line to another at various points in the system. Generally there is a main valve at the source or pump. Then there are valves at filters, sub-main lines, chemical injector locations and finally at drainage points. There are two main types of valves: butterfly or gate valves. They can be either manual or automatic types.

Chapter 10

Fertility Management in Vineyards

Fertility management in a vineyard begins during the site selection and preparation period. A soil test of the proposed vineyard site will yield valuable information on soil pH and nutrient status. Information on collection and submission of soil samples is available from University of Missouri Outreach and Extension offices. The suggested soil pH range for hybrid and American grape cultivars is 5.5 to 6.5. The suggested ranges for soil potassium (K) and soil phosphorus (P) are 150 to 250 and 80 to 100 pounds per acre, respectively. Base saturation numbers of 65% to 75% for calcium, 10% to 15% for magnesium, 3% to 5% for potassium, and less than 2% for sodium should be adequate (Wolf et al., 1995).

Agricultural lime is commonly used to raise soil pH. The amount needed depends on initial and target pH, and the ENM rating of the lime. Dolomitic limestone will add magnesium as well as raise pH. Add sufficient amounts of K and P fertilizers to bring soil levels to suggested ranges. All of these materials are best added during the site preparation period, when incorporation into the soil is possible.

Newly planted grape plants usually do not require additional nutrients during the first season, as long as soil pH and nutrient levels are adequate. Fertilization during the second and third years is usually limited to nitrogen. Apply 0.66 to 1.66 ounces of actual N per plant in the second year, and double this rate in the third year. Apply the fertilizer in a ring around each plant, but do not let fertilizer contact the plant. Apply dry fertilizers as buds break in the spring.

As vines mature and crops are harvested, vineyards may require periodic applications of one or more nutrients, and adjustment of soil pH with lime. A combination of soil analysis, plant observation, and plant tissue analysis are used to determine grape nutrient needs.

A soil test is recommended every two or three years in bearing vineyards to monitor soil pH. Agricultural lime is applied to raise the pH; do not apply more than 4 tons per acre per application. If additional lime is needed, split the application into 2 to 3 tons per acre applications, spread over several years.

The grape grower should develop a profile of each cultivar in the vineyard with regards to visual observations of growth. Among the information to collect for each cultivar is pruning weights of 6 to 10 vines, dates when shoot growth ceases and trellis is filled with foliage, size and color of leaves, yield of vines, average cluster weight, and fruit quality. Three to four years of data collection are needed to establish the profile.

Tissue analysis reveals the concentration of essential nutrients within vine tissues. In grapes, the only tissue sampled is the leaf petiole, which is the slender stem that connects the leaf blade to the shoot. Basically, there are two reasons to collect petiole samples. The first is the routine evaluation of nutrient status. The second reason is to diagnose a particular visible disorder in which a nutrient problem is suspected (Gu, 1998).

Nutrient levels fluctuate in the vine, and no one sampling time is best for all nutrients. Petiole sampling at full bloom will provide a good measure of vine nitrogen, boron, and several other nutrients. Other nutrients, such as potassium, are better sampled for at veraison. In practice, growers generally collect samples at full bloom for routine evaluation of vine nutrient status. If a problem related to a specific nutrient such as potassium is suspected based on the bloom sample, collect a second sample at veraison. Petiole samples may be collected at any time to help diagnose an unknown visible disorder. In this case collect a sample of the tissue in question, and a second sample of healthy petioles from another vine for comparison.

A petiole sample should represent a relatively homogenous management unit not more than 10 acres in size. Sample each cultivar separately, and make sure that the sample uniformly represents the entire unit. Sample separately areas of different soil type or weak or strong vine areas. Avoid atypical leaves, diseased or damaged leaves, and dead or severely stressed tissue. Don't sample immediately after a nutrient spray. Sample early in the day, before leaves are water stressed.

Each tissue sample should consist of 75 to 100 petioles. For the bloom time sample, collect petioles from leaves opposite the first or second flower cluster from the bottom of the shoot, at full bloom. For the veraison sample, collect petioles from the youngest fully expanded leaves on the shoot, usually located from 5 to 7 leaves back from the shoot tip. Collect no more than 2 petioles per vine, and choose leaves from shoots exposed to sunlight. Remove the leaf blade first, then remove the petiole from the shoot. Place petioles in clean paper bags and keep cool. In most cases, dry the petioles as soon as possible in a dust free area at room temperature. Label the dried samples for your records, and submit the samples to the University of Missouri Soil and Plant Testing Lab (local University Outreach and Extension offices can provide assistance). Private labs are also available to analyze petiole samples. For consistent results, use the same lab for each petiole sample.

Nitrogen is the nutrient used in greatest amounts by bearing vines, and is commonly applied annually to Missouri vineyards. No single index serves well as a guide in assessing the vine's need for nitrogen fertilizer. Instead, a number of observations made over several years is the best way to determine nitrogen status. Visual observation of vine growth is the primary criteria, coupled with plant tissue analysis for verification or as a backup in judging response to nitrogen fertilization. Table 10-1 summarizes the key characteristics for diagnosing nitrogen status. In general, an annual application of 40 to 80 pounds of actual N per acre, applied at bud break, is recommended. This amount is modified based on the criteria mentioned earlier (Gu, 1997).

Of the other nutrients, potassium, magnesium, and boron are most commonly related to nutrient problems. Petiole analysis, coupled with visual observation of the vines, is used to determine the status of these nutrients. Table 10-2 includes sufficiency tissue levels for several nutrients (Wolf et al., 1995).

Table 10-1. Diagnosis of grapevine N status based on visual observation, vine growth, fruit quality, and petiole N contents (Vineyard and Vintage View 12(2):12)

	Deficient	Adequate	Excessive
Trellis filling by foliage	Fail to fill by Aug 1	Fill by Aug 1	Fill with excessive foliage (more than 2 layers of leaves)
Yield	Chronically low	Acceptable	Low due to fewer clusters and/ or poor fruit set
Pruning weight	≤ 1/4 lb per foot of cordon or arm	0.3 to 0.4 lb per foot of cordon or arm	≥ 0.4 lb per foot of cordon or arm
Mature leaves	Uniformly small and light green or yellow	Normal size and uniformly green	Exceptionally large and very deep green
Shoot growth	Slow and ceases in midsummer	Rapid and ceases in early fall	Rapid and ceases in late fall. 8 to 10 feet by mid-July
Internodes	Short	4 to 6 inches	≥ 6 inches and possibly flattened
Fruit maturation	Advanced	Normal	Delayed
Fruit quality	Poor, including poor color in red varieties	Normal	Poor
Bloomtime petiole total N	Less than 1%	1.2 to 2.2%	Greater than 2.5%
Bloomtime petiole nitrate-N	<350 ppm	5000 to 1200 ppm	> 2000 ppm

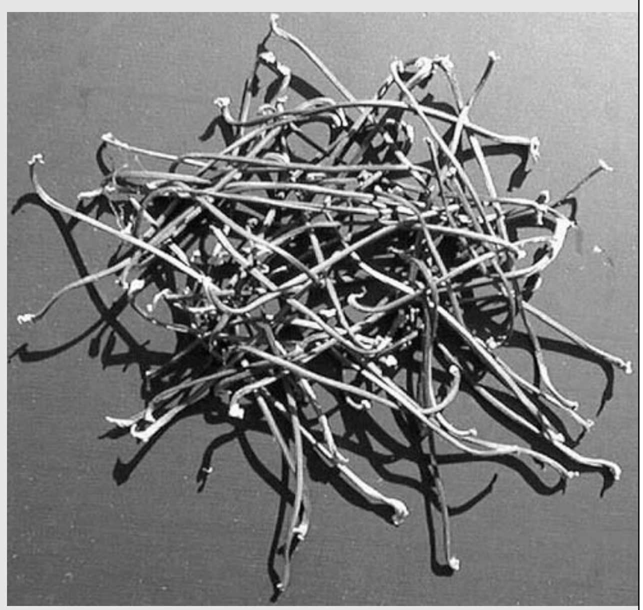
Table 10-2. Sufficiency ranges of essential elements based on bloom-time sampling of leaf petioles (Wolf et al., 1995)

Nutrient	Sufficiency Range
Nitrogen	1.20-2.20 %
Phosphorus	0.15-? %
Potassium	1.50-2.50 %
Magnesium	0.30-0.50 %
Iron	40-? ppm
Manganese	25-1000 ppm
Copper	7-15 ppm
Zinc	35-50 ppm
Boron	30-100 ppm

A. Select petiole opposite the basal clusters during full bloom

B. Save the petiole and discard the blade

C. Fresh petioles ready to be sent for testing or drying



D. Dried petioles ready to be sent to the laboratory

Fig. 10-1. Bloomtime petiole sampling (Vineyard and Vintage View 13(2):4)

Chapter 11
Disease Management

Disease management is an important and integral part of grape production. The warm and humid growing season that characterizes the grape growing areas of Missouri favors the development of many diseases, especially those caused by fungi. Disease management represents a major annual expense in the production of grapes in this state as well as other areas of the middle and eastern United States.

Although grape growers rely upon fungicides as a major disease control strategy, other strategies remain important and can reduce chemical useage. Among these are cultural methods, sanitation, resistant cultivars, and pathogen-free planting stock.

Cultivar Susceptibility and Fungicide Effectiveness

Cultivars differ in their susceptibility to diseases. For example, Catawba is extremely susceptible to black rot and downy mildew and only slightly susceptible to powdery mildew, whereas Chancellor is moderately susceptible to black rot and highly susceptible to downy mildew and powdery mildew (Table 11-1). Because of these differences the fungicides that should be used in a spray program will depend upon the cultivar. Only fungicides that will effectively control the diseases specific to a cultivar should be used on that cultivar. Note that some cultivars are sensitive to sulfur or copper sprays (Table 11-1).

Specific fungicide recommendations are not given in this publication, as these are frequently revised. Refer to the *Missouri Commercial Grape Pest Control Guide* (MS-19 revised annually) for current pesticide recommendations.

Disease Forecasting

Disease forecasting can be used to determine when to apply fungicides for control of certain grape diseases. Forecasting plant disease depends upon knowing the exact environmental conditions needed for initiation of infection by the pathogens causing those diseases. Each different fungus causing a grape disease requires a specific set of temperature and moisture conditions to occur simultaneously over a given period of time to cause a particular disease. These conditions are necessary for spore formation, dispersal, germination, and penetration of susceptible host tissue by the pathogen.

The conditions required for black rot infection are the easiest to illustrate as a model for infection. After overwintering in old infected grape berries, and when the temperature rises in the spring, the black rot fungus produces spores, which are ejected into the air under moist conditions. If the spores are carried by air currents to susceptible tissue such as leaves, shoots, flowers, and developing fruit, infection will take place if a set of conditions occurs simultaneously.

Table 11-2. Black rot infection period prediction table

Temperature ^{o}F	Minimum Leaf Wetness duration in hours for light infection
50	24
55	12
60	9
65	8
70	7
75	7
80	6
85	9
90	12

(Data from R.A. Spots, Ohio State University)

Table 11-2 shows the temperature and leaf wetness conditions that are favorable for black rot infection. For example, at 55 ^{o}F grape leaves must be wet for 12 hours for infection to take place, whereas at 70 ^{o}F only seven hours of leaf wetness are required for infection.

A number of instruments are available which can be used to forecast grape diseases. Black rot, which has a simple disease model, can be forecasted using no more than a thermometer and the observation of length of time that vines are wet. However, the disease models for predicting downy mildew, powdery mildew and Botrytis bunch rot are much more complex and use additional environmental parameters. Plant disease forecasting instruments are available which contain prediction models for several grape diseases on computer chips. These computerized instruments collect environmental data and make the determination of when the infection period for a particular disease has occurred.

In order to use infection period information to control diseases, fungicides must be applied which will kill or inhibit the growth of the fungal pathogen after the infection process is initiated. These fungicides are referred to as being curative or eradicative in their action.

Major Fungal Diseases in Missouri

Black Rot

Pathogen: *Guignardia bidwelii* (Ellis) Viala & Ravaz

Impact: Black rot is the most important limiting factor of grape production in Missouri. It develops in every growing season and, if left uncontrolled, it will destroy fruit on most cultivars. The development of the pathogen is favored by the weather conditions during most of the spring and early summer, and therefore the application of a preventive spray schedule during the susceptible growth stages is essential. In fact, the chemical control of black rot should form the backbone of the spray schedule from mid-bloom until veraison. Because disease buildup can be explosive, the appearance of symptoms in the vineyard calls for an immediate application of a curative fungicide. The only cultivar that possesses good genetic resistance to this disease is Norton/ Cynthiana.

Symptoms: Berries: sunken brown spots develop and rapidly spread through the entire berry. Small black pustules develop in the center of the spots, the berry desiccates and then becomes mummified in a matter of days, Leaves: tan spots develop with small black pustules, concentric with the lesion margin; the leaf blade remains flat.

Susceptible growth stages: From mid-bloom until veraison for flowers and fruit. Also susceptible from bud break to July for leaf lesions.

Favorable conditions: Warm, humid, and wet weather. Black rot develops only if warm temperatures and free water (from rain or dew) on the plant surfaces coincide.

Control measures:

Preventative sprays. Good control of black rot is essential for the production of grapes in Missouri. To achieve adequate control in most cultivars, preventative fungicide sprays must be applied on a regular schedule from the beginning of shoot development through veraison. Sprays should be reapplied after periods of rain that wash off the protective coating of fungicide. An exception to this is when systemic fungicides are used as preventative sprays. Most systemic fungicides are effective for up to seven days early in the season during rapid growth and up to 14 days after growth has slowed later in the season.

If applied after the black rot fungus has infected the fruit or leaves, preventative sprays of non-systemic fungicides will not prevent disease development. Black rot control with preventative non-systemic fungicide sprays is dependent upon keeping all susceptible plant parts coated with an effective fungicide. This is especially important when rain and heavy dews occur, since the black rot fungus initiates new infections only when the fruit and leaves are wet. Preventative sprays are applied at shorter intervals during the early part of the season in order to keep the young tissue of rapidly developing leaves and fruit coated.

Curative sprays. Curative fungicides, having "kick-back" action against black rot, can be applied up to 72 hours after the beginning of an infection period for control of black rot. The sooner that a spray is applied after the infection period, the greater the black rot control achieved. However, preventative fungicide sprays should still be the basis for good black rot control.

Cultural practices. Removal of mummified clusters from vines, and covering those mummified clusters that have fallen to the ground with soil helps prevent the overwintering of the fungus. Maintenance of an open canopy to promote rapid drying of rain and dew will reduce black rot infections.

Downy Mildew

Pathogen: *Plasmopara viticola* (Berk & Curt.) Berl. & de Toni

Impact: The conditions of the Missouri summer are highly favorable for downy mildew. Fortunately, many hybrid and native American grape varieties grown in the state offer some genetic resistance to this disease. *Vinifera* varieties, however, are extremely susceptible to downy mildew, and need to be painstakingly protected. If the weather stays wet and warm during September and early October, the leaves can get severely infected, and the plants can be prematurely defoliated. This may be a problem because the fallen diseased leaves will help overwinter a large amount of inoculum for the following season, and because the defoliated plants will not be able to accumulate an adequate amount of carbohydrate for the winter. For these reasons, it is advisable to control the disease even after harvest.

Symptom: Translucent, oil spot-like areas develop on the upper surface of the leaves. The spots rapidly turn yellow, and a white velvety growth (mildew) appears on the lower side of the leaf, precisely opposite to the spots. Note that downy mildew always appears on the lower side of the leaf, never on the top! Subsequently, the leaf spots turn necrotic brown and the mildew withers away.

Susceptible growth stages: Flowers and fruit are susceptible until veraison; leaves and new shoot growth remain susceptible all through the season.

Favorable conditions: Warm, humid, and wet weather, especially when humid nights are followed by rainy days; disease develops only if warm temperatures and free water (from rain or dew) on the plant's surface coincide.

Control measures: Any cultural practice that promotes rapid drying of the foliage, such as good weed control and high trellises, will help reduce downy mildew. Keeping canes on high trellises and removing suckers at the base of the vine also lowers the chance of the fungus being splashed up on new growth in the spring. Tilling fallen leaves into the soil will reduce overwintering inoculum of the fungus available for new infections in the spring.

Fungicide sprays are important in the control of downy mildew. The frequency of sprays should be increased in wet weather for adequate control on susceptible cultivars such as Catawba.

Powdery Mildew

Pathogen: *Uncinula necator* (Schw.) Burr.

Impact: This disease rarely causes serious damage in Missouri because the weather tends to be too hot and wet for the development of the pathogen. Nevertheless, mild and humid weather may facilitate the development of the disease in susceptible cultivars. Care should be taken when the disease is controlled with sulfur sprays, because many of the hybrid and American grape varieties grown in the state are sensitive to sulfur. In vineyards where powdery mildew has become difficult to control in previous years, a dormant lime sulfur spray applied shortly before budbreak provides excellent control for the following growing season. Lime sulfur applied during dormancy does not present a danger to sulfur-sensitive varieties.

Powdery mildew infection frequently develops on the leaves of most varieties in September and October in Missouri. If the variety is susceptible to the disease, it is advisable to control the pathogen at this stage to prevent a heavy inoculum pressure in the following season.

Symptoms: White powdery growth (mildew) appears on the upper side of the leaves. Note that this disease never develops on the lower side of leaves! Fruit may crack open if heavily infected. Powdery mildew is usually accompanied by a characteristic moldy odor in the vineyard.

Susceptible growth stages: From immediate pre-bloom to fruit set; heavy infection on older leaves in September and October.

Favorable weather conditions: Humid and warm (but not hot) weather; free water hinders disease development.

Control measures: Powdery mildew has become more important with the increased planting of some of the susceptible French-American hybrid and *Vitis vinifera* cultivars. During the growing season, preventative sprays of fungicides may be used on highly susceptible cultivars to prevent an outbreak of powdery mildew. Maintenance of an open canopy to lower humidity will help reduce powdery mildew infections.

Phomopsis Cane and Leaf Spot

Pathogen: *Phomopsis viticola* (Sacc.) Sacc.

Impact: Phomopsis is a cool climate disease that develops in Missouri only when the weather is cool and wet during the early part of the growing season. The fungus causes lesions at the base of the stem. It makes the stem brittle and may kill perennial wood. In a dry or warm spring, the disease will not appear. In Missouri, the economic impact of this stage of the disease is questionable. As the weather warms up later in the spring, the pathogen stops growing but will survive in the tissues during the summer. If August turns cooler and rainy, the pathogen will resume its growth, will sporulate, and may cause serious fruit rot. The primary reason why the cane and leaf spot stage of disease needs to be controlled is to reduce the possibility of fruit rot by reducing inoculum levels.

Symptoms: On most hybrid grape varieties, small black spots develop on leaves and canes; on *Vitis vinifera* varieties, cane lesions can be larger and deeper. Leaf spots often coalesce along veins and are surrounded by a yellowish halo.

Susceptible growth stages: From beginning of growing season until fruit set.

Favorable conditions: Cool, rainy weather in April and May.

Control measures: Phomopsis cane and leaf spot is most likely to become a problem when inoculum is allowed to build up on the dead canes in the vineyard and if the weather is wet during the first few weeks of shoot growth. The disease can be controlled by a combination of sanitation and fungicide application. Pathogen-free propagation materials should be used for planting and replanting. Diseased and dead wood should be removed and destroyed by shredding, disking or plowing into the soil, or burning. Under heavy disease pressure, a preventative spray program should begin as early as $^{1}/_{2}$-inch shoot growth and continue through fruit set. The period from bloom through fruit set is a critical time to prevent fruit infection.

Phomopsis Fruit Rot and Rachis Blight

Pathogen: *Phomopsis viticola* (Sacc.) Sacc

Impact: The fruit rot/rachis blight stage of the disease occurs in Missouri only when the weather turns cool and rainy at the end of July or early August. While such summer conditions are relatively rare, they do occur occasionally and allow the disease to cause serious damage to the fruit. The problem can be particularly severe if the leaves and the canes had a heavy phomopsis infection in the spring. Phomopsis fruit rot is quite difficult to diagnose in its early phases, as the characteristic fruiting bodies (pustules) of the fungus will appear on the decayed berries only in the later phase of the disease. If sudden fruit decay is associated with shriveled-up rachis, it is likely to be caused by *Phomopsis viticola.*

Symptoms: Berries turn brown first and develop small black pustules only when the entire berry has been spoiled. Affected berries remain round, but occasionally fall off the rachis. When infected, the rachis shrivels up and dries out.

Susceptible growth stages: Rachis infection can take place from cluster emergence until ripening; fruit infection can happen from bloom to pea-size berry stage, but symptoms develop only after veraison.

Favorable conditions: Cool, rainy weather during ripening; heavy rains appear important.

Control measures: The control measures recommended for the cane and leaf spot stage described above are essential for control of the fruit rot stage. No fungicide is known to provide eradicative control of Phomopsis fruit rot once rot symptoms have developed.

Macrophoma Rot

Pathogen: *Botryosphaeria dothidea* (Moug. ex Fr.) Ces. & de Not

Impact: The pathogen that causes macrophoma rot is a common microorganism in Missouri. The disease used to be known only as a fruit rot of muscadine grapes, but more and more recent observations suggest that it also is an important problem in grape varieties grown in Missouri. In its early stages, the rot is difficult to identify and to differentiate from phomopsis fruit rot. The pathogen is able to grow in numerous woody plant species, causing such diverse diseases as white rot of apples and stem blight of blueberries. Because many other plants can serve as inoculum source, it is important to eliminate abandoned fruit trees from the vicinity of the vineyard. The pathogen appears to be difficult to control in other plant species, and nothing is known about its control in grapes in Missouri.

If fruit rots present a perennial problem in the vineyard, the most promising solution may not come from the application of a novel fungicide, but from canopy management. The maintenance of an open canopy that dries rapidly and that maintains low air humidity is the best way to prevent fungal growth. Chardonel is susceptible.

Symptoms: This fungus blights rachis and flowers and spoils berries. In the early stages, the rachis becomes soft and off-colored, and later develops elongated black lesions; parts of the cluster may become blighted. Rot of ripe berries occurs suddenly and may be associated with rachis blight.

Susceptible growth stages: Rachis is susceptible from fruit set to bunch closing, berries become susceptible after veraison.

Favorable conditions: Not well known, but rain and wet weather appear to favor the development of the disease.

Control measures: Sprays applied immediately after bloom and continuing to harvest have been recommended for control of this disease in other areas. No fungicide is known to provide eradicative control once the disease has established itself. Maintenance of an open canopy, removal of old diseased trees from around the vineyard, and sanitation (pruning out of old wood, removal of diseased plant material) will aid in control of Macrophoma.

Botrytis Bunch Rot

Pathogen: ***Botrytis cinerea*** **Pers.**

Impact: Recent evidence indicates Botrytis bunch rot probably does not occur in Missouri as often as had been assumed. Other late-season berry rots are often mistakenly identified as caused by *B. cinerea.* However, *Botrytis* can cause economic losses, particularly on some tight clustered hybrid and vinifera cultivars in cool weather. Once established, infection can move rapidly throughout berries on a cluster.

Symptoms: Early infections of new growth cause tissue to turn brown and dry out. Infections can spread from infected flower parts and aborted fruit to the rachis and pedicels causing brown spots that later turn black. Ripening white grapes turn brown and dark-colored fruit turn red. Infection spreads rapidly within tight clustered cultivars. In wet weather, infected berries become covered with a brownish-gray mold.

Susceptible growth stages: Any new growth, especially flowers. Fruit from veraison to harvest.

Favorable conditions: Cool, damp weather with 56 to 66 °F optimal for infection. High temperatures during the latter part of the season inhibit the bunch rot phase.

Control measures: Cultivars differ in susceptibility to Botrytis bunch rot based on the compactness of their clusters, the thickness and anatomy of the berry skin, and their chemical composition. Susceptible cultivars may need to be protected against Botrytis bunch rot by a combination of cultural practices and chemical control. Disease development can be reduced by avoiding excessive vegetative growth. This can be accomplished with cultural practices such as controlled nitrogen fertilization, increased aeration and exposure of clusters to the sun with appropriate trellising systems, shoot positioning, and leaf removal. Controlling diseases and insect pests capable of injuring the berries, particularly the grape berry moth, will also reduce Botrytis bunch rot development. Botrytis bunch rot can be chemically controlled only with preventive treatments. Leaf removal in the fruiting zone improves spray coverage and drying of clusters after periods of dew and rain, thus reducing the incidence of Botrytis.

Bitter Rot

Pathogen: *Greeneria unicola* (Berk & Curt.) Punithalingam

Impact: Bitter rot occurs on grapes in warm humid areas. The causal fungus attacks muscadine as well as bunch grape species. Infected fruit have a bitter flavor that is carried through the winemaking process, imparting a burnt, bitter taste to wine. Catawba seems to be especially susceptible with entire clusters rotting at harvest. Lack of control can result in a total crop loss.

Symptoms: Bitter rot is often mistaken for black rot because the symptoms are similar. However, bitter rot infections of the fruit occur in late season, whereas black rot infections do not occur after veraison. Although the pathogen can invade undamaged ripening fruit, its occurrence is usually associated with cracking at the point where the fruit is attached to the pedicel. The first visible sign is the development of black pimple-like structures of the fungus on the skin around the pedicel and spreading in a matter of a few days to cover the entire surface. At the same time, white- to light red-colored cultivars turn brown while dark red- to black-fruited cultivars remain dark. The fruit begin to shrivel and regardless of color eventually turn black. Under certain weather conditions the fungus can spread throughout an entire cluster of fruit.

Favorable conditions: Warm wet weather at ripening favors the development of bitter rot. It usually occurs more frequently on berries of cultivars that have a tendency to split at the pedicel due to rain at ripening. However, other damage, such as that caused by insects or birds, during ripening can also provide a point of entry for the pathogen.

Control measures: Since bitter rot can develop so rapidly, late season fungicide sprays are important for control on cultivars that have a tendency to crack in wet weather. However, these fungicides must be applied as protective sprays. Prevention of insect and bird damage is also an important control measure.

Anthracnose

Pathogen: *Elsinoe ampelina* (de Bary) Shear

Impact: Anthracnose causes damage most frequently by weakening the canes, and thereby predisposing them to breakage in windy weather. The disease proves to be difficult to control once established during the growing season. Damage to fruit is usually not significant.

Symptoms: The canes develop necrotic lesions on the basal internodes. The lesions penetrate deep into the stem, making it brittle. Young leaves develop gray, necrotic spots that are often irregular in shape and may coalesce. Spots are surrounded by a yellowish or red halo. The center of the lesions may fall out, giving a shot-hole appearance. As leaves expand, tissue around the lesions becomes puckered and may tear in windy conditions. The fruit develops circular lesions that are sunken with a dark margin and gray center.

Susceptible growth stages: Starting from flowering, the plants are susceptible as long as succulent green tissues are formed.

Favorable conditions: Heavy rains and warm weather.

Control measures: Research in Missouri has shown that certain grape cultivars, including Cayuga White, Reliance, and Vidal blanc, are highly susceptible to anthracnose. In vineyards where anthracnose has become a problem, a dormant spray of liquid lime-sulfur is essential for effective control. Lime sulfur applied during dormancy does not present a danger to sulfur-sensitive varieties. Protection of the rapidly growing, succulent, green shoots of susceptible cultivars with fungicides is also important. Pruning out infected wood during dormancy and removal from the vineyard prior to budbreak should reduce primary inoculum of the anthracnose fungus in the coming growing season.

Eutypa Dieback

Pathogen: *Eutypa armeniacae* Hansf. & Carter

Impact: Although eutypa dieback is present in Missouri, the disease is not considered economically important. As more and more vineyards are coming of age, however, it is important to scout for the symptoms in the spring. Eutypa slowly kills internal tissues in perennial wood, causing partial or complete dieback of cordon arms or entire vines.

Symptoms: Young shoots are stunted with short internodes and small, cupped and occasionally tattered leaves. The leaf symptoms are best visible in May and early June when normal healthy shoots are less than 10 inches long.

Susceptible growth stages: Infection occurs during the winter and spring when fresh pruning wounds provide access to the internal tissues for germinating spores.

Favorable conditions: Warm periods during dormant pruning, especially when plants are in deep dormancy and wound healing is slow.

Control measures: Sanitation is essential. Dead grape wood should be removed from the vineyard and destroyed. In regions where eutypa dieback is a serious problem, the use of a double trunk system is recommended. In Missouri, no fungicide is labeled for the protection of pruning wounds.

Oxidant Stipple

Ozone-induced injury, known as oxidant stipple, is a foliar disorder that sometimes occurs in Missouri vineyards. Initial symptoms are small brown flecks on the upper surfaces of mature leaves. These flecks can increase in size later in the growing season, resulting in large necrotic areas. Severe cases have been associated with reduced yield and soluble solids. In general, American grapes are more susceptible to oxidant stipple than hybrids, but large cultivar differences are seen within each group. The most severely affected cultivars (many of which are not recommended for Missouri) listed in descending order of susceptibility are Ives, Elvira, Concord, Chambourcin, Baco noir, Leon Millot, Marechal Foch, Rougeon, Catawba, DeChaunac, Villard noir, and Villard blanc.

While the grower has no control over air quality within the vineyard, certain vineyard practices can influence the severity of oxidant stipple damage. Maintaining optimal nitrogen levels, controlling crop size, and avoiding excessive irrigation lessen the degree of damage.

Bacterial and Viral Disease Management

Crown Gall

In Missouri, the only major bacterial disease of grapes is crown gall. The causal agent of the disease is *Agrobacterium vitis*, a Gram-negative bacterium that is a common member of the microflora that inhabits the grape root rhizosphere and the internal tissues of the vines. This bacterium can cause disease only if it comes in contact with a wounded grapevine cell. When this happens, the bacterial cell transfers a fragment of its own DNA into the plant cell. The DNA integrates into one of the grape chromosomes. This DNA fragment contains genes, so-called oncogenes, that direct the synthesis of plant hormones. The cells that receive the bacterial DNA are referred to as transformed cells. The synthesis of hormones by the transformed grapevine cells will lead to a rapid cell division and to a rampant proliferation of the diseased tissue which leads to the formation of a dysfunctional mass of cells, the gall.

Most frequently affected by the disease are the cambium and the transport system of the trunk. The diseased portion of the vascular tissue is unable to carry out its nutrient transport function, and if the gall girdles the trunk, the vine will starve to death. In addition, the cambium in the diseased tissue is killed and the affected area will not be able to form new vascular elements. As a result, even those plants that survive the disease can become severely weakened. Researchers in California registered a 20% to 40% reduction in yield, and a 10% to 40% reduction in vigor in plants that had 50% or more of their crown circumference covered with galls. The cultivation of the resulting incomplete, low-producing vineyard is unprofitable, and the replacement or retraining of the dead or injured plants requires additional expenses. Crown gall is particularly severe in Missouri and other midwestern states where changeable winter weather inflicts freeze damage to the grapevine tissues and favors the development of the disease.

Once the bacterium has invaded the vine, the vine will remain infected over its entire life. Therefore, the only control strategy available to growers is prevention. Recent research results suggest that planting *Agrobacterium*-free propagating wood into non-vineyard soil will result in vines that will stay free of the disease unless the disease is introduced from outside. The major factors that limit the practicality of this approach is that *Agrobacterium*-free propagating material is commercially unavailable. Growers and nurseries often propagate plants from symptomless vines, assuming that the progeny will be free of the disease. The lack of crown gall symptoms on a vine, however, does not mean that it is free of the bacterium.

Several techniques have been developed to test propagating wood for the presence or absence of the pathogen, but unfortunately none of them has proven completely reliable. Hot water treatment of dormant propagating wood also falls short of fully eradicating the bacterium from the canes. The only certain way to produce *Agrobacterium*-free plants is by passing them through shoot tip culture. This, however, is a long-term process and can be organized and carried out only by well-equipped nurseries or academic institutions. It is our prediction that *Agrobacterium*-free propagating wood will be commercially available in the future, just as certified virus-free propagating wood of *Vitis vinifera* cultivars is commonly available now.

In the absence of pathogen-free propagating material, growers can still reduce crown gall damage in their vineyards with careful cultivar and site selection. In general, one should avoid the cultivation of cold-tender cultivars in Missouri, not only because of the injury directly inflicted by the cold, but by the greater susceptibility of these plants to crown gall. Growers should also be very cautious about planting cultivars that are known to be highly susceptible to crown gall. Chancellor, a once popular hybrid cultivar in Missouri, for example, all but disappeared from the state because it was devastated by the disease. As a rule of thumb, *Vitis vinifera* cultivars tend to be more susceptible than hybrids and American *Vitis* cultivars. Whenever grafted vines are planted, the crown gall susceptibility of the rootstock cultivar should also be taken into careful consideration. On grafted vines the cold- and crown gall-sensitive graft union can be protected from freezing temperatures by covering it up with soil (hilling).

A common practice to moderate the economic impact of crown gall in Missouri is to train vines to have multiple trunks. Should one of the trunks be killed by crown gall, the replacement trunk is already in place to provide production. Mechanical injuries to the trunk should also be avoided as much as possible, as any injured tissue may become the site of gall formation.

Vineyard site selection is also important. One should avoid poorly drained, low-lying areas, because the disease tends to be much more severe in such locations. In general, the more conducive a location is to cold injury, the more likely it is that the vines will be damaged by crown gall there. When an old vineyard site is re-planted with grapes, the larger roots of the old vines should also be removed, and the soil should be left fallow for two to three years. This will reduce, but not completely eliminate, the agrobacterial population. If the grower cannot afford to fallow the field, the soil should be fumigated before planting the new vines.

In summary, the extent to which grapes can be protected from crown gall is currently rather limited. The future availability of pathogen-free propagating material is expected to be a major improvement in crown gall control. In addition, current efforts in research are likely to bring additional control strategies with the application of crown gall-antagonistic bacteria and genetic engineering.

Viral Diseases

Until recently, little was known about the occurrence of grape viruses in the eastern and midwestern United States. Recently, however, several reports have pointed out that at least one virus, the 3rd serotype of grapevine leafroll-associated virus (GLRaV-3) is widespread in this region. Canadian researchers have reported that GLRaV-3 is the most common virus in eastern Canadian vineyards, and that it is predominantly associated with French hybrid grapes. The common occurrence of GLRaV-3 in American *Vitis* grapevines has been documented from New York, where infected Concord, Catawba, Elvira, and Niagara vines have been identified. The widespread occurrence of GLRaV-3 in French hybrids has also been reported from Missouri.

Of six commercial vineyards sampled on the Ozark Plateau and the Missouri River valley in Missouri, four had GLRaV-3-infected plants. Disease incidence was also high for the American *Vitis* cultivars Norton and Catawba. In addition to GLRaV-3, a high disease incidence of the grapevine fleck virus (GFkV) has also been found in a Vidal Blanc vineyard in Missouri. These results leave little doubt that many of the French hybrid vineyards in eastern and midwestern North America are heavily infected by at least one leafroll virus, and with perhaps other viruses.

Since French hybrid, American hybrid and American grape cultivars do not develop any visible symptoms when infected by these viruses, this could mislead our perception of grape viral diseases. The potential for damage by these viruses on grape production can never be precisely predicted. The risk, however, exists as long as viruses are present in the vineyard. The potential risk is compounded particularly with the current situation in which dissemination channels of viruses are not checked robustly, and the problem of mixed infections of different viruses within individual vines.

For the future of the grape industry, we initiated a virus elimination program at the Missouri State University State Fruit Experiment Station based on a rationale that it is always safe to propagate vines from clean stocks in the beginning. The goal of this program is to cure the most important hybrid cultivars of their viral pathogens and make these cultivars available to nurseries and growers. Contact the Missouri State University State Fruit Experiment Station for more information.

Table 11-1. Relative Disease Susceptibility and Sensitivity to Sulfur and Copper of Grape Cultivars Under Missouri and New York Conditions

Cultivar	Black Rot	Downy Mildew	Powdery Mildew	Anthracnose	Copper Sensitivity[1NY]	Sulfur Sensitivity[2NY]
Aurore	+++	+	++	+	++	no
Baco Noir	+	+	++	+	?	no
Cabernet Franc[2 yr]	+++	+++	++	++	+	no
Canadice	+++	+++	++	++	?	?
Catawba	+++	+++	+	+	++	no
Cayuga White	+++	++	++	+++	+	no
Challenger	+++	+++	++	+++	?	no
Chambourcin	+	+	+++	+	?	?
Chancellor	++	+++	+++	++	+++	yes
Chardonel	++	++	++	+	?	no
Chardonnay[3 yr]	+++	+++	+++	+++	+	no
Chelois	+	+	++	+	+	no
Concord	+++	++	+	+	+	yes
Couderc Noir[2 yr]	++	+++	++	++	?	?
DeChaunac	++	+	++	++	+	no
Delaware	+++	+++	++	++	+	no
Glenora	+++	+++	+++	+++	?	?
Himrod	+++	+++	+++	+++	?	no
Leon Millot	+++	++	+++	+	?	?
Marechal Foch	++	+	++	++	?	yes
Melody[NY]	+++	++	+	?	?	no
Missouri Riesling[2 yr]	++	+++	++	++	?	no
Niagara	+++	++	++	?	+	no
Norton/Cynthiana[3]	+	++	+	+	-	yes
Rayon d'Or	+++	+	++	+	?	?
Reliance	+++	++	+	+++	?	?
Riesling[NY]	+++	+++	+++	?	+	no
Rougeon	+++	+	+++	++	+++	yes
Seyval blanc	+++	+	+++	+	+	no
Steuben	+++	+++	++	+	?	no
Traminette	+++	+++	+++	+	?	?
Venus	+++	+++	+	++	?	?
Vidal blanc	++	+	+++	+++	?	no
Vignoles	+++	++	++	+++[4]	?	no
Villard blanc	+++	+	+++	+++	+	?
Villard Noir[2 yr]	+++	+++	+++	++	?	?
Vincent	+++	+++	+++	+	?	?
Vinered	+++	+++	++	+++	?	?
Vivant[2 yr]	+++	+++	+++	+++	?	?

Key to ratings: +++ = highly susceptible/sensitive, ++ = moderately susceptible/sensitive, + = slightly susceptible /sensitive, ? = unknown susceptibility/sensitivity.

Ratings based upon 4 or 5 years data collected at the State Fruit Experiment Station unless otherwise noted.

[1]Ratings from the Cornell University Pest Management Recommendations for Grapes. Copper applied under slow, cool drying conditions may cause injury. Sulfur injury may occur on tolerant cultivars if the temperature is 85°F or higher during or shortly after application.

[2]Observations in Missouri indicate that Cynthiana/Norton is very sensitive to Endosulfan and is likely sensitive to some other commonly applied pesticides.

[3]Fruit of Vignoles is highly susceptible to anthracnose while foliage and shoots are only slightly susceptible.

[NY] Ratings under New York conditions.

[2 yr or 3yr]Disease susceptibility based on only 2 or 3 years data collected at the State Fruit Experiment Station.

Chapter 12

Insect Pest Management

Grapes have many insect pests that attack all parts of the plant. Fortunately only a few of these pests pose a serious economic threat in Missouri. The following discusses the insect pests most commonly encountered in the vineyard. Specific insecticide recommendations for control are not given, as these may change. Current recommendations can be found in the *Missouri Commercial Grape Pest Control Guide* (MS-19 revised) that is updated each year. Another useful reference is *Insect and Mite Pests of Grapes in Ohio* (Williams et al., 1986)

Climbing Cutworm and Grape Flea Beetle

Both climbing cutworm and grape flea beetle attack the buds of the grapevine when they first start swelling early in spring. Buds will be found which have the interior eaten out, usually through a hole in the side of the bud. There is no reliable way to tell the damage of these two insects apart. The grape flea beetle is about $^{3}/_{16}$ inch long and steel blue in color. They can be seen on the canes and attacking buds on warm, sunny days. Cutworms are brown in color, and feed only at night. They hide under loose bark or in trash on the ground during the day, and then crawl up the trunk to feed at night. If damage is observed and flea beetles cannot be seen, one can examine the canes after dark with a flashlight. Flea beetle damage often occurs in the edge of vineyards near wooded or brushy areas. Cutworms are usually more prevalent in vineyards planted in sandy soils or those with weeds and grass under the vine.

Growers should scout their vineyards every other day during bud swell to determine if either of these pests are doing economic damage. Damage can be quite significant because buds that are attacked fail to develop. Cutworms often move along the canes and can kill every bud. Insecticides are not needed unless these pests are damaging buds. In vineyards with a history of cutworm damage, the grower might opt to apply an insecticide at early bud swell each year. In an average or normal year, the buds grow quickly, and once the buds have grown out to ½ inch these insects are no longer a threat. In years with cool spring weather, the buds may grow out very slowly, so they are prone to damage for 2 weeks or more. Under such conditions, the grower should scout the vineyard every few days until the danger stage is past.

Grape Berry Moth

The grape berry moth is the most important pest of the fruit. This insect overwinters as pupae within a flap of grape leaf. The fallen grape leaves frequently are blown out of the vineyard during winter winds, and may concentrate in fence rows and weedy areas, brush and woods near the vineyard. For this reason, berry moth is often most severe on the edge of vineyards near these areas. The overwintering adults usually appear in the vineyard at the end of bloom, where they deposit eggs on the newly set berries. When the eggs hatch, the larvae web together several very small berries and consume them. This damage can be seen as a light webbing in which the berries are missing. The mature larvae make cocoons by cutting a flap out of a leaf, usually near the edge. The flap is folded over and secured by silk, and the larvae pupate inside. When mature, adults emerge and deposit eggs on the developing berries. When the larvae hatch, they burrow into the grape berry, usually where two berries touch. This tunneling results in the affected berries turning red or purple in the area of the entrance. A single larva may tunnel into several berries before it is mature. The mature larvae again pupate and usually emerge about the end of August in Missouri. This generation can be especially damaging because infested berries frequently are attacked by rots that destroy more berries than just the ones infested by the berry moth. Heavily infested grapes can have so much rot that they are unacceptable to processors.

Grape berry moth can be controlled by applying insecticides. The first application should be made right after bloom. This application will also give control of a large number of minor pests that sometimes infest grapes. Applications should be continued throughout the season with a maximum of two week intervals. A sex pheromone that attracts male grape berry moths to a trap is available commercially. These traps can be placed in the vineyard and will enable the grower to determine when adult berry moth emergence is starting, and when peak emergence is occurring.

Grape Root Borer

The damage caused by the grape root borer is insidious in that the grower normally will not see it. However, this pest is probably present in all vineyards in Missouri. The borer is the larva of a clear winged moth that greatly resembles a common wasp. This larva feeds inside the grape root for almost two years. When it is mature, it leaves the root and tunnels to just beneath the soil surface where it makes a cocoon. Adults begin to emerge from the soil during the first week of July in Missouri, and emergence may continue until early October. After mating, females deposit eggs on grape leaves and weeds under the vine. These eggs are loosely attached and most of them probably fall to the ground. When the eggs hatch, the larvae immediately burrow into the soil in search of grape roots, which they enter and where they feed for about 22 months. The effects of this root feeding are not usually evident in vigorous vineyards. However, in vineyards that are under stress from lack of water, poor nutrition, or lack of weed control, a general decline may result. Vine growth may decline, along with yield, and winterkill may occur. Over a period of a few years, the vineyard may decline to a state where it is no longer sustainable.

Control of the root borer is difficult because the larva is inside the root where it cannot be reached with insecticides. One insecticide has been approved for treating the soil under the vine, but it is fairly expensive. Growers can minimize damage by keeping the vines in good health through proper nutrition and watering. Pheromone traps are also available for monitoring adult male root borer emergence and numbers.

Potato Leafhopper

The potato leafhopper is a very small green or white wedge shaped insect about $^1/_8$ inch long. This leafhopper feeds on at least 200 different plants. It does not overwinter in Missouri, but is carried north each year from the gulf coast states by spring winds. This leafhopper feeding causes the leaves to take on a characteristic cupping and yellowing. This leafhopper is probably present in small numbers in all vineyards, but occasionally is found in damaging numbers in a few vineyards. Insecticides will give control if needed.

Grape Cane Gallmaker

This insect is a very small snout beetle, about 1/8 inch long and brown or black in color. Adults overwinter in brushy or wooded areas and in May move to the vineyard. The female chews holes just above a node in the new canes when they are 10 to 20 inches long, and deposits an egg in the hole closest to the node. A red gall about ¾ to 1 inch long then develops at the site of the egg deposition. New adults emerge from the gall in August, and there is only one generation each year. This damage is usually first noticed when the vines are pruned. The galls at this time are hard and have a longitudinal crack in them. Since the galls usually occur beyond the site of clusters, the damage is mostly cosmetic and there is no loss of crop. If chemical control is deemed necessary, it should be applied when the shoots are 3 to 6 inches long and again when they are 10 to 12 inches long.

Grape Phylloxera

There are two forms of grape phylloxera, a leaf form and a root form. The leaf form overwinters as an egg under the bark of the vine. Upon hatching, the nymphs crawl to the new leaves where they settle and feed. This feeding causes a gall to form around the insect on the underside of the leaves. These galls have an opening on the upper surface of the leaf. Mature phylloxera deposit eggs in the galls, and when they hatch, the crawlers exit the galls through the openings and crawl to new leaves to repeat the cycle. The leaf galls on most American grape cultivars rarely become numerous enough to cause damage, but can cause severe damage on Delaware and several of the French hybrid cultivars. The leaves on susceptible cultivars may curl up, dry out, and fall from the vine. The leaf form of phylloxera can be controlled using insecticide applications.

The root form of phylloxera can be very damaging. The insect overwinters as immatures on the roots. Feeding on the roots causes gall-like growths to appear, which eventually die and rot, thus depriving the vine of its root system, which can cause death. The American cultivars are resistant to the root form, and are thus not damaged by it. However, the *Vitis vinifera* cultivars are very susceptible to the root form, and these cultivars are usually grafted on resistant rootstocks. Recent evidence suggests that certain French hybrids are also susceptible to the root form; contact the Missouri State Fruit Experiment Station for more information. There is no chemical control for the root form of the grape phylloxera.

Hornworms

Hornworms are the larvae of various species of hawkmoths. These worms are frequently found feeding on grapes, but are of little economic concern because normal berry moth control measures also give good control of sphinx moth larvae. However, the pandorus sphinx moth larvae can do damage to newly planted vineyard which are not under a regular insecticide program. These larvae can get as large as a thumb, and can be a rich brown, green, or yellow color. They have a very good appetite and can eat all the leaves off a newly planted vine in a very short period of time. The grower should scout newly planted vineyards for this pest. Infested vines will have areas where the leaves are missing, with only the leaf stems left. The ground under such areas may be covered with droppings which look similar to rabbit droppings. The larvae feed mostly at night, but they can commonly be found hiding of the shaded north side of the main trunk of the vine near the ground. Larvae can be destroyed by hand if they can be found, individual infested vines can be treated with an insecticide, or the whole vineyard can be treated.

Other Foliage Feeders

There are several insects that feed on the leaves, but are normally controlled by the grape berry moth sprays. Rarely are insecticide applications needed to control these pests, as they normally do little real damage. They are briefly described here so that the grower can recognize them. The larvae of **grape flea beetle** larvae feed on the upper surface of leaves, resulting in skeltonized areas. These larvae are a dirty brown or green color. The **grape leaffolder** folds the leaf and feeds inside the fold. These are frequently found on wild grape. **Eight-spotted forester** larvae are yellow, white and black and consume all of the leaf except for the leaf petiole and the heavy veins. **Grapevine Epimenis** larvae are very similar to the eight-spotted forester, but they feed within a shelter made by drawing the edges of a leaf together forming a somewhat ball shape. The **grape plume moth** feeds in the terminal leaves that it webs together. The larvae are small, green or yellow in color, and covered with white hairs.

Chapter 13
Weed Control

Weed control is very important in grape growing. Weeds compete with vines for soil moisture and nutrients. Strong weed competition during the first and second years of establishing a new vineyard will greatly reduce vine growth and delay full bearing. This is the number one mistake that new grape growers make. For mature bearing vines, early through mid-season weed control is most important because vines must grow vigorously to develop a canopy with maximum photosynthesis to support flowering and fruit set. From ripening (veraison) through the remainder of the season, additional vegetative shoot growth is usually not beneficial. Mature bearing vines can tolerate some weed competition at this time. These could be short, annual grass and broadleaf weeds. Perennial weeds should be controlled. Climbing or tall growing weeds should also be controlled because they compete with vines for sunlight and restrict air movement in the vineyard. In the latter case, leaves and fruit dry-off slowly following rainfall. This increases the potential for fungal disease outbreak. Mid- to late season weeds that grow to maturity will become a source of weed seed the following season. Mowing or post-emergence, contact herbicides should be used to prevent them from maturing.

Permanent sod cover is usually established between trellis rows in Missouri vineyards. Perennial, cool-season grasses such as common bluegrass or tall fescue are seeded as the cover. These must be kept mowed during the growing season or they will also compete with vines. This is better than allowing native weed species to establish in row middles every year. Native weed cover must have timely mowings or post-emergence, contact herbicide treatments to prevent uncontrolled weed growth. It is also unsuitable for sloping vineyard sites where soil erosion can occur. Cultivation of row middles is not recommended because of shallow, rocky soil and sloping ground in many vineyards. Damaged vine roots, soil erosion, and loss of soil structure are detrimental effects of cultivation.

Mulching is a very effective way of controlling weeds in both row middles and beneath the trellis. This is a labor intensive practice unless it is mechanized. Mulch can be expensive unless a large source close to the vineyard is available. A consideration might be to grow straw or hay for mulch. Most growers would consider mulching impractical for all but a very small vineyard. However, growers that do not want to use herbicides in their vineyard should consider mulching. Combining a wide grass alley between trellis rows along with a narrow mulched strip beneath the trellis can effectively control weeds. The mulch will have to be replenished because of decomposition. Even for those growers that will use herbicides, mulching is a good practice around first year vines with shallow root system that cannot tolerate pre-emergence herbicides. Straw, hay, sawdust or bark mulch can be applied in a two to three foot diameter circular area around the vine in a thick layer to obtain season long weed control. Weeds must still be controlled in other areas of the vineyard. Growers that use mulch around young vines or along the trellis row need to check vines periodically for any sign of rodent feeding and take corrective action if needed. This may be the use of rodent bait and/or moving mulch away from the vine trunk.

Weed control should start one or two growing seasons before planting a vineyard. The goal is to eliminate aggressive, woody and herbaceous perennial weeds, and to reduce the amount of annual weed seed in the soil. This is usually accomplished by applying a broad spectrum, non-selective, post-emergence herbicide to the entire planting area. Weeds with extensive root systems are often difficult to control and may require additional spot-treatment applications of herbicide to get a good kill.

After weeds have died, brush-hog the area to reduce the ground cover height. Follow this by cultivation to work the ground cover into the soil and prepare a seed bed for establishing a cover crop or a permanent sod cover. If the vineyard will not be planted for a year or more, cover crops are useful because they displace weeds and add organic matter to the soil when cultivated in.

Depending on the site and the amount of ground cover to be incorporated, cultivation may need to be a combination of both plowing and multiple discings or the discings alone to prepare the soil. In some pasture ground that is being converted to vineyard it may be possible to eliminate full-field cultivation and only apply herbicide and cultivate the area where vines will be planted. This requires having a suitable pasture grass that is in good condition as an established cover, and careful layout of planting rows.

Remember that problem weeds are much easier to eliminate through a combination of broad spectrum, non-selective, post-emergence herbicide applications and cultivation. This is most effectively done before the vineyard is planted. Afterwards it becomes much more difficult because herbicides that can be used in vineyards are more limited, and vines and trellis interfere with cultivation.

Perennial, cool-season grasses are the preferred cover between trellis rows. The alternative which are perennial, warm-season grasses are either too competitive or expensive to establish. Cool-season grasses should be seeded from early September through early October. Spring seeding is less desirable because of competing, early season, weed growth. Enough time should be allowed for any cover crops to be cultivated into the soil. Additional time for residue breakdown and seedbed preparation will be required. This means starting your final cultivations from early through mid-August.

Drilling seed to a shallow depth in prepared soil is the preferred method of seeding. The strips where the trellis will be erected and vines planted can be left unseeded. Broadcasting seed followed by very shallow incorporation or rolling is an alternative method. This usually places seed in the area where vines will be planted. Germinating grass can be allowed to grow and killed out along the planting row the following spring using cultivation or post-emergence herbicide. In the latter case where the dead cover is left undisturbed, vines can be planted into the residue which acts as a mulch. Trellis construction is best done during late winter or early spring before vines are planted.

The use of herbicides beneath the trellis is the most common way to control weeds in

Missouri vineyards. Herbicides are applied to the soil pre-emergence (before weeds germinate) or post-emergence (after weeds germinate.) Some herbicides have both post and pre-emergence activity. The following table lists the common chemical names of herbicides that can be used in vineyards.

Table 13-1. Herbicides for Vineyard Use

Common Name	Time of Application	Weeds Controlled
Dazomet	Preplant	Soil Fumigant
Dichlobenil	Pre-emergence	Annual Grass and Broadleaf
Diuron	Pre-emergence	Annual Grass and Broadleaf
Isoxaben	Pre-emergence	Annual Broadleaf
Napropamide	Pre-emergence	Annual Grass and Broadleaf
Norflurazon	Pre-emergence	Annual Grass and Broadleaf
Oryzalin	Pre-emergence	Annual Grass and Broadleaf
Simazine	Pre-emergence	Annual Grass and Broadleaf
Pendimethalin	Pre-emergence	Annual Grass and Broadleaf
Trifluralin	Pre-emergence	Annual Grass and Broadleaf
Oxyfluorfen	Pre and Post-emergence	Annual Broadleaf
Pronamide	Pre and Post-emergence	Annual Grass and Broadleaf
Clethodim	Post-emergence Systemic	Annual and Perennial Grass
Diquat	Post-emergence Contact	Annual Grass and Broadleaf
DSMA	Post-emergence Contact	Annual Grass
Fluazifop	Post-emergence Systemic	Annual and Perennial Grass
Glufosinate	Post-emergence Contact	Annual Grass and Broadleaf
Glyphosate	Post-emergence Systemic	Annual and Perennial Grass and Broadleaf
MSMA	Post-emergence Contact	Annual Grass
Paraquat	Post-emergence Contact	Annual Grass and Broadleaf
Pelargonic Acid	Post-emergence Contact	Annual Grass and Broadleaf
Sethoxydim	Post-emergence Systemic	Annual and Perennial Grass
Sulfosate	Post-emergence Systemic	Annual and Perennial Grass and Broadleaf

Growers should consult the *Missouri Commercial Grape Pest Control Guide* for current recommendations on the use of these herbicides as well as any new herbicides that become labeled. Common names, trade names, formulations, toxicity signal words, application rates, surfactant requirement, pre-harvest intervals, restricted entry intervals, and important comments are listed in the guide.

The application rate for the treated strip area beneath the trellis is equal to the rate per acre for broadcast treatment times the strip width in feet divided by row spacing in feet. Pre-emergence herbicides often need rainfall or irrigation to move them into the soil where they are active. Prolonged exposure on the soil surface can lead to decomposition or volatile loss. Labels attached to herbicide containers should always be read for this and other current information on the use of the product.

Newly planted vines are a special problem for growers because they cannot compete with weeds and their shallow root systems can be injured by pre-emergence herbicides. Napropamide and Oryzalin are the only pre-emergents that can be used around newly planted vines. Applying less than the full rate is advised, usually around three-fourths rate. The soil should be settled or packed around the vine with no depression where spray can collect near the trunk. Mulch around the vine, particularly sawdust, will absorb much of the herbicide. Remember that extra nitrogen fertilizer may be required around mulched vines because of nitrogen tie-up by the decomposing mulch.

The use of a grow tube over each vine is a practice that should be considered. These are usually polyethylene plastic tubes 4 to 5 inches in diameter and about three feet tall. They are placed over the newly planted vine and staked or tied to the trellis. Tubes act as a training aid by directing growing shoots upwards. They also shield the vine from herbicide spray. Growers using these tubes have effectively eliminated pre-emergence herbicide use the first year and have gone to post-emergence sprays to control weeds. Tubes must be removed later in the growing season before cordons are established on the trellis.

Several of the listed herbicides can only be used in non-bearing vineyards, prior to planting through the second growing season. This will be written in the comments section of the *Missouri Commercial Grape Pest Control Guide*. Bearing usually occurs in the third year for a well grown vine. A number of additional herbicides can be used around bearing vines. Two to three year old vines still have shallow roots that can be injured by pre-emergence herbicides. The use of half rates of Diuron, Norflurazon and Simazine is advised. Napropamide and Oryzalin can be applied at a full rate. Four to five year old vines are usually well established and can have full rates of pre-emergence herbicide applied around them.

Using the same pre-emergence herbicide every year allows weeds that are not controlled to spread in the vineyard. Because of this it is advisable to use alternative herbicides from one year to the next. Tank mixing two pre-emergence herbicides for application in one year is another way to reduce the number of uncontrolled weeds. For example, combining a good grass herbicide such as Napropamide or Oryzalin with a good broadleaf herbicide such as Diuron, Oxyfluorfen or Simazine will increase the number of weed species controlled. The product labels of both herbicides should be consulted to determine allowable tank mixes and application rates. Pre and post-emergence herbicides can be effectively tank-mixed to increase weeds controlled. Because post-emergents can injure vines, they generally are used from late March through early June before grape shoots reach close to the ground. Spraying on calm days is advised, to reduce the risk of herbicide drift to non-target areas! Again consult product labels for allowable pre- and post-emergence tank-mixes and application rates.

Post-emergence herbicides are either contact or systemic in action. Diquat, DSMA, Glufosinate, MSMA, Paraquat and Pelargonic Acid are contact herbicides, meaning they kill the above ground part of the weed that the spray contacts. The root system can remain alive and regenerate the weed, particularly if it is a perennial. Clethodim, Fluazifop, Glyphosate, Sethoxydim, and Sulfosate are systemic herbicides, meaning they translocate

in the weed and kill both the above and below ground parts of the weed. Three post-emergence herbicides only control annual and perennial grasses. These are Clethodim, Fluazifop and Sethoxydim. Although it is a good idea to minimize spray on the vine, these grass herbicides can contact vine foliage without injury.

Post emergence herbicides that control both broadleaf and grass weeds should not contact vine foliage. They are usually applied through early June before foliage has developed close to the ground where spray applications are made. Glufosinate and Pelargonic Acid are unique in that they can be used for grape sucker control on mature vines. Consult labels for this use.

Missouri grape growers are advised to obtain a copy of the *Missouri Commercial Grape Pest Control Guide*, which includes current information on weed control.

Chapter 14
Bird and Deer Management

Bird Management

Bird depredation is a serious problem for Missouri grape growers. Birds of several species, including robins, starlings, and blackbirds, can quickly consume entire crops. Bird damage typically begins at veraison, weeks before harvest. Birds consume fruit and also damage remaining fruit, leading to loss of quality and increased incidence of bunch rots. Regardless of the control strategy, measures must be in place by veraison.

Many strategies are used for bird management, and they very widely in cost and effectiveness. The most effective and most costly method is netting. Plastic or nylon nets are placed over the vines, either directly on the plants or supported overhead on posts and wire. Netting is costly, but with proper care nets will last 3 to 5 years. Also available are disposable nets, intended for a single season of use.

Other strategies involve auditory scare devices (propane cannons, amplified distress calls, cracker shells) and visual scare devices (kites, balloons, reflective tape, mirrors). Birds become accustomed to scare devices quickly, and these strategies are most effective when their location in the vineyard is changed every few days. Bird control is enhanced when visual and auditory devices are combined.

Chemical bird repellants may hold promise for Missouri. Compounds such as methyl anthranilate and sucrose may repel birds from grapes. Visit with specialists at the Missouri State University State Fruit Experiment Station for the latest information on bird management.

Deer Management

Deer are a problem for Missouri grape growers. Browsing injury is particularly damaging to young vines. The size of Missouri's herd has increased greatly in recent years, as has the level of damage.

In general, thinning of the deer herd through hunting is not effective in reducing deer damage in areas with high deer populations. Damage control permits are available from state agencies to supplement hunting, but exclusion is the most effective way of reducing deer damage.

Several fence designs are used to exclude deer from vineyards. A 6-12 foot fence made of woven wire, netting, or multiple strands of high tensile wire is perhaps the ultimate barrier. Other deer fence configurations include a slanted fence that has 7' posts slanted to be 4' high on the deer side, making a barrier that is about 6' wide. Using two fences 3 to 5 feet apart also gives the deer a wider barrier and may confuse the deer's sense of depth perception. High tensile electric fence has also provided good results. Using peanut butter on the wires attracts deer to touch the wires. Using conducting tape or rope is more visible and

deer are more attracted to touch it.

Several chemicals are labeled as deer repellants. Check product labels for information on application rates and timing.

A thorough discussion of deer management is available in the publication *Deer Damage Control Options* (Lee, 1998), available from the Kansas State University Agriculture Experiment Station or online at http://www.oznet.ksu.edu/library/wldlf2/c728.pdf.

Chapter 15
Harvest Management

The optimum time to harvest grapes depends on the cultivar, the nature of the growing season, and the intended use of the fruit. Harvest date can vary from year to year, depending on environmental conditions.

The process of ripening involves several stages. The first obvious sign of approaching ripeness is veraison, or change in the berry color. Unripe green fruit develop color pigments (red or purple cultivars) or become lighter in color and translucent (green or yellow cultivars). Soon after veraison the fruit will develop aromas characteristic of the cultivar. Sugar content of the fruit begins to rise, while acid content decreases. Acid strength, measured as pH, weakens. Other flavor and aroma compounds in the fruit undergo changes.

Wineries have very specific requirements for fruit quality, and will pay varying amounts of money for the crop based on quality parameters. Those parameters include sugar content (measured as degrees Brix), pH, and titratable acidity. For a given cultivar, a range of acceptable values is usually given. In some cases, all the parameters will be in acceptable ranges at harvest. In other cases, harvest date is determined by one parameter, even though other indices may be outside the ideal range. Most wineries consider pH to be the single most critical parameter, as it is difficult to correct out of range pH values during the winemaking process. Sugar content and acidity are easier to adjust. The generally accepted values for wine grapes at harvest are soluble solids, 18 to 24 °Brix (white cultivars) and 21 to 25 °Brix (red cultivars); total acid content, 0.6-1.0 g/100 ml; and pH, 3.0-3.5.

A good way to accurately time harvest for a given cultivar is by measuring the above parameters for a representative fruit sample. The most common sampling procedure in Missouri is to collect a random sample of at least 200 berries. The sample must represent the entire crop. Sample an equal number of berries from both sides of the row, and sample from throughout the entire vineyard. Avoid end plants or atypical plants. Sample cultivars and different locations separately. Collect the initial sample 3 weeks before the expected date of harvest. Sample weekly until the week before harvest, and then every 3 to 4 days. Collect samples at the same time of day for each sampling date. Crush the fruit, extract the juice, and perform the chemical analysis to arrive at the quality parameters. Further information on berry sampling, including the procedure for measuring quality parameters, is available in several references (Editor, 1995; Watson, 1992). In addition to using sugar, acid, and pH levels, the grape grower must become familiar with qualitative measures of ripeness, such as the development of characteristic flavor and aroma components. Sensory evaluation of flavor and aroma components of the juice sample should accompany the chemical analyses mentioned above

(Zoecklein, 2001). With certain cultivars, for example, undesirable compounds develop during the ripening process and harvest time is based in part on the levels of these compounds.

Harvest parameters for table grapes include color, flavor, aroma, and a sugar/acid ratio of 15:1 or higher.

Other factors enter into the harvest decision. Adverse weather, presence of bunch rot, level of bird damage, and scheduling decisions at the winery can all influence the timing of harvest. Damaged fruit must be harvested without delay to minimize loss of fruit quality and to reduce crop loss.

Grapes for fresh market sale are harvested by hand. Clusters may be packed directly into sales containers, such as 5 or 10 pound boxes, or into baskets that hold from 8 to 12 quarts. Processing fruit may be harvested by hand, commonly into lugs or boxes that hold 15 to 20 pounds. Processing grapes are also harvested by machine, often into bins that hold 2000 pounds. Grapes may be harvested in a once-over single picking, or harvested in two pickings one to two weeks apart. Avoid harvesting during the heat of the day; grapes are usually picked from dawn to 11:00 am. Grapes that are mechanically harvested can be picked during the night.

Once harvested, transport grapes as quickly as possible to the consumer or the processor. This is particularly the case with mechanically harvested fruit. If fruit must be held for a period of time, ideal storage conditions are under refrigeration at 30 to 32 ^{o}F and 85% to 90% relative humidity.

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