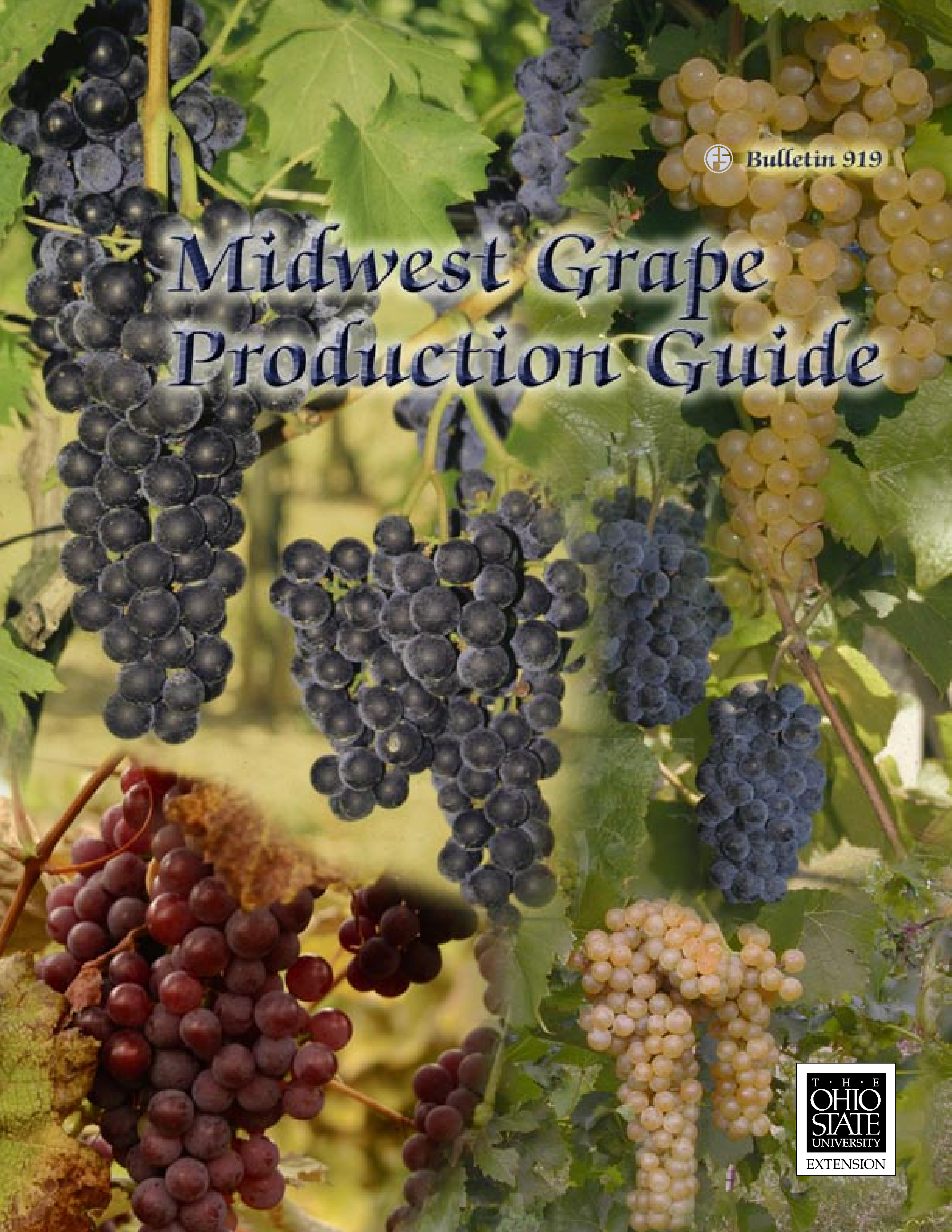
Bulletin 919

Midwest Grape Production Guide



THE OHIO STATE UNIVERSITY EXTENSION

Bulletin 919 For-sale publication

Keith L. Smith, Associate Vice President for Agricultural Administration and Director, Ohio State University Extension
TDD No. 800-589-8292 (Ohio only) or 614-292-1868

5/05—3M—xxxxxx

Authors

Imed Dami
Assistant Professor and Viticulture Specialist
Department of Horticulture and Crop Science
Ohio Agricultural Research and Development Center
The Ohio State University

Bruce Bordelon
Associate Professor and Viticulture Specialist
Department of Horticulture and Landscape Architecture
Purdue University

David C. Ferree
Professor Emeritus
Department of Horticulture and Crop Science
Ohio Agricultural Research and Development Center
The Ohio State University

Maurus Brown
Assistant Professor and Extension Educator
Department of Extension
The Ohio State University

Michael A. Ellis
Professor and Extension Specialist
Department of Plant Pathology
Ohio Agricultural Research and Development Center
The Ohio State University

Roger N. Williams
Professor
Department of Entomology
Ohio Agricultural Research and Development Center
The Ohio State University

Douglas Doohan
Associate Professor and Weed Specialist
Department of Horticulture and Crop Science
Ohio Agricultural Research and Development Center
The Ohio State University

Acknowledgments

Editing
Joy Ann Fischer, Communications and Technology

Graphic Design
Tim Bowman, Communications and Technology
Jesse R. Ewing, Communications and Technology

Photography
Bruce Bordelon, Ken Chamberlain, Imed Dami, David C. Ferree, Jodi Miller, Gene Sigel, Tom Zabadal

Illustrations
Imed Dami, Department of Horticulture and Crop Science
Jesse R. Ewing, Communications and Technology

The authors wish to thank the New York Agricultural Experiment Station, Cornell University, for supplying some of the figures used in this publication. Appreciation is also extended to the Ohio Wine Producers Association for providing some photographs used on the cover.

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Introduction and History

Grape production in the United States is expanding rapidly as new growers are starting vineyards in all regions of the country. Commercial wine grape production in the Midwest, along with production in California, Oregon, and New York, has increased with the demand for high-quality wine.

During the last seven years (1997–2004) in Ohio, the number of licensed and bonded wineries has increased from 43 to more than 80. Indiana, Michigan, Illinois, and Missouri are experiencing similar expansion as more people are becoming familiar with the wines produced from grapes grown in the Midwest.

Commercial wine-grape production has a long history in the Midwestern states. Some of the earliest work with grapevines occurred in Ohio and Indiana.

A Swedish immigrant, John James Dufour, worked diligently on improving grape growing in Indiana during the early 19th century. He settled in the prairie town of Vevay, Indiana, shortly after returning to the United States in 1816. Dufour chose the most suitable location available to start his new vineyards and begin making wine. He brought with him from Sweden considerable experience in growing grapes and making wine.

In addition to Dufour, Jean Daniel Morerod was well known in Vevay for his grape-growing ability. Morerod helped to pioneer some of the earliest wine making in southern Indiana.

Another great figure in American viticulture was a young Cincinnati attorney, Nicholas Longworth, who moved from New Jersey in 1803. His interest in growing grapes and making wine gave him notoriety in the United States as an important viticulturist. By the 1820s, Longworth was seeking out sources of various grape cultivars to grow in his newly established vineyards, cultivars that included the Catawba grape.

John Adlum, District of Columbia, was noted as the person from whom Longworth obtained the original Catawba vines. As the Catawba grape became more popular for making wine, Longworth quickly became an important spokesperson for the Cincinnati grape-growing area. The Ohio River Valley developed a national reputation for growing grapes, which led to it being nicknamed the Rhine of America.

For more than three decades, grape production around Cincinnati increased until grapevines began to experience serious decline due to the diseases of downy mildew, powdery mildew, and black rot (Figure 1). As grape diseases became more widespread, insects caused additional problems that resulted in a decrease in grape production in southwestern Ohio. Southern Ohio grape growers abandoned their vineyards and looked for other areas of Ohio to grow grapes.

Although the Lake Erie grape-growing area is much farther north than Cincinnati, its weather patterns are moderated by a large body of water. The Lake Erie area has been a good location for grape production and wine making because of the favorable attributes of an extended growing season and well-drained sandy soils. The Lake Erie grape-growing region has been a strong production area for more than 100 years and is still a strong viable area for growing American, French hybrid, and Vinifera wine grapes.

Northern Ohio grape production increased rapidly through the mid-1860s. Early success stories of grape growing along Lake Erie and on the islands led several individuals to start growing grapes in this region (Figure 2). By 1874 Ohio grape acreage totaled more than

FIGURE 1. Bordeaux application to control diseases in the early 1900s.

FIGURE 2. Grape harvest in the Lake Erie Region in the early 1900s.

10,000 acres and grew to a peak of 28,000 in 1889.

Unlike the level of attention given to the production of Catawba around Cincinnati, most grape production in northern Ohio was devoted to the American varieties, Concord and Niagara, in the mid- to latter 1800s. From the early 1900s through today, the Concord and the Niagara grapes have been the most widely grown grape varieties.

In 1919, Ohio was the first state to vote against the sale and the consumption of alcohol, ushering in the era of Prohibition. After Prohibition was enacted, Ohio grape production declined dramatically from a high of 32,000 acres, which was mostly planted to Catawba.

During Prohibition, grapes were only used for juice and fresh consumption and thus the demand for Concord and Niagara grapes increased. Some sacramental wine was produced for religious purposes, and home wine making was common. It was not until after the repeal of Prohibition in 1933 that grapes were once again used for commercial wine making.

Since the mid-1970s, increased attention has been paid to growing French hybrid and Vinifera grapes for making high-quality wine. Of the 2,000 acres of grapes grown in Ohio today, some 300 to 400 acres are devoted to French hybrid and Vinifera production.

Missouri is a grape-producing state with a great history of wine making. Some of the first grape and wine producers in Missouri, as in Indiana, were from Sweden. In the town of Hermann, Missouri, in the early 1840s, a man by the name of Jacob Fugger became known for growing some of the earliest wine grapes including Isabella, Cynthiana (Norton), and Catawba. Until Fugger began growing grapes for commercial wine production, Jesuit priests had made wine in the early 1820s from locally grown wild grapes.

Charles Riley worked on grafting European vinifera onto American grape species in the 1870s. His use of native rootstocks was helpful in controlling phylloxera in Europe. Grape production in Missouri consists of predominantly red and white American varieties and to a lesser extent French hybrid and Vinifera varieties.

Illinois, although known for corn and soybeans, is becoming a popular region for wine-grape production. Early wine production started in Navoo, in western Illinois, by German settlers. Grape and wine production was limited until the 1990s at which time several growers started vineyards, and new wineries opened for business.

Today Illinois has more than 40 licensed and bonded wineries and more than 200 vineyards with some 1,000 acres. Most of the grape production is in the southern part of the state, but more vineyards are being planted in central and northern Illinois.

Grape production is an intensive cropping process. Maintaining modern vineyards in the Midwest requires recruiting migrant labor to accomplish certain tasks. As vineyard mechanization became more prevalent in the late 1960s, the number of migrant laborers needed dropped to only a few individuals who prune and tie vines in the juice-grape vineyards. Most of the grape harvest is done mechanically in juice-grape vineyards, with a few of the larger wine-grape growers using machines to harvest their vineyards.

Table grapes are produced on a very small scale in the Midwest. Most of the dessert grapes are imported from California or Chile. Some effort has been given to developing a seedless table-grape industry in Ohio and Indiana. For the most part, production and shipping costs have limited the desire for planting large numbers of acres of table grapes in the Midwest.

Some growers have planted one to two acres of table grapes as an alternative crop to diversify an established fruit farm. Most of these grapes are sold through roadside or farm markets. One reason for growing seedless table grapes locally is the fresh home-picked flavor that cannot be duplicated with imported grapes.

The Grapevine

The growth habit of the grape is in many ways similar to that of other fruit crops. Yet it is sufficiently different to warrant special study to understand the application of many cultural practices.

Grape flowers and fruit clusters are borne only on new shoots arising from dormant buds. These buds are formed in the axils of leaves the previous season and are called compound buds. This compound bud or *eye* contains a group of three separate buds.

When growth starts in the spring, the primary or central bud breaks dormancy and produces the fruiting shoot (Figure 3). On young vines, this shoot may remain entirely vegetative and produce no fruits. Grape shoots do not form terminal buds, and the tip typically dies back in the winter to the lignified or *ripened* portion of the cane.

FIGURE 3. The fruiting shoot grows from the primary bud.

Spring frosts may occasionally kill the tender primary shoot in its early stages of growth. In this case, the secondary or tertiary buds in the eye develop shoots that may—or may not—bear fruit (Figure 4). This shoot normally is less vigorous and less productive than the primary shoot. However, this characteristic of the grape permits development of a partial crop even though the primary shoots are lost.

Severe spring frosts may kill both primary and secondary buds. In such cases, fruit production is lost for that season, and the remaining shoot growth may be extremely vigorous.

FIGURE 4. Frost injury to the primary shoot results in new shoot growth from a secondary or a tertiary bud.

Cluster initiation for next year's crop begins during mid-summer in the developing buds, which are in the leaf axils of the current season's shoots. By the end of the growing season, the buds are fully developed and contain leaf and cluster primordia.

The following spring as these buds begin growth, final development of the flowers occurs. By this time, shoots are 6-inches long, and clusters are clearly visible. Flowering or bloom occurs after the shoots reach 18 to 24 inches, or about four weeks after bud break.

Morphologically, the grape fruit cluster is a modified tendril. Whether a tendril or a flower cluster, development is determined by the vine's genetic code. The number of flower clusters that may develop from a single dormant bud is determined to a great extent by vine vigor and growing conditions, especially exposure to sunlight during the previous season.

Each grape species has a definite number of flower clusters per shoot. Location of these clusters on the shoot also is specific. The location and number of fruit clusters on the shoot are factors to consider in determining the vine training and pruning system. The American grape (*Vitis labruscana*) characteristically forms two to four flower clusters per shoot located at nodes 2, 3, 4, and 5 from the base of the shoot. Many species of grape, including most cultivars of *V. vinifera*, form only two flower clusters per shoot.

French hybrids as a group tend to flower prolifically, have four or more clusters per shoot, and produce flowering shoots from buds at the base of shoots and latent buds in the cordon as well as *count* buds in the canes.

Grapes flower later than most tree fruit and are mostly pollinated by wind. Fruit set is influenced by the weather, being greatest under sunny, warm, dry conditions.

Berry growth and development occurs in three stages. Rapid cell division and growth begin in the berries following pollination at Stage I, followed by Stage II of slow berry growth, while rapid shoot and leaf growth occurs. *Veraison*—softening of the berry and development of berry color—signals Stage III, where acid levels decrease and sugars increase until the grapes are mature and harvested.

Frequently during the growing season, a short, weak shoot is produced in the axil of the leaf adjacent to the bud and is known as a *summer lateral.* These lateral shoots can be important sources of photosynthetically active new leaves. However, they often do not mature well enough to survive the winter and are usually removed in dormant pruning.

After the leaves drop in the fall, the term *cane* is applied to the mature, dormant shoot. It is from these canes that next year's fruiting wood is selected at pruning time and from which propagation wood is taken.

The grapevine root system has important functions of moisture and nutrient element absorption as well as anchorage of the vine and production of plant hormones. In addition, the root system serves as the primary storage organ for the carbohydrate and nitrogen reserves required for early spring growth of the vine.

The root system is concentrated in the well-aerated upper 18 to 24 inches of soil but can penetrate deep into soil if not impeded by a hard pan or a high water table. By proper selection of rootstocks, grapevines can be grown in a wide range of soil types.

Grapevines require some kind of structural support for commercial and home production. The trellis or arbor provides support so the vine can be managed efficiently. This support exposes more foliage to sunlight, which increases bearing surface and improves fruit color and quality.

Wire trellises, arbors, or other structures desired for a specific purpose or design may be used. Grapevines must be pruned annually to maintain productivity and fruit quality.

Site Selection

Climate

General climatic conditions in many sections of the Midwest are favorable for growing grapes. Most American and French hybrid grapes can be grown where the frost-free period is from 150 to 180 days. The longest frost-free growing seasons in the region are found along the shores and islands of the Great Lakes and in the southern areas bordering the Ohio River Valley.

Information presented in climatological charts is general, so specific sites that have more or less desirable conditions can be found within any general area. Sites should be evaluated individually, and cultivars should be selected according to the length of the site's growing season and the expected minimum winter temperatures.

If the growing season is too short for a particular cultivar, fruit may not mature completely and may be poor in quality and low in sugar content at harvest. In addition, the vines may not mature properly in the fall, leading to possible winter injury. If the cultivar is not hardy enough to survive the winter, vine performance would be unsatisfactory.

Vineyard disease problems may be related in part to climate, especially humidity and temperature. Diseases such as black rot and downy mildew are more frequent under warmer temperatures and high humidity than in cooler, drier areas. Consequently, disease-control programs may need altering from one climatic region to another, as from northern to southern parts of the region.

Winter Temperatures and Spring Frosts

The Concord cultivar is generally one of the most cold-hardy grapes commercially grown in the Midwestern United States. Other cultivars often are damaged more than Concord in any particular season. Some of the other cultivars commonly produced commercially are significantly less winter hardy than Concord. A relative rating of winter hardiness for the various cultivars is provided in the section on *Cultivar Selection* beginning on page 18.

Vines begin to acclimate or *harden off* to cold temperatures as they go dormant in the fall. Early in the winter months, vines may not have achieved adequate hardiness to withstand temperatures below 0°F. However, by the first week of January, vines have usually achieved maximum winter hardiness and may be able to withstand temperatures as low as -10°F to -30°F, depending on the cultivar. Consequently, the extent of cold damage that may occur is dependent on the time of the year and the level of cold (Figure 5).

In addition, the pre-freeze conditions can also affect the amount of damage that occurs. This is especially true if there are warm periods (*January thaws*) followed by rapid drops in temperature. In many years, it is not the mid-winter cold that is responsible for cold injury but the fluctuating temperatures that occur in late winter.

By late winter, the rest requirement of the vine also has usually been achieved. After the winter rest period is completed, the vine is ready to grow, and only cold temperature keeps it dormant. Any significant warming can cause the vine to deacclimate (lose cold hardiness). If subsequent cold temperatures occur, vines

FIGURE 5. Riesling vine with top killed by -22°F temperature with regrowth from the base.

can be damaged. When injury occurs, it is frequently difficult to determine exactly when or how a vine was damaged unless it is periodically examined throughout the winter.

Once growth starts in the spring and the buds have extended to approximately 2 inches in length, they are susceptible to damage from temperatures below 28°F. Temperature variations caused by mesoclimates within a vineyard usually exist; temperatures usually are lowest near the ground, and they increase with elevation. Therefore, when possible, growers should establish vines on a trellis and grow them at a height of 5-1/2 to 6 feet.

Once primary buds are dead or damaged, various effects will result, depending on the variety (Figure 6). Although secondary buds generally will produce fruit, the crop will be significantly reduced. This subject is discussed further under *Selection of Cultivars, Pruning and Training,* and *Cultural Practices That Aid in Disease and Insect Control.*

FIGURE 6. Bud cross section showing dead primary (dark tissue in the center), but live secondary and tertiary buds on either side.

Topography

Selection of a site with desirable climatological characteristics helps to reduce cultural problems and assure success of the vineyard. The best vineyard sites are those with full sunlight, freedom from frost injury, and good soil drainage.

The most frost-free sites are those higher than the surrounding areas. Cold air drains from higher sites into lower areas. Avoid low areas where cold air may settle, because injury is likely to be greater and yields are likely to be lower where low-temperature injury occurs. Sites south and east of the Great Lakes often provide favorable temperature conditions in both spring and fall. Even in these locations, vineyards on higher elevations are less subject to frost damage than those in low areas.

Generally, sites with steep slopes (15% or more) should be avoided in commercial plantings because of soil erosion and difficulty in operating vineyard equipment. Cool temperatures on northern slopes often delay vine growth enough in the spring to aid in avoiding frost damage. However, these slopes may be subject to harsher winter conditions.

The opposite effect may occur on a southern slope, resulting in earlier spring growth and increased risk of frost injury. A western slope may have the disadvantage of exposure to prevailing winds that, in some areas or seasons, could be strong enough to damage vines and cause special trellising problems. On the other hand, movement of prevailing winds through a vineyard helps dry dew and rain from the foliage and helps reduce disease problems.

Monitoring or mapping of site conditions before planting is very desirable. Any prior knowledge of an area's elevation effects and other conditions may help producers locate their vineyard above certain critical levels and avoid damaging seasonal frosts. Advice from those who have grown fruit trees or vines in a given area can help potential producers find the elevation or location of the thermobelt and thus avoid undesirable areas.

Soils and Water Drainage

Grapes can be grown on a variety of soil types. However, the highest vine vigor and yield and the most efficient production are achieved on soils with good internal drainage. Water drainage means surface removal of water as well as percolation or internal movement of water. With good management, vineyards have produced satisfactorily on soils ranging from gravelly loams to heavy clay and silt clay loams.

Producers should avoid soils that are consistently wet during the growing season (Figure 7). These soils may have an impervious subsoil or other drainage problems. In poorly drained soil, roots may penetrate only 2 feet or less, whereas on a deep, well-drained soil, they will penetrate 6 feet or more. Soils with only fair drainage require more intensive soil management (*e.g.*, tiling), and yields may not be satisfactory (Figure 8).

FIGURE 7. Poor drainage with standing water should be avoided.

Just as cold air should not be allowed to stagnate on a vineyard site, neither should water be allowed to accumulate. The vineyard must be arranged so that no ponding or puddling of water will occur for extended periods following a rain. This is especially crucial during the growing season.

Subsoil characteristics are important when choosing a vineyard site because they often indicate the nature of internal drainage. For example, a bright, uniformly yellowish-brown subsoil indicates good internal drainage. Subsoils showing slight mottling of yellow, gray, and orange indicate only moderate drainage. Poorly drained subsoils are characterized by greater mottling or, in some cases, a uniform dark-gray color.

FIGURE 8. Equipment used to install drain tile between rows in a vineyard with imperfect soil drainage. Photos courtesy of Gene Sigel.

The USDA Natural Resources Conservation Service (NRCS) has mapped most of the soils in the Midwest. Before producers establish a planting, they should contact the local NRCS office to obtain county soil surveys and examine the soil conditions in the proposed vineyard site. Soil maps are helpful in determining soil-drainage characteristics and in evaluating potential sites. However, maps are not substitutes for taking soil borings on the site and making visual evaluations of the subsoil.

Internal water drainage is extremely important, especially for the more cold-tender French hybrid or vinifera grapes. A soil profile, as shown in Figure 9, can allow water to move freely through it. However, many Midwestern soils have *fragipans*, impermeable layers or texture changes that prevent free downward movement of water following rain or irrigation.

Lateral movement of water at a given depth below the surface can result in overly wet conditions, harming the vines. Therefore, even a sloped vineyard can have problems with internal drainage. Operating equipment in wet vineyards in early spring or late fall can also cause compaction and create serious problems.

FIGURE 9. Example of soil profile with adequate drainage.

Producers should note that general soils and topographic maps that give the major soil types and conditions for an area are not sufficient to determine the best location for the vineyard.

Specific sites for small acreage may be found that are considerably more favorable than the general map would indicate. Therefore, potential growers should not be discouraged based upon this general information, but should request detailed topographic and soils maps from their local NRCS office. These maps provide more information on the conditions for a specific site.

If the general topography (elevation, slope, etc.) is favorable but the internal drainage is imperfect, tile drains should be considered. Tile drainage generally improves most sites for the production of grapes and other fruit crops. Producers should carefully examine these conditions before the vineyard is planted.

Although grapevines grow and produce best on fertile, well-drained soils, naturally high fertility is not essential. Through proper fertilizer applications and soil management practices, even low-fertility soils can be improved to grow high yields of quality fruit. Thus, drainage considerations usually are more important than soil fertility when selecting a vineyard site. Improving soil fertility generally is more economical than compensating for poor water and air drainage on the site.

Because erosion is a major concern, most vineyard rows should be planted perpendicular to the predominant slope. Row directions running up and down slopes should be avoided. Contour plantings should also be avoided as they may introduce cultural or management problems and may result in weaker trellising.

Cultivar Selection

Selection of the proper cultivars to plant is a major step toward successful viticulture. Before planting, commercial growers should give serious thought to the market outlet and the requirements of the processor or consumer who will purchase the crop. Cultivars that are in greatest demand or sell for the highest price also are often the most difficult to produce.

Key Factors

Choosing a grape cultivar is based primarily on two major factors—market outlook and viticultural characteristics. Some important considerations are listed here, and these factors should be studied prior to planting. These considerations are listed in the order of importance:

- **Vine Hardiness:** Tolerance to low winter temperatures and/or spring frosts is often the limiting factor in cultivar selection in the Midwest.
- **Fruit Characteristics:** For a new grape cultivar to have real commercial value, it must first produce fruit that results in wine, juice, or eating quality that is superior or equal to the quality of available cultivars.
- **Season of Ripening:** Selected cultivars should be able to ripen their fruit and wood (hardening off) prior to the first killing frost in a given site. Late cultivars, for example, require a long growing season.
- **Tolerance of Diseases and Insects:** Resistance to the most common and destructive diseases and insect pests generally is not available in the present commercial cultivars. New cultivars that exhibit at least limited tolerance to some diseases or insects are highly desirable. Susceptible cultivars require more expensive cultural practices and in many cases should be avoided.
- **Vine Characteristics:** In addition to fruit quality, vine characteristics and productivity also must be superior to those of the cultivar being replaced. It is difficult to obtain a new cultivar with both fruit and vine characteristics superior to one already established, but this is the objective of the grape breeders. If the new cultivar has not been thoroughly evaluated by experiment stations or established with growers in similar climates and soil conditions, a trial planting should precede any extensive commercial planting.

Three basic types of grapes are grown in the Midwest—American, Hybrids, and European. The characteristics of cultivars in each type that have proven adaptability or have shown promise and potential in university and industry tests in the Midwest are presented in the tables on the following pages. Although many factors influence winter hardiness, as previously described, generally the temperature ranges assigned to the hardiness classes are based on maximum cold hardiness in midwinter and are ranked as follows: tender, 0°F to -10°F; slightly hardy, -5°F to -15°F; moderately hardy, -10°F to -20°F; hardy, -15°F to -25°F; and very hardy, -25°F to -35°F.

American Cultivars

The American type (*e.g., Vitis labrusca, Vitis aestivalis, Vitis riparia*) has the widest distribution throughout the northern half of the United States. Major producing areas include the Great Lakes region, the Pacific Northwest, the Midwest, and eastern states from Delaware to New England.

Examples of important cultivars include Concord, Catawba, Delaware, Niagara, and Norton. Most American-type grapes are *slip-skinned*—that is, the flesh separates readily from the skin. Generally, they are processed into juices, jams, jellies, wine, or sherry. Well-managed vineyards have high yields of six to 12 tons per acre. American-type cultivars are generally hardy and widely adapted in the Midwest. (See Figure 10 and Table 1.)

Figure 10. Norton (Cynthiana) is an American-type cultivar widely grown in the lower Midwest.

Table 1. American Cultivars for the Midwest.

Cultivar	Color	Average Cluster Wt. (lbs)	Winter Hardi-ness*	Days from Bloom to Harvest**	Ripening Date	Remarks
Concord	Blue	0.30	Hardy	115	Late	Standard of juice quality and most commonly grown backyard grape.
Van Buren	Blue	0.30	Hardy	80	Early	Vigorous Concord type.
Buffalo	Blue	0.31	Hardy	85	Early-Midseason	Concord type; distinct flavor; table use.
Fredonia	Blue	0.28	Hardy	95	Midseason	Earlier Concord type; vigorous.
Alden	Blue	0.48	Moderately Hardy	100	Midseason	Adherent skin; productive; muscat flavor; mostly table use.
Steuben	Red	0.32	Hardy	100	Midseason	Spicy flavor; non-uniform color.
Catawba	Red	0.26	Hardy	120	Late	Used for wine and sherry.
Delaware	Red	0.16	Hardy	100	Midseason	Used for wine; stores well.
Niagara	White	0.35	Hardy	110	Late Midseason	Used for wine and white juice.
Norton (Cynthiana)	Blue	0.16	Hardy	125	Very late	Used exclusively for wine; long season; only adapted to long frost-free sites (180+ days). While classified as an American-type, Norton is a selection of *V. aestivalis* and lacks the foxy flavor associated with *V. labruscana* cultivars.

* Winter hardiness rating: tender, 0°F to -10°F; slightly hardy, -5°F to -15°F; moderately hardy, -10°F to -20°F; hardy, -15°F to -25°F; and very hardy, -20°F to -35°F.

** Bloom occurs four to six weeks after bud break.

Table Grape Cultivars

Vinifera table grape cultivars, such as Thompson Seedless or Flame Seedless, do not have sufficient cold hardiness to be grown in the Midwest. Although Concord and many other seeded grapes such as Buffalo, Alden, Steuben, Seneca, Golden Muscat, Edelweiss, Swenson Red, Yates, and others are grown and consumed fresh, berries without seeds are most in demand for table use, and these will be listed separately (Table 2) due to their uniqueness. (See Figure 11.)

Since fruit appearance and berry size greatly influence marketability, special cultural practices, such as application of gibberellic acid sprays, girdling, and thinning, must be used to produce table grapes commercially. Each cultivar demands a special mix of these practices for optimum marketability.

A recent publication—*Growing Table Grapes in a Temperate Climate*, Michigan State University Extension Bulletin E2774—describes the cultural practices and special management needed to successfully produce table grapes in the Midwest.

Table 2. Seedless Table Grape Cultivars for the Midwest.

Cultivar	Color	Average Cluster Wt. (lbs)	Winter Hardiness*	Days from Bloom to Harvest**	Ripening Date	Remarks
Canadice	Red	0.28	Moderately Hardy	75	Very Early	Productive; good clusters.
Einset	Red	0.20	Hardy	75	Very Early	Slip skin; mild strawberry flavor; may shatter.
Himrod	White	0.22	Moderately Hardy	75	Very Early	High quality; straggly clusters.
Marquis	White	0.50	Hardy	105	Midseason	Highly productive; high quality; loose clusters; resists cracking; susceptible to downy mildew in wet years.
Mars	Blue	0.29	Hardy	80	Early	High productivity; medium clusters; disease resistant.
Reliance	Red	0.33	Hardy	90	Early Midseason	High quality; productive; uneven color; susceptible to berry cracking.
Vanessa	Red	0.24	Hardy	105	Midseason	Adherent skin; compact clusters; firm, crisp flesh; requires girdling for berry sizing.
Lakemont	White	0.50	Moderately Hardy	80	Early	Adherent skin; firm flesh.
Jupiter	Blue	0.29	Moderately Hardy	85	Early	Muscat flavor; oval berries; large, 4.3 g; very susceptible to downy mildew.
Neptune	White	0.53	Moderately Hardy	97	Midseason	Compact clusters; low vigor; adherent and thick skin; oval berry, 3.2 g.
Suffolk Red	Red	0.24	Moderately Hardy	90	Midseason	Loose clusters; good flavor.

* Winter hardiness rating: tender, 0°F to -10°F; slightly hardy, -5°F to -15°F; moderately hardy, -10°F to -20°F; hardy, -15°F to -25°F; and very hardy, -20°F to -35°F.

** Bloom occurs four to six weeks after bud break.

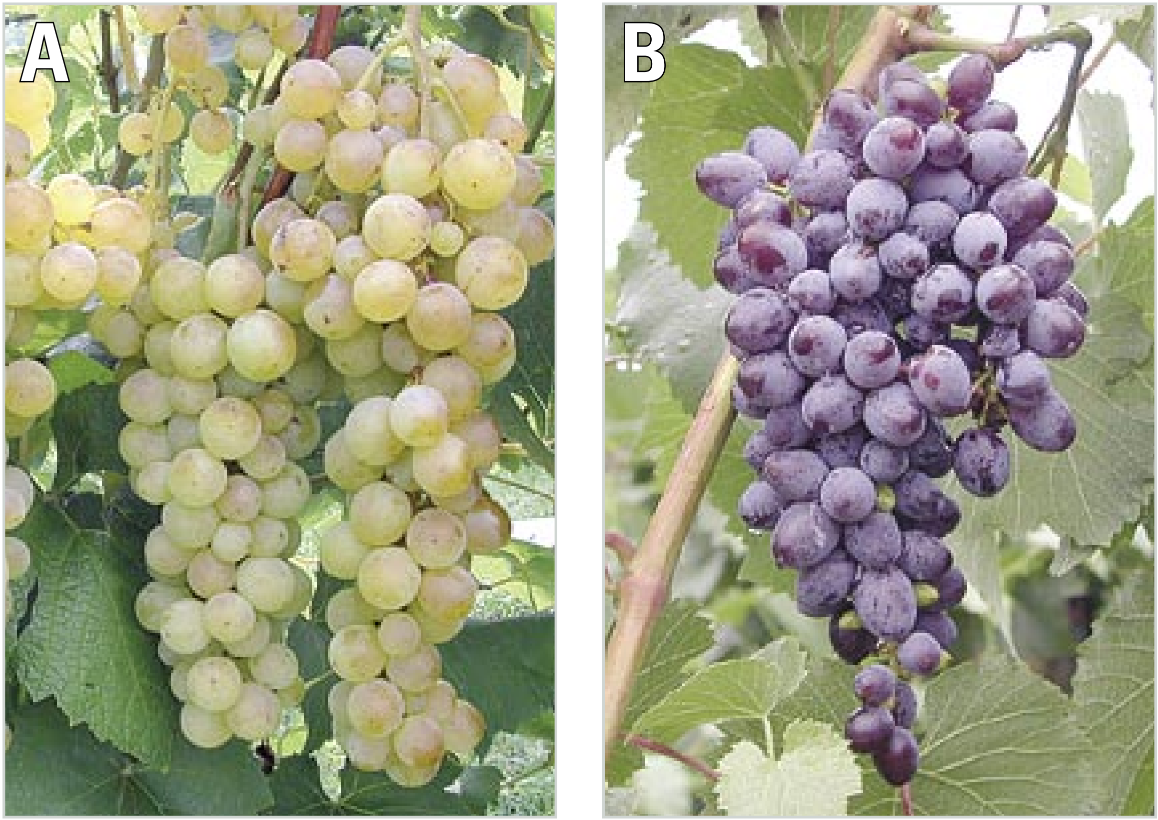

Figure 11. Marquis (A) and Jupiter (B) are new promising high-quality seedless table grape cultivars.

Hybrid Cultivars

The French-American hybrids have been widely planted in the Midwest since the mid-1940s. This group includes new cultivars or interspecific hybrids produced by crossing European or Vinifera grapes with one of the American species. Many were introduced from French breeding programs, and the cultivar name often includes the name of the breeder —for example, Vidal (Vidal 256).

In addition to the hybrids developed in France, many newer hybrids have been developed by breeders in the United States. These new cultivars are being widely planted in the Midwest. Hybrids are generally used in wine production and possess more winter hardiness and disease resistance than most of the *V. vinifera* parents. The most widely planted hybrids have a wine flavor close to European grapes. (See Figure 12 and Table 3.)

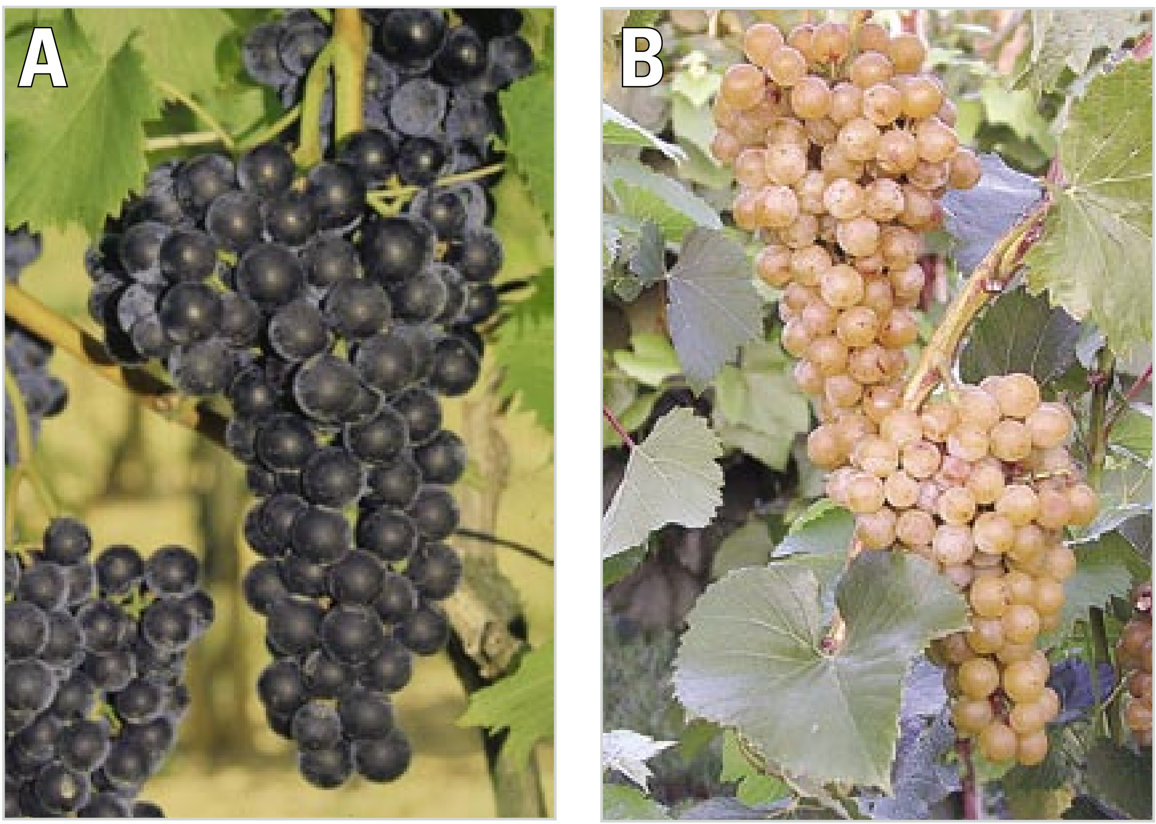

Figure 12. Chambourcin (A) and Traminette (B) are grown successfully in the Midwest.

Table 3. French-American Hybrid Cultivars for the Midwest.

Cultivar	Color	Average Cluster Wt. (lbs)	Winter Hardiness*	Days from Bloom to Harvest**	Ripening Date	Remarks
Cayuga White	White	0.33	Moderately Hardy	100	Midseason	Fully ripened produces labrusca character; susceptible to anthracnose.
Chambourcin	Blue	0.42	Moderately Hardy	115	Late	Moderate vigor; large clusters; needs thinning; high-quality wine.
Chancellor	Blue	0.25	Hardy	100	Early Midseason	Thinning necessary; good vigor; fruit susceptible to downy mildew; susceptible to crown gall in low wet sites.
Chardonel	White	0.36	Moderately Hardy	110	Late Midseason	Requires no thinning; loose clusters; less susceptible to bunch rot than Seyval; more cold hardy than Chardonnay but less than Seyval.
DeChaunac	Blue	0.24	Hardy	105	Midseason	Moderate red wine quality; good vigor and productivity; requires thinning.
Frontenac (MN 1047)	Blue	0.27	Very Hardy	100	Late Midseason	Productive; loose clusters; requires thinning; high acid, requires malolactic fermentation; very resistant to downy mildew; bird predation a problem.
GR-7	Red	0.31	Hardy	100	Midseason	Productive; moderately susceptible to downy and powdery mildew and botrytis.
LaCrescent (MN 1166)	White	0.24	Very Hardy	105	Late Midseason	Loose clusters; small berries, 1.5 g; susceptible to downy mildew; fruity wine.
LaCrosse	White	0.25	Very Hardy	104	Late Midseason	Fruity wine; hardier than Seyval; moderate vigor and productivity.
Leon Millot	Blue	0.18	Very Hardy	85	Early	Small, loose clusters; small berries; bird predation a problem.
Marechal Foch	Blue	0.20	Very Hardy	90	Early	Small, tight clusters; low vigor; bird predation a problem.
St. Croix	Blue	0.24	Very Hardy	99	Early Midseason	Vigorous; cluster thinning required; wines lack tannin; low productivity.
Seyval blanc	White	0.43	Hardy	100	Early Midseason	Moderate vigor; requires thinning; clusters susceptible to bunch rot.
Traminette	White	0.24	Moderately Hardy	110	Late Midseason	Vigorous; hardier than Gewurztraminer but similar wine.
Vidal blanc	White	0.34	Moderately Hardy	110	Late Midseason	Good vigor; late budbreak; requires thinning; loose clusters; adaptable to many wine styles, including ice wine; best if grafted for virus protection.
Vignoles	White	0.17	Hardy	105	Midseason	Small tight clusters; moderate yields and vigor; very susceptible to bunch rot; high-quality wine.

* Winter hardiness rating: tender, 0°F to -10°F; slightly hardy, -5°F to -15°F; moderately hardy, -10°F to -20°F; hardy, -15°F to -25°F; and very hardy, -20°F to -35°F.

** Bloom occurs four to six weeks after bud break.

European Cultivars

European-type (*Vitis vinifera*) cultivars are most widely produced in warmer regions of the world such as California, Mediterranean countries *(e.g.,* France, Italy, Spain, North Africa), and Australia. Examples of widely grown vinifera cultivars are Thompson Seedless, Riesling, Chardonnay, Cabernet Sauvignon, Cabernet franc, and Merlot. (See Figure 13.)

Although cultivars vary slightly, fruit buds of most vinifera are injured at temperatures of -10°F, and vines are often killed if the temperature reaches -15°F or lower. Since the Midwest experiences these temperatures during many winters, *V. vinifera* should be grown only on the very best sites, and special cultural practices should be used to lessen vine injury. Even if special practices are used and all precautions are taken, vine injury and death can occur during exceptionally cold winters. (For example, in February 1994, temperatures dropped to between -20°F and -30°F over much of the Midwest.)

A description of several vinifera cultivars grown on the best sites in the Midwest is presented in Table 4.

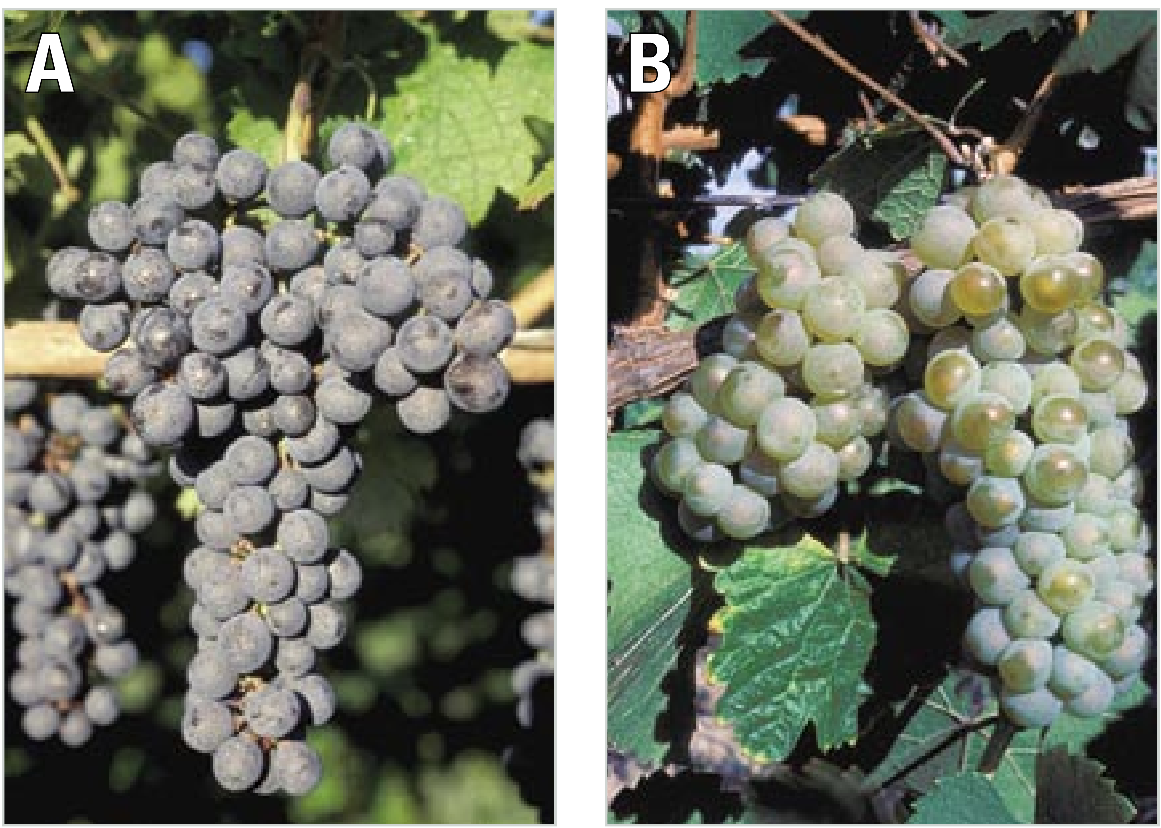

FIGURE 13. Vinifera cultivars such as Cabernet franc (A) and Riesling (B) are grown successfully only in the best sites in the Midwest or in proximity to the Great Lakes. (Photos courtesy of Dr. Tom Zabadal.)

Table 4. Vinifera Cultivars Grown on the Best Sites in the Midwest.

Cultivar	Color	Average Cluster Wt. (lbs)	Winter Hardiness*	Days from Bloom to Harvest**	Ripening Date	Remarks
Cabernet franc	Blue	0.23	Slightly Hardy	115	Late	Loose clusters; vigorous; easily over cropped.
Cabernet Sauvignon	Blue	0.18	Tender	120	Very Late	Needs a very long season; less hardy than Cabernet franc.
Chardonnay	White	0.23	Tender	110	Late Midseason	Susceptible to all diseases and cluster rot; must have good control program; breaks bud early.
Lemberger	Blue	0.30	Slightly Hardy	110	Late Midseason	Large clusters; medium-sized berries; productive; vigorous.
Pinot gris	Pink Gray	0.22	Tender	105	Midseason	Tight clusters of small berries; variable color development; moderate vigor.
Pinot noir	Blue	0.16	Tender	110	Late Midseason	Small clusters; clones vary greatly in cluster architecture and characteristics; crop must be controlled to produce quality wine.
White Riesling	White	0.18	Slightly Hardy	110	Late	Must avoid over cropping; susceptible to cluster rots at harvest; high-quality wine.

* Winter hardiness rating: tender, 0°F to -10°F; slightly hardy, -5°F to -15°F; moderately hardy, -10°F to -20°F; hardy, -15°F to -25°F; and very hardy, -20°F to -35°F.

** Bloom occurs four to six weeks after bud break.

Data shown here came from trials by Lake Erie in Ohio. Growers should consult with viticulture specialists about the best sites for vinifera in their states.

Special Cultural Practices Necessary for Vinifera Cultivars

1. **Rootstocks:** Vinifera cultivars are all susceptible to grape phylloxera (root form), which is endemic on wild grapes in the Midwest. Phylloxera feeds on the roots, weakening the vines, reducing yield and berry quality, and rendering the vine more susceptible to winter injury. Rootstocks resistant to phylloxera must be used and the selection based on the cultivar's vigor and soil conditions. (See Table 5.)

2. **Protection of Graft Union:** Hilling or mounding soil over the graft union and several inches up the trunk each fall can help protect the graft union even if cold injury or death occurs in the top of the vine (Figure 14). A new trunk can be initiated from this protected area, and production is lost for only one year.

Recent work in Michigan demonstrated that a heavy application of straw was nearly as effective as soil. The soil or mulch must be removed in the spring to avoid rooting of the scion and losing the phylloxera resistance and growth influence of the rootstock. Un-hilled vines in areas with no snow cover were killed in 1994, while hilled vines survived to produce a new trunk.

Table 5. Rootstocks Commonly Used in the Midwest.

Rootstock	Species	Relative Scion Vigor	Phylloxera Resistance	Nematode Resistance	Drought Resistance	Lime Resistance	Soil Adaptability Wet	Soil Adaptability Clay
Riparia Gloire	*V. riparia*	2	5	2	1	6%	4	1
Rupestris St. George	*V. rupestris*	4	4	2	3	15%	2	2
5BB	*V. riparia* x *V. berlandieri*	4	4	3	2	20%	4	2
SO4	*V. riparia* x *V. berlandieri*	4	4	4	2	17%	4	2
5C	*V. riparia* x *V. berlandieri*	3	4	4	2	17%	4	3
3309 C	*V. riparia* x *V. rupestris*	3	4	1	2	11%	4	2
101-14	*V. riparia* x *V. rupestris*	2	4	2	1	9%	4	2
1616 E	*V. riparia* x *Solaris*	2	3	1	1	11%	2	1

Information adapted from Galet, 1979; Howell, 1987; Pongracz, 1983. Scale: 5 = best or highest to 1 = worst or lowest.

FIGURE 14. Hilling-up of European grape cultivars is a common practice in the Midwest. Hydraulic grape hoe (A) during hilling in the fall; hilled-up vines (B) protect graft unions and trunks from cold injury during winter.

3. **Crop Management:** Many vinifera cultivars have the potential to crop heavily and if crop load is not controlled, the vine carbohydrate reserves are not restored. Vines with inadequate reserves of carbohydrates stored in the canes, cordons, trunk, and roots are more susceptible to injury from cold and will be injured at milder temperatures than vines with adequate carbohydrate reserves. Vines carrying an excessive crop also are delayed in hardening off in the fall.

4. **Leaf Quality:** Most vinifera are susceptible to disease such as mildews that reduce leaf photosynthesis and impair carbohydrate production. Thus, a more thorough spray program should be used to prevent leaf diseases.

5. **Multiple Trunks:** Since winter injury is probable, it is advisable to have multiple trunks (two to four) of different ages for vinifera. Often one trunk will be injured and develop crown gall, while another may escape (Figure 15).

FIGURE 15. Having multiple trunks is beneficial should winter injury occur. One trunk has been injured and has developed crown gall at the base, while the other trunk is still alive.

Grapevine Propagation

In most instances, grape growers should purchase planting stock from nurseries or commercial propagators. Occasionally, however, it is necessary or desirable for growers to produce their own vines. For instance, it might be desirable to increase a new cultivar before a supply of plants is commercially available or to produce replacements for missing vines in an established vineyard. Growers should be aware that many new cultivars are patented, and propagation may be restricted.

Cultivars of grapes, like many other fruits, can be reproduced or propagated asexually. Grapes do not grow true from seed; that is, the seedlings will not be genetically identical to the cultivar that produced the seeds. Most grapevines are reproduced by hardwood cuttings or by layering of canes. These methods of asexual propagation ensure that the plants are genetically identical to their parents. In some instances, scions of healthy cultivars are grafted upon specific rootstocks. Cuttings or scions should always be taken from vines known to be true to name. Methods of asexual propagation are described in the following sections.

Field (Nursery) Propagation

The most common way to propagate grapes is by hardwood cuttings. Almost all commercially grown cultivars are easy to propagate from cuttings. Cuttings should be made from well-matured dormant canes of the preceding year's growth. The preferred cane size is 1/4 inch to 3/8 inch in diameter with 4- to 6-inch internodes.

Cuttings usually are made in late fall or early winter. Each cutting should contain three to four buds, although two-bud cuttings are satisfactory in mist or greenhouse propagation. Make the basal cut just below the lower bud, and the upper cut 1 to 2 inches above the top bud. Make cuts so that the upper and lower ends of the cutting can be easily identified.

The cuttings may be sorted into uniform lengths and bundled for convenience in handling. Place the cuttings in cold storage (32°F to 35°F). Cuttings can also be stored by burying them in a well-drained trench and covering them with up to 3 inches of soil until spring. Buried cuttings should be mulched with 8 to 12 inches of straw for protection against severe cold.

As soon as the soil can be worked in spring, remove cuttings from storage or the trench and plant them in nursery rows (Figure 16). The rows should be located on deep, well-drained, fertile soil that is in a good state of tilth. Space rows 3 to 4 feet apart and make a furrow 6 to 7 inches deep. Set cuttings vertically in the furrow about 5 inches apart and firm soil with the top bud just above the soil surface.

It is critical that the cuttings are set in the same direction that they were growing so that the basal end of the cutting is down and the distal end is up. The polarity must be maintained for the cuttings to root. Cuttings also can be planted through black plastic mulch to help control weeds and to retain heat and moisture.

As the season advances, shoots will develop from the above-ground bud, and roots will develop from the nodal regions below ground. Vines should be maintained in the nursery row in a high state of vigor during the growing season. Control of diseases, insects, and weeds in the nursery row is critical. Regular watering and application of fertilizer will ensure adequate growth. New vines will be ready for planting in the vineyard early the next spring. To compensate for cuttings that do not survive, start about twice as many cuttings as vines required.

FIGURE 16. Grapevine propagation in the field (nursery).

Greenhouse Propagation

To produce new vines for spring planting during the same year, hardwood cuttings can be rooted during late winter under a mist system in the greenhouse (Figure 17). This method saves one year in the propagation of new vines over conventional outdoor rooting methods.

For greenhouse propagation, take cuttings from healthy vines of the desired cultivars in early December before any major winter damage has occurred to the wood or buds. Make two- to four-node cuttings as described in the previous section, then tie the cuttings in bundles, wrap in damp burlap or place in polyethylene bags, and store at 32°F to 33°F.

In early February, cuttings are removed from storage and inserted into a suitable rooting medium in the greenhouse (Figure 17). Vermiculite or peat/perlite is excellent for rooting because of their freedom from weed seeds and diseases. Sand or mixtures of sand and peat are also satisfactory.

Before insertion into rooting media, the lower ends of the cuttings can be dipped in a commercial rooting hormone such as indole-butyric acid. However, rooting hormones are generally not needed. A flat or greenhouse bench should be filled with media to a depth of 6 to 8 inches. Cuttings are planted so that the lower cut and node are pushed down to near the bottom of the flat or bed with the upper bud extended just above the media surface.

FIGURE 17. Grapevine propagation in a greenhouse mist bench.

Space cuttings 1 to 2 inches apart in rows 2 to 3 inches apart.

As soon as the cuttings are in place, mist them intermittently to maintain a high and constant relative humidity during the rooting period. A mist system that operates automatically for approximately 6 seconds every 6 to 10 minutes during the day is satisfactory. The duration and frequency of the mist may need to be adjusted as the cuttings begin to grow shoots and to account for sunny or cloudy conditions. The mist can be turned off at night.

Bottom heat provided by heating cable under the flats or in the bottom of a bench hastens rooting. Rooting is most satisfactory if day temperatures in the greenhouse are maintained between 65°F and 70°F and night temperatures around 60°F.

Usually, the cuttings develop roots and leaves within four to six weeks (Figure 18). At this time, the rooted cuttings can be transplanted into one- to two-gallon pots for easy transplanting to the field later. A suitable mixture for filling the pots is 1/3 peat, 1/3 sand, and 1/3 soil. Another alternative is a premixed commercial potting soil. Steam sterilization of the soil mixture before filling the pots prevents weed growth and diseases.

After the rooted cuttings have been potted, place them back under the mist for a few days to allow the roots to become established in the new medium. Once established, the plants should be moved to a conventional area in the greenhouse. Moderate temperatures of 70°F to 75°F encourage growth of new vines.

The vines must be watered regularly and receive weekly applications of a dilute fertilizer solution to maintain growth. The fertilizer solution should contain nitrogen, phosphorus, and potassium. Minor elements are also desirable, depending on the potting mix used. Slow-release fertilizer mixes are also available and can be incorporated into the soil before transplanting.

FIGURE 18. Potted grapevine progagated from hardwood cutting in the greenhouse.

Plants are ready for setting in the vineyard when new shoots are about 12 inches long. If plant growth becomes excessive in the greenhouse, lower temperatures must be used to slow growth and harden the vines before they are taken to the field. During the hardening-off period, maintain night temperatures at 40°F to 45°F and day temperatures at 65°F to 70°F. Regardless of the state of growth, new vines should not be transplanted until all hazard of frost is past. Greenhouse-grown plants are extremely sensitive to frost.

The entire process also can be carried out in individual pots or elongated rooting containers by using peat and perlite or a commercial potting mix and placing the cuttings directly in the containers under mist as described earlier.

Regularly inspect cuttings in the greenhouse for insects and diseases. Whiteflies and powdery mildew can be troublesome pests. To eliminate these pests, use an appropriate pesticide according to label directions.

Layering

All grape cultivars can be propagated by layering. This method is used primarily for replacing missing vines in established vineyards. However, it is too cumbersome for production of large numbers of plants.

Layering is done in late winter or early spring. Vigorous one-year-old canes are used. The canes remain attached to the mother plant. This supports the establishment of a well-rooted plant during the first season. Lay the canes in a shallow trench dug in the desired location of the new vine. Place a two- to three-node section of the cane at the bottom of the trench. At least two distal buds should extend above the soil surface. Cover the part of the cane in the trench with 3 or 4 inches of soil and tamp firmly.

Roots normally develop from the covered nodes in a few weeks. Leaves and new shoots will develop from exposed terminal buds. During the growing season, any shoots developing between the layered area of the cane and the mother vine should be removed.

New plants produced in a vacancy in the vineyard are left in place, and the connecting cane is cut off the following spring after the new vine is well established. If the layered vine is to be moved, it should be dug and transplanted after one year's growth.

Grafting

Grafting allows growers to propagate grape cultivars on a special rootstock, such as one resistant to certain root parasites. The European (vinifera) grape, for example, is highly susceptible to a destructive insect pest known as grape phylloxera or root louse. Consequently, cultivars of this species cannot be grown on their own root systems in phylloxera-infested soils. Therefore, it is necessary to graft European cultivars on phylloxera-resistant rootstocks to grow them successfully on many U.S. soils and those in other parts of the world. Experience indicates that rootstocks with high phylloxera resistance are also resistant to certain parasitic nematodes.

The use of resistant rootstocks for European cultivars is more important than for American and French hybrid grapes, with some exceptions. Therefore, most U.S. vineyards have been established with own-rooted vines, especially Concord. The root systems of these cultivars apparently carry considerable tolerance to phylloxera and other soil-borne parasites. However, differences in tolerance have been found in some American grape cultivars. Delaware, for example, has performed better on tolerant rootstocks than on its own roots.

Where vigor of own-rooted vines is characteristically low, favorable results can be expected from using resistant rootstocks. Poor vine vigor and productivity often occur on sites where old vines were removed and the vineyard replanted. In replant situations such as this, resistant rootstocks may prove a distinct advantage with American cultivars or with French hybrids.

Among the rootstocks carrying high resistance to phylloxera, nematodes, and possibly other soil-borne parasites are Couderc 3309, 5BB, and SO4. These rootstocks are conventionally propagated by cuttings or layering. Once rooted, the stocks can be used for grafting to any desired cultivar.

Bench grafting is commonly used in propagating grape cultivars (especially vinifera) on special rootstocks. This operation is conducted indoors and involves grafting of single bud scions onto rootstock cuttings (Figure 19). Grafting is done in early spring before growth

FIGURE 19. Bench grafting: Grafting machine with grafted and waxed cuttings. Insert: Omega cut graft. Scion (left); disbudded rootstock (right).

starts. Once callusing is complete, the grafted cuttings are planted into the nursery.

Although top-working is not a common mode of propagation, it is possible to change over a grapevine or vineyard to another cultivar by using chip, cleft, or whip grafting techniques (Figure 20). Dormant scions must be used in all instances. Such grafting is most successful in midsummer. However, American cultivars are among the hardest to top-work.

FIGURE 20. Side whip grafting technique.

Vineyard Establishment

Site Preparation

Preparation of the proposed vineyard site is important and should begin the year before planting. A soil test should be conducted the season before planting to provide information on soil pH status, liming, and fertilizer requirements.

If soil pH is below 5.5, apply agricultural ground limestone to raise the pH to a more desirable level (5.5 to 6.8). The application should be made well before planting time and the limestone incorporated into the soil. For highly acidic subsoils, deep-plowing with limestone is recommended.

Soil testing also will provide information on soil fertility and fertilizer needs for the first-year vineyard. Animal manures, when available, may be applied in the fall before spring planting of the vines. A suitable application is 10 to 12 tons of horse or cow manure per acre or 50 to 75 pounds per 100 square feet.

Site preparation in the year prior to planting should include land leveling, drainage tile installation (when needed), and fertility adjustments based on a soil test (Figure 21).

At this time, growers also must pay special attention to controlling persistent weed pests such as thistle, Johnsongrass, quackgrass, dock, or woody species such as brambles.

Several safe and effective herbicides are available to control such troublesome weeds in the preparation period, but they cannot be used after the vines are planted. If possible, avoid sites that are severely infested with such weeds until the weeds have been eradicated. If the available site has internal drainage problems or areas where water will pond, install drainage tile and waterways before planting (see the section on *Soils and Soil Drainage*).

If the area to be planted is in sod and free of weeds, at least two options are open to the grower, depending on the topography of the site. If the proposed vineyard is on a hillside or sloping ground and erosion is a consideration, an approved systemic herbicide can be applied in the fall while the vegetation is actively growing. Herbicide is applied to the row area where the vines are to be established. The row middles will remain in sod. In fall or early spring, these row areas are tilled so the sod mat or ground cover is destroyed and a friable planting soil is established.

Figure 21. Site preparation in the fall prior to planting in the following year. (A) Site subsoiled, plowed, and leveled. (B) Perennial grass established as permanent cover crop.

If the proposed vineyard site is located on relatively level or gently sloping ground so that erosion is not a serious consideration, or if it is necessary to apply lime, the site should be plowed in the fall to incorporate the lime and seeded to a suitable winter cover crop. One week before plowing, apply a systemic herbicide to kill spreading roots and rhizomes of perennial weeds (see the section on *Weeds and Weed Control*).

Most grasses establish better if sown between mid-August and mid-September, rather than during the spring. An application of 35 pounds of actual nitrogen per acre at the time grass is sown will stimulate growth. Ordinary perennial ryegrass at 80 to 120 pounds per acre, Kentucky bluegrass at 20 pounds per acre, or a mixture of ryegrass and fescue, such as Companion grass at 20 pounds per acre, have proved to be adequate ground covers for vineyard row middles.

If ample time is available, the best results are achieved by applying lime and fertilizer, plowing, and growing a cultivated crop on the site the season before planting the vines. However, you must be certain that the herbicide used will not carry over and affect the grapes the following year. When the crop is removed, drill the grass cover crop in the row middles.

Final site preparation should be made as early in the spring as the soil can be worked, preferably in late March or early April. After plowing or tilling, apply and disk (or till) the required fertilizer into the soil before setting the vines.

Even though early spring preparation is advisable, it should not be done until the soil is dry enough to work properly. If soil is worked too wet, the advantages of early preparation will be lost because soil structure may be damaged. The effects of a *puddled* soil, particularly one with high clay content, may result in poor vine growth for a number of years.

Vineyard Design

The vineyard should be designed to achieve the following goals:

- Prevent soil erosion—the most important goal.
- Use land area efficiently.
- Optimize vine performance.
- Facilitate management and equipment operation.

Vineyard rows need to be straight for trellis strength. On sloping land, rows should be across or perpendicular to the slope. It may be necessary to divide the vineyard into blocks to accommodate depressions or other characteristics. If erosion control can be accommodated, it is preferable to orient rows north-south. This orientation provides the most even distribution of light in the canopy and has been associated with improved yields and berry quality.

Row spacing depends in part on the proposed training and trellising system and the equipment to be used in the vineyard, such as a mechanical harvester. Nine- to 10-foot spacings between rows are common and generally ample, but 11 or even 12 feet between rows may be needed to accommodate divided training systems (*e.g.*, Geneva Double Curtain), large equipment, or steep slopes. An 8-foot spacing between rows is satisfactory for small plantings, but this is considered too restrictive for most commercial operations. In general, as distance between rows increases, yield per acre decreases.

Spacing vines in the row at 8-foot intervals has proved satisfactory for average conditions. However, closer spacings have produced higher yields under certain conditions. Cultivars that produce less vigorous growth, such as Delaware, some French hybrids (Seyval and Chambourcin), and some vinifera, may be set closer together than Concord or others of similar vigor. Highest yields generally have been obtained from vineyards containing 600 or more vines per acre.

To create conventional, straight rows, establish a baseline along the edge of the field. Drive a stake at each end of the proposed line. Generally, these stakes are located by measuring a desired distance in from the edge of the field to allow turning space for equipment. By sighting from one stake to the other, additional stakes are placed on the baseline to mark it. A careful tractor operator can plow a furrow along the baseline, which also serves as the first row of grapes.

There are several ways to establish rows parallel to the baseline or first row. A simple way is to establish a perpendicular line at each end of the row. First, set a stake on the baseline 30 feet from the end. Then, place a stake 40 feet from the end of the baseline on the assumed perpendicular line.

Measure the angular distance between the 30- and 40-foot stakes. If the distance is 50 feet, the assumed line is correct and can be extended by sighting. If it is not, move the 40-foot marker—not the 30-foot marker—until there is 50 feet between the two stakes. Stakes can be driven on this second base at the proper intervals to indicate the row ends.

The procedure used to mark the baseline is repeated until the required number of rows has been marked. A pole the length of the desired interval between vines can be used to space vines in the row as they are planted. However, a planting chain with lead markers at designated intervals is much more accurate.

It is important to leave enough space at the end of rows for machinery to turn. A 25- to 30-foot headland at each end of the vineyard should be adequate. It also is important to leave sufficient space on the sides of the vineyard to allow easy movement of equipment. If rows are long, 20- to 25-foot-wide crossing alleys at about 500-foot intervals will ease vineyard management.

Polyethylene Mulch Application

Black polyethylene mulch has been used successfully in establishing new vineyards. However, the introduction and the availability of approved pre-emergence herbicides and the increased cost of plastic have reduced its use. Its popularity may return if herbicides are withdrawn or become unavailable to growers.

The planting procedure begins with thorough tillage of the row areas. One week before tillage, or earlier, apply a systemic herbicide to kill spreading roots and rhizomes of perennial weeds. A rotary-type tiller is recommended for soil preparation. Fertilizer and/or lime can be incorporated into the soil during tillage, as recommended by soil test results.

When the row is properly prepared and the fertilizer thoroughly tilled in, roll black plastic over the row, pull it tight, and hold the edges down with a small ridge of soil. Laying the plastic mulch is easy with modern equipment and requires little or no hand labor. In small plantings, lay the plastic by hand in a similar manner. Ordinary black plastic, 3- to 4-feet wide and 1.5 millimeters thick, is satisfactory.

After the mulch is in place, mark off the plant spacings and set vines through the plastic. Plastic should be laid down well ahead of the planting. It is advisable to lay plastic when soil moisture conditions are near ideal because the soil dries slowly beneath the plastic. As soon as mulch is laid on some of the rows, planting can proceed as rapidly as possible, even on days when mulch laying or tilling is not advisable.

Vine Preparation and Planting

Handle young vines carefully to prevent drying out or other damage after they have been dug or received from the nursery. If dormant vines are not planted immediately, place them in cold storage (32°F with high relative humidity) until planting time.

If proper facilities are not available, carefully *heel-in* vines in a sheltered location. To heel-in plants, dig a shallow trench and place vines in the trench so the tops are exposed. Cover the roots with soil and firm the soil. If the soil is not moist enough, water newly set vines to prevent the roots from drying out.

Vines should be transplanted to their permanent location as soon as possible. Soaking dormant vine roots in water two to three hours before planting also will increase their chance of survival.

Early spring is the most suitable time for planting grapevines in the Midwest. Fall planting generally is not recommended because fall-set plants are likely to be lost to heaving during the first winter. If plants must be set in the fall, plow a 4- to 6-inch mound of soil around the base of the young vines, or mulch them with straw to protect against heaving and severe cold.

Do not prune roots except to remove broken or dead portions. Plant as much of the root as possible, ensuring good distribution in the trench or hole. Most of the reserves of the vine are stored in the roots and to ensure maximum growth, plant as much of the root system as possible. Normally vines purchased from a commercial nursery have been pruned, but if not, they should be pruned to a single cane.

It is critical to keep vine roots moist during planting and transporting to the field. Grafted grapevines should be set in the hole with the graft union several inches above the soil line and soil firmed around the roots. After soil settling, the graft union should be 2 to 3 inches above the soil line. Setting too deep will result in scion rooting and loss of phylloxera resistance of the rootstock. Non-grafted vines should be set with the junction of the older wood and new canes at the soil line.

To plant, plow a straight furrow 10 to 12 inches deep for the row. This depth will accommodate a large root system without packing a mass of roots into a small hole. Spread roots well, cover with a few inches of topsoil, and tamp firmly. A plow or disk may be used to finish filling the furrow. A short, 9- to 12-inch diameter, tractor-powered posthole auger also can be used for planting. In small plantings, the entire operation can be done by hand. In large operations, a commercial vine-planting machine often is used. (See Figure 22.)

FIGURE 22. A tree planter is best used in large planting operations.

When planting is completed, the node from which the lowest cane will arise should be at or just above the soil level. Prune the single cane remaining after planting so that only two or three live buds remain. Some growers prefer to leave five or six buds. As these shoots develop, all but two of the most vigorous are removed when about one-inch long. This pruning provides two shoots to develop into vigorous new canes. (See the *Pruning and Training* section on handling young vines and the use of grow tubes.)

If polyethylene mulch is used, a common planting procedure is to force the long, narrow blade of a tilling spade through the plastic into the soil to a depth of 10 to 12 inches. The opening is widened by a back-and-forth motion, leaving an open hole. Insert the dormant vine and tamp soil firmly around the new plant. When vines are grown in pots or similar containers, an ordinary hand-type posthole digger is useful. After planting, pull the plastic closed around vines and place a small amount of soil on the surface.

Trellis Construction

Constructing the trellis can be the greatest cash expense in vineyard establishment, and it must be strong enough to carry heavy fruit loads and withstand strong winds. The trellis must be durable, and its real cost is determined by years of service, rather than initial cost. The physiological function of the trellis is to expose foliage and fruit to sunlight, and generally, the higher the trellis, the more foliage will be exposed and the more productive the vineyard. The best time to construct a trellis is during the first growing season or the following spring before growth begins. Waiting beyond this time will result in delayed harvest of profitable crops.

End posts should be large (4-1/2- to 6-inches diameter) and longer than line posts (9 to 10 feet instead of 8 feet) because they must serve as anchor points as well as wire supports. Copper-salts-treated pine, locust, and other suitable posts are commonly used. Posts should be pressure-treated as they will last 10 to 15 years longer than posts dipped in the same preservative. Set end posts about 3 feet in the ground and at a slight angle with the top leaning away from the direction of the row. The top should extend at least 6 feet above ground level after setting to support the top trellis wire at the desired height.

End posts can be braced in several ways. A common method is to set a screw anchor a few feet outside the end post. The angle of the wire attaching the anchor to the post should be about 34 degrees (Figure 23).

FIGURE 23. End posts are set 3 feet in the ground at a 60-degree angle and anchored with a screw-type steel anchor.

Another bracing method uses a brace wire from the top of the end post to a dead-man anchor in place of the screw anchor. The dead man is buried 36 to 48 inches from the post. A double-wire brace extends around the post near the top and to the anchor. The brace is tightened against the anchor by twisting the wires together. Other types of braces with the guy wire are available.

Line posts generally are cut 8- to 9-feet long with a minimum of 3-inches diameter at the top. They are set 24 to 30 inches deep and spaced 20 to 24 feet apart in the row. The exact spacing depends on vine spacing. It is suggested that posts be driven with a post pounder because it takes less installation time, and a driven post is more stable than a post set in an augured hole.

High-tensile-strength steel wire is becoming popular in newly set vineyards. Its strength and durability are in several ways superior to conventional wire. Because this wire has much greater tensile strength (200,000 psi), it must be handled differently than regular iron or galvanized wire.

Galvanized 9-gauge wire was the standard for many years. While high-tensile steel wire is initially more expensive than galvanized wire, it is more durable and may be the most economical over a long period. Rusted wire can seriously chafe vines. High-tensile-strength steel wire should have Class III galvanizing, and a wire gauge of 11 to 12.5 is acceptable, with 12.5 gauge most commonly used. The number of wires and their location depend on the training system.

The length of wire needed for an acre of grapes depends on row spacing, the gauge of wire used, and the training system. Wire is generally sold by weight, and the length in feet for 100 pounds of the following gauge wire is: 11 gauge = 2,617 feet; 12 gauge = 3,300 feet; 12.5 gauge = 3,846 feet. The weight of wire needed for a single wire at various row spacings is shown in Table 6. The weight needed for additional wires required by the training systems can be multiplied using the weight for a single wire.

Wires may be secured to end posts in various ways. A common method for galvanized or iron wire is to wind the wire around the post once or twice and then twist the end several times around the wire as it is stretched to the next post. Special devices also are available to attach the wires to the posts. These devices simplify adjustment of the wires by using a crank or a cinch that eliminates removal of wires from end posts when tightening or loosening. If high-tensile-strength steel wire is used, a special wire-crimping tool is required. There are also several types of wire anchors and connectors specifically designed for high-tensile wire.

Wires are fastened to line posts with ordinary staples or inserted in holes drilled in wooden line posts. The staples must be driven deep enough to hold the wires close to the post, but with enough play that the wire will slip through when tightening is needed. Staples are less likely to pull out if wires are hung on the windward side or the uphill side of posts. With steel posts, regular fence wire fasteners are used.

Table 6. Pounds of Wire Needed for a Single Wire per Acre as Influenced by Row Spacing and Gauge of Wire Used.

Vineyard Row Spacing (Ft)	Trellis Length/Acre (Ft)	Pounds of Wire for a Single Wire/Acre		
		11	12	12.5
6	7,260	276	215	190
7	6,223	237	185	163
8	5,445	207	162	143
9	4,840	184	144	127
10	4,356	166	129	114

Adapted from Zabadal, T. S. 1997. (Vineyard Establishment II). Michigan State University Extension Bulletin E-2645.

Pruning and Training

Pruning and training are perhaps the most important cultural management practices for grapes. A thorough understanding of the concepts of pruning severity and crop load is critical to sustained production of high-quality fruit.

Pruning and Training Young Vines (*See centerfold.*)

Pruning and training of young grapevines are done to establish a vine form that meets the requirements of the training system. The grower should decide which training system to use prior to planting the vineyard. The information presented here will assume that the vines will be trained to a high cordon (HC) system, the most common training system for American and French hybrid wine grapes in the Midwest. Growers planning to use other training systems will need to make modifications to these directions.

Good vine growth during the first two years is critical to the future performance of the vineyard. Vines that do not establish well due to poor cultural management are usually set back several years. One main goal is to establish a large healthy root system by promoting maximum amounts of healthy, well-exposed foliage. To accomplish this goal during the first two years, care must be taken to train vines properly, control weeds, provide necessary nutrients, and control diseases and insects.

Once vines are planted, the grower has several options for pruning and training the vines. Support should be provided for young vines to keep them off the ground. This will greatly reduce disease problems and provide full sun exposure for maximum growth.

The trellis can be established soon after planting to provide this support. If the trellis cannot be established during the planting year, then a single stake should be driven next to each plant, and the shoots tied to the stake. Though it is not necessary to establish the trellis during the planting year, doing so greatly facilitates vine training. (See Figure 24.)

FIGURE 24. Establishing the trellis during the planting year facilitates vine training.

First-Year Management

Proper training begins during the year of planting, and the goal is to develop strong, straight shoots that are long enough to be retained as trunks for the second growing season. Shoot vigor is directly related to management of weeds and fertility. If weeds are controlled and if the vines receive adequate nitrogen fertilizer, then they should produce several shoots capable of reaching the top wire of the trellis system.

In this case, the vines can be left unpruned, or pruned to six to eight buds after planting. Vines left unpruned will develop more functional leaf area and larger root systems than vines pruned to a small number of growing shoots.

If, however, the grower is not prepared to adequately control weeds and provide needed nutrients, then unpruned vines are likely to produce several short shoots, none of which will be long enough to retain as trunks at the start of the second year. In this case, vines should be pruned to a few buds and all growth removed, except the two strongest shoots. This should assure that at least one shoot will be long enough to retain as a trunk.

Generally, mistakes are made by rushing vineyard establishment when growers are not fully committed to good vineyard management. In this case, it is recommended that vineyard establishment be delayed until a commitment can be made.

Grow Tubes

In recent years, grow tubes, or vine shelters, have become popular for vineyard establishment (Figure 25). These plastic tubes create a greenhouse-like environment around the plant that promotes rapid shoot growth early in the season. This early rapid growth usually results in a single dominant shoot that has long internodes and is very straight.

FIGURE 25. Grow tubes used after grapevine planting during the establishment year.

Proponents claim increased first-year vine growth and subsequent earlier production, with vines being capable of producing a crop in the second growing season. However, little scientific evidence supports these claims.

Research in the Midwest has not shown an overall growth increase in vines from using grow tubes. Though tubed vines grow faster early in the season, by the end of the season there is no difference in vine size between tubed and un-tubed vines. In addition, research has shown that restricting growth to a single shoot, whether by use of a grow tube or by pruning alone, also reduces overall vine growth.

In a recent study, we found that vines left unpruned and allowed to develop six to eight shoots developed three times more total leaf area than vines trained to a single shoot (tubed or un-tubed) and, more importantly, had at least twice as much root dry weight. The difference in root system size is especially critical since one of the primary goals in vineyard establishment is development of a large healthy root system.

A strong correlation was shown between total leaf area and root dry weight, which suggests that growers should try to maximize leaf area during vineyard establishment. In most cases, the use of grow tubes will lead to reduced leaf area during the first growing season.

The primary advantage of using grow tubes in the Midwest appears to be protection from broad-spectrum contact herbicides, such as glyphosate and paraquat, and animal depredation and a reduction in the time needed for early-season vine training. However, the time saving is generally offset by the labor required to install and remove the tubes.

Protection of vines from post-emergent herbicides allows the grower to apply broad-spectrum herbicides easily and safely with conventional spraying equipment. Good weed control is critical for achieving acceptable vine growth, so this offers an advantage.

Grow tubes also keep the vines off the ground with minimal tying required during the first few weeks of growth. However, once the shoots grow out of the top of the tube, they must be tied to a string or a stake to prevent damage from wind blowing them across the top of the tube. Grow tubes must be removed in mid-August to early September to promote hardening of the new growth and aid in winter survival.

Second-Year Management

During the second year, the primary goal is much the same as the first year—maximizing vegetative growth. Weed management and nutrition are again critical for acceptable vine growth.

At the start of the second year, canes of the previous year's growth will be retained to be the trunk(s). It is important to retain only healthy canes that are free of mechanical damage or winter injury, if the vine is to have good strong trunks that will be productive and healthy for several years. Additionally, the straightness of the trunks is determined at this time. Not only are straight trunks more esthetically pleasing, they are also easier to manage, especially if mechanized pruning and harvesting are planned.

One method to ensure straight trunks is to cut the cane off about 4 inches shorter than the top wire, tie a short piece of twine to the end of the cane and secure it tightly to the tensioned top wire. (Note: The top wire must be tensioned at the start of the second season).

A second method is to tie a piece of twine from a spur at the base of the vine to the top wire. The cane is then gently wound around the piece of twine and tied to the top wire. Bamboo or wood stakes can also be used to train straight trunks, but they increase cost.

If a double trunk system is desired, then two canes are retained as trunks. If possible, the two canes should originate from below ground. Proper planting depth of own-rooted vines will encourage development of shoots from below the ground surface. On grafted vines (all European vinifera cultivars are grafted onto Phylloxera-resistant rootstocks and some hybrids are grafted to increase vigor), the shoots must originate from above the graft union, and the graft union must remain above the soil line to prevent scion rooting.

If double trunks are desired, but there is only one cane of sufficient length and quality to retain as a trunk, then a shoot can be retained from the base of the vine during the second growing season. If none of the first-year canes is of sufficient length to reach the top wire, then the vine should be cut back to six to eight buds and handled as a first-year vine.

In addition to establishing the trunks, the cordons will be developed during the second season. Shoots are retained at the appropriate position and trained along the top wire. On moderately vigorous vines, thin to the best two to four shoots at the top of the trunks. On more vigorous vines, several shoots can be retained above the middle wire to increase the total leaf area. All shoots below the middle wire should be removed unless one is to be retained as a second trunk.

Some growers like to pinch the tips when these shoots reach the appropriate cordon length (4 ft. for 8-ft.-spaced vines). This promotes lateral branching and early development of spurs on the future cordon. However, some growers prefer to let the shoots grow full length and cut them back to the appropriate length at the beginning of the third season.

Third-Year Management

At the beginning of the third season, the best canes are retained to be the cordons. Other canes are cut back to renewal spurs or completely removed. If pencil-size lateral shoots are present on the cane and have persisted—are healthy and not winter damaged—they can be cut back to one- to two-node spurs. If laterals are not present or are too small, the "canes to be cordons" should be cut back to two-feet long (for a four-foot long cordon) or a 10-node cane (whichever is the shortest). This practice minimizes the negative impact of apical dominance, which thus promotes uniform bud break and shoot growth along the cordons. It also reduces the frequency of blind nodes on cordons in subsequent years. The extension of the cordon is established in the following season.

The new cordons should be loosely wrapped about one full turn over the top wire. Securely attach the end of the cordon to the top wire with wire twist ties and loosely attach the base of the cordon to the top wire with plastic chain-lock or similar ties that are strong but loose. The cordon should be wrapped loosely around the top wire so there is room for it to expand over time.

Many growers reverse the direction that they wrap the cordon on each side of the vine to reduce the chances that the vine will unwind. That is, the cordon on one side of the vine is wrapped over then under the wire, and the cordon on the other side is wrapped under then over the wire.

Pruning Mature Vines
(*See centerfold.*)

The primary purpose in pruning mature grapevines (four years and older) is to balance the amount of crop produced to the vine's capacity to ripen the crop. Understanding the relationship between pruning, yield, and vine vigor is a necessity for the grape grower.

Pruning modifies the size and form of the vine, making it possible to produce more high-quality fruit. At the same time, pruning helps the vine maintain adequate vegetative vigor for high yields in future crops. If training efforts during the first two years have been successful, the third-year vine is fully formed and trained for the desired training system. Consequently, the pruning procedure for a three-year-old vine is essentially the same as for a mature vine.

The wood remaining after pruning in the third season is used to produce the crop. The amount or extent of pruning is done in proportion to the amount of wood produced in the second growing season, or vine vigor. The same principle applies in the fourth and all consecutive seasons. Additional information is presented in *Balanced Pruning* on page 44.

By today's standards, a good mature Concord vineyard is capable of producing six or more tons of grapes per acre. If the vines are planted 8 feet apart in the row with 10 feet between rows, there will be 545 vines per acre. This means the average yield must be at least 22 pounds per vine. An average cluster of grapes usually weighs 3 to 4 ounces. Therefore, 80 to 100 clusters per vine are needed to produce 22 pounds of fruit. Because each fruit-bearing shoot produces one to three clusters, 40 to 50 shoots per vine can produce the crop.

A single shoot arises from a bud, but not all shoots flower and set fruit. Consequently, more than 50 buds per vine may be necessary to produce the 6-ton crop. French hybrids and vinifera cultivars differ from Concord; however, the principles are the same. Refer to Table 7 for average cluster weight so that adjustments can be made in cluster number and, subsequently, bud number.

The mature grapevine will have several hundred buds before pruning, and more than half are capable of producing fruiting shoots. If all buds remain, the vine will overcrop, resulting in delayed fruit maturity, small berries, and small clusters. More important, the vine will not produce enough good fruiting wood for the next year's crop. On the other hand, if the vine is over-pruned, the current season's crop will be reduced, and new growth may be overly vigorous. Excessively vigorous growth produces poor fruiting wood for the following season.

Time of Pruning

Grapevines can be pruned throughout the dormant season. However, fall-pruned vines are more prone to winter injury than those left unpruned. Growers should wait until late winter or early spring to prune so that uninjured canes can be selected for fruiting. Some cultivars are much more prone to winter injury than others, so if time is limited, growers can prune their hardiest cultivars first and the least hardy cultivars last.

Delaying pruning until later in the dormant season also tends to hold back growth that may be affected by untimely frosts. However, pruning should be completed before bud swell since cane removal may cause bud breakage, especially on vines trained with catch wires such as the vertical shoot-positioned system (VSP). *Bleeding*—flow of sap from the wounds—may occur when vines are pruned late, but this does no harm to the vine.

Table 7. Approximate Number of Clusters per Vine for Different Cluster Sizes and Crop Yields. (Based on 8 x 10 spacing, 545 vines/acre).

Cluster Size	4 Tons/Acre	6 Tons/Acre	8 Tons/Acre
Large Clusters (1 lb)	15	22	30
Medium Clusters (1/2 lb)	30	44	60
Small Clusters (1/4 lb)	60	88	90

Types of Pruning

There are two basic types of pruning—*cane* pruning and *spur* pruning. These differ only in the length of the one-year-old fruiting wood that is retained. Cane pruning requires that long, 10- to 20-node fruiting canes be retained for fruiting. Spur pruning utilizes short, 2- to 6-node canes (called spurs) for fruiting.

Most cultivars will perform well using either cane or spur pruning. Some training systems employ both types of pruning. Some cultivars have been reported to perform better when cane pruned because the buds that are four to 12 nodes from the base of the cane are more fruitful than at the basal two or three nodes. Proper shoot positioning should improve fruitfulness of the basal nodes and make spur pruning feasible.

Some cultivars have a tendency to push many secondary and tertiary buds from canes and latent buds from cordons. Short spur (two node) pruning seems to exacerbate this problem whereas long spur (six node) or cane pruning seems to reduce this tendency. Whichever type of pruning is performed, the training system must effectively display the fruiting wood.

Characteristics of Retained Wood at Pruning

Grapevines produce fruit only from one-year-old wood, called a cane; thus, long or short canes should be retained during pruning. These canes are selected based on the following criteria:

1. Good sun exposure of shoots and leaves during the previous growing season. *Sun canes* from well-exposed shoots should be retained. *Shade canes* that do not have good sun exposure should be removed.

2. Canes should be healthy and free from diseases, such as powdery mildew and/or Phomopsis.

3. Canes should be at least 1/4 inch in diameter (pencil size) at about the fifth and sixth buds and nearly the same thickness at the 10th bud. Large-diameter (more than 1/2 inch) canes, called *bull canes,* should be removed because they are more susceptible to cold injury.

4. Canes should originate from arms near the main trunk (Umbrella Kniffin) or near the cordon (Bi-lateral cordon or Geneva Double Curtain).

5. Cane bark should be a bright and uniform reddish-brown color.

6. Internode length (distance between two buds or nodes) should be 5 to 8 inches (generally closer for non-Concord types).

Balanced Pruning

Although 60 or more buds can easily be left on a grapevine, a crop of 6 tons per acre cannot be expected unless the vine has sufficient vigor to support such a fruit load. To determine the potential fruit capacity of a vine at pruning time, growers can use the concept of *balanced pruning*. The principle is valid for all grapes in general, but varies in magnitude from one cultivar to another. The procedures outlined in this section have been developed for Concord. Also discussed are modifications of the principle to apply to other cultivars.

Balanced Pruning Procedures

1. Estimate the amount (weight) of one-year-old wood; select the fruiting canes to be retained; and remove all other one-year wood (leaving a margin of error).
2. Weigh the one-year-old prunings from the vine to determine *vine size*. Weight of the one-year-old prunings is highly correlated to the total leaf area the vine possessed the previous season and, thus, its potential to mature a crop. After pruning and weighing a few vines, growers will make more accurate weight estimates. Only periodic

weighing is necessary afterward. Note that wood older than one year, if removed, should not be counted as part of the pruning weight (Figure 26).

3. Apply the vine size value to the pruning formula to determine the total number of buds to leave.

   For best results with Concord, use the (30 + 10) formula. This means that 30 buds are left for the first pound of prunings plus 10 buds for each additional pound of wood removed. If the prunings weigh 1 pound, leave 30 buds; if 2 pounds, leave 30 + 10 = 40 buds; if 2.5 pounds, leave 30 + 10 + 5 = 45 buds; and so on.

   Pruning formulas vary depending on the type of grape or cultivar. See Table 8 for suggested pruning formulas for commonly grown cultivars.

   For example, if a Concord grapevine has a vine size of 3 pounds, then prune so that 30 + 10 + 10 = 50 buds remain on the vine.

   Using a cane-pruned training system (such as the Umbrella Kniffen), the grower would leave five or six canes, each with 10 to 12 good buds, plus some renewal spurs.

   Using a spur-pruned training system (such as the bi-lateral cordon), the grower would leave 10 or 12 fruiting spurs, each with 5 or 6 buds plus some renewal spurs.

   Leaving 10% to 20% more buds than called for by the balanced pruning formula will adjust for lack of fruitfulness. If winter injury is significant, then adjustment can be made for percentage live (or dead) buds.

FIGURE 26. Balanced pruning consists of weighing the pruned wood from one-year-old canes to determine the number of buds to retain for optimum cropping.

Evaluating and Adjusting for Winter Injury

Cold injury to grape buds is relatively easy to detect. Using a sharp razor blade, make a series of cross-sectional cuts across the buds, getting deeper with each cut until the primary bud is exposed. Cutting too shallow reveals only the brown bud scales, and cutting too deeply misses the center of the bud and reveals the basal tissue, which may appear alive even if the bud is not. Live buds appear bright green while dead buds appear brown or black.

It is important to thoroughly sample the vineyard and properly handle the canes prior to evaluation of cold damage. Collect canes with 100 or so buds from each cultivar. A sample of ten 10-bud canes is usually sufficient. Samples should be collected after the end of the cold period has occurred, brought indoors, and allowed to warm for 24 to 48 hours to make the damaged buds easier to differentiate from live buds.

Samples should be representative of the type of wood that will be left at pruning in terms of the node position on the canes. For instance,

Table 8. Suggested Pruning Formulas for Various Grape Cultivars.

Grape Cultivar	No. of Buds for 1st Pound of Prunings	No. of Buds for Each Additional Pound	Maximum No. of Buds
American Cultivars:			
Concord	30	10	60-70
Catawba	25	10	40-50
Delaware	25	10	40-50
Niagara	30	10	60-70
Norton (GDC)	60	10	80-90
French-American Hybrids:			
Foch	30	10	60-70
Leon Millot	30	10	60-70
Baco Noir	20	10	50-60
Vignoles	15	15	60-70
Vidal	15	5*	30-40
Chelois	10	10	30-40
Chambourcin	20	20*	30-40
Chancellor	20	10*	30-40
DeChaunac	20	5*	30-40
Seyval	20	10*	30-40
Villard blanc	20	10	30-40
Chardonel	20	20?	40-50
Traminette	20	20?	40-50
European (Vinifera) Cultivars:			
	20	20*	40
Seedless Table Grape Cultivars:			
Canadice	30	10*	50
Himrod	30	10*	50
Mars	30	10	60-70
Reliance	30	10*	50
Vanessa	30	10*	50
* Requires cluster thinning.			
? Tentative formula.			

if you normally spur prune to five or six node spurs, then you will want to pay particular attention to damage to the basal five or six buds. Depending on the circumstances, there can be considerable difference in cold damage to buds from the base to the tip of a cane. Keep track of the position of the buds as you cut and record the damage so you will know what part of the cane has the most damage.

Adjusting Pruning Level to Maintain Vine Balance

For American cultivars in which secondary buds are not very fruitful, the general rule of thumb is as follows:

- If less than 15% of the primary buds have been killed, then prune as normal.

- If 15% to 50% have been killed, then adjust the pruning formula proportionally to the bud kill to account for the dead buds.

  For instance, if you have 30% bud kill on Concord, you will want to leave 30% more buds than is called for by the 30 + 10 formula. For a vine that produced 2 lbs. of prunings, you would leave 40 + (30% x 40) = 40 + 12 or 52 buds. The extra buds retained should make up for the percent that has been killed and should produce fruit that will help keep the vine in balance.

  It is important to determine if there is a relationship between bud kill and node position. If most of the damage is confined to basal buds (because they were shaded and did not acclimate well), then you would want to leave longer spurs rather than more short spurs to account for the total number of buds.

- If more than 50% of the primary buds have been killed, then **do not prune,** or only prune to eliminate the canes close to the ground or out of the vine space. Wait until growth begins in the spring to prune these cultivars so that a more accurate assessment can be made.

  For French hybrid cultivars that have fruitful secondary buds, the increase in number of buds to retain may not be proportional to bud damage. There is no exact formula to determine the number of extra buds to retain, but realize that some adjustment is necessary. It is always best to leave more buds than needed, rather than fewer. Final adjustments can be made by removing shoots after bud break.

Pruning to Avoid Frost Damage

Frost is another possible time of cold injury to buds following budbreak. Pruned vines tend to bud out earlier than unpruned vines. However, delaying pruning until after budbreak is not practical in most cases because cane removal may cause a significant amount of bud breakage. On cold tender cultivars and cultivars that bud out early (such as Marechal Foch), the best approach may be to do a first rough pruning, leaving considerably more buds than required (long spurs), then follow up to adjust bud number after budbreak. This approach, often called *double pruning*, can sometimes delay budbreak of the desired basal buds by up to two weeks (Figure 27.) It is most practical on spur pruning systems such as high cordon or VSP.

Other Pruning Considerations

Pruning and cluster thinning**:** In general, pruning formulas work well for American and vinifera varieties. However, some French hybrids tend to overcrop (very fruitful buds) and using the pruning formula alone to control yield is not adequate. In this case, balanced pruning should be followed by cluster thinning (Table 8). Examples of varieties that require cluster thinning include Chambourcin, Chancellor, Seyval, and Vidal.

Pruning and shoot thinning**:** Under conventional trellising systems, if more than 60 buds

FIGURE 27. Double pruning delays bud break of basal buds, thus minimizing crop loss from frost injury. A follow-up pruning is necessary to adjust bud count.

should be left on a pruned vine, considerable shading may occur. A general rule of thumb is that six shoots per foot of row are about the maximum that can be left and still achieve good sunlight distribution on the leaves. This varies somewhat with cultivars, but it is a good rule to follow.

This means that vines spaced at 8 feet apart in the row will have the best sunlight distribution with about 50 shoots. Leaving an additional 10 buds can make up for blind nodes. Pre-bloom shoot thinning can be used to make the final adjustment in shoot number.

***Assessing vine balance and crop load*:** Each vine must be pruned according to its own individual capacity. If the crop was large last year, the vine may not have produced enough growth this year to mature a similar amount of fruit. Nutrition and moisture may have been limiting factors. If the yield was low, examine and evaluate the canes of the previous season according to the guidelines given for size, color, and internode length. (See *Characteristics of Retained Wood at Pruning*.)

Table 9 lists guidelines for growers to assess whether their mature vines are balanced. This balance is gauged by *vine size*, *crop size*, and the ratio between the two called *crop load*.

Vine size is measured by weighing cane pruning per vine (in pounds) during the dormant season. *Crop size* is the fruit weight per vine (in pounds) measured at harvest. *Crop load* is the ratio of crop size/vine size.

Table 9. Assessing Grapevine Balance Based on Vine Size, Crop Size, and Crop Load.

Class of Vine Size	Vine Size (Lbs/ft of Canopy)	Vine Size (lbs/vine) On 8-Ft Vine Spacing	Crop Load (Crop Size / Vine Size)
Small	Less than 0.25	Less than 2	More than 15
Comments and Recommendations: "Overcropped" vines. Vines produce too much fruit and not enough shoots. Should reduce crop by cluster thinning and fertilize to restore vine size.			
Medium	0.3 – 0.4	2.4 – 3.2	5 - 12
Comments and Recommendations: "Balanced" vines. This situation is optimum. Should keep the same vineyard practices.			
Large	More than 0.4	More than 3.2	Less than 3
Comments and Recommendations: "Vigorous" vines. Vines produce too many shoots and not enough fruit. Reduce or withhold fertilization; practice canopy management; may convert to a divided training system if none of the short-term remedies work.			

Optimum crop load ranges between 5 (for low-yielding vinifera) and 12 pounds of fruit or higher (for high-yielding vinifera and hybrids). This means that for every pound of prunings produced, 5 to 12 pounds of good-quality fruit can be produced by the same vine. For example, if a grapevine has a vine size of 2.5 lb. (pruning weight), then in order to achieve a balanced vine, the optimum crop size for this vine should range between 5 x 2.5 = 12.5 lbs. and 12 x 2.5 = 30 lbs. of fruit.

Disposal of Prunings

After the vine or vineyard section has been pruned, the prunings are placed between the rows. Prunings should be removed carefully from the trellis to avoid breaking those canes retained for production. The prunings may be removed from the vineyard or chopped between the rows with a heavy-duty rotary mower or flail mower. Most commercial vineyards chop the prunings, which reduces labor for this operation while adding a small amount of organic matter to the soil.

Training Systems (*See centerfold.*)

Training is the arrangement of the vine on the trellis. There are many different types of training systems for wine grapes, but all have the same goals:

- To position the annual shoot growth so that the fruit and leaves receive optimum exposure to light.
- To position the fruit for ease of pest control and ease of harvest.
- To facilitate pruning and other vineyard management operations.

Optimum sunlight exposure of leaves and fruit ensures good fruit quality and bud fruitfulness. Without adequate exposure, fruit quality suffers and vine productivity is reduced.

The most efficient training systems provide well-spaced, evenly distributed fruiting wood along the trellis to promote maximum interception of sunlight and provide optimum sun exposure for clusters and shoots. In addition, a well-designed training system will produce a high canopy surface area and low canopy density. This encourages high production of sugars with minimal effects of shading.

Researcher and grower experiences have shown that shoot density of about six shoots per foot of canopy is optimal. This should provide a canopy that has one to two layers of leaves and minimal shading. As shoot density gets higher, leaf layers increase and shading occurs.

Shading has detrimental effects on fruit quality, such as lower soluble solids; higher total acidity; higher pH; reduced color, anthocyanin, and phenolic content; and increased potassium content. Wine quality can be adversely affected by each of these changes. Understanding that sunlight exposure is necessary for good fruit quality is the basis of training and trellising system selection.

Choosing a Training System

Growers are advised and cautioned that there is no universal training system. One-size-fits-all does not apply in choosing a training system. With this in mind, a grower should realize that choosing a training system depends on several factors, including the anticipated vigor of the vineyard, cultivar to be planted, capital and annual labor cost, equipment used, and the potential to mechanize the vineyard.

Trellis construction is one of the most expensive components of vineyard establishment. It makes sense to carefully consider the reasons for choosing a particular training system.

Anticipated Site Vigor

Anticipated or potential site vigor is probably one of the most important factors in selecting a training system, but it is difficult to assess. The selection of a training system and vine spacing should be based on the anticipated vigor of the vineyard.

In the Midwest, many vineyards are being established for the first time, thus predicting vine vigor prior to vineyard establishment is challenging. Table 10 provides guidelines for selecting the proper training system and vine density based on vine vigor and potential site vigor.

Vine vigor is affected by rain, soil type, depth, fertility, water-holding capacity, and cultivar. Thus, information on these factors should be gathered to assess the anticipated vigor of the site as accurately as possible. New growers should check neighboring vineyards to have a general idea about vigor potential in their area.

Eventually, growers should be able to rank their new vineyard sites as *low*, *moderate*, or *high* vigor. In general, in a low-vigor site, choosing a non-divided canopy training system (*e.g.*, VSP) is the most adequate, whereas in a high-vigor site, choosing among divided canopy training systems (*e.g.*, GDC) is recommended (Table 10).

Cultivar Characteristics

The choice of the training system must take into consideration cultivar and rootstock vigor, growth habit, cold hardiness, and disease susceptibility. The choice of the training system is often dependent on the growth habit of the cultivar being grown.

Most American and French hybrid cultivars tend to have a downward, or procumbent,

Table 10. Guidelines to Matching Training Systems with Potential Vineyard Vigor Based on Anticipated Site Vigor, Variety Vigor, and Row and Vine Spacing.[1]

Training System Selection	Anticipated Site Vigor[2]			Scion and Rootstock Vigor[2]			Row Spacing Selection[3]		Vine Spacing Selection[4]	
	High	Moderate	Low	High	Moderate	Low	Narrow	Wide	Narrow	Wide
Non-Divided Canopy										
Vertical Shoot Position	-	+	++	-	+	++	++	-	++	-
High Cordon	+	++	-	+	++	-	++	+	+	++
Divided Canopy										
Smart Dyson	++	++	-	++	++	-	++	-	++	+
Scott Henry	++	++	-	++	++	-	++	-	++	+
Geneva Double Curtain	++	+	-	++	+	-	-	++	+	++
Lyre or “U”	++	+	-	++	++	-	-	++	+	++

[1] Anticipated Site Vigor Ranking: High = deep and fertile soil, abundant water availability, and high water-holding capacity; Moderate = moderately deep and fertile soil, moderate water availability, and moderate water-holding capacity; Low = shallow and low fertility soil, scarce water availability, and low water-holding capacity.

[2] ++ Most appropriate match; + Appropriate match; - Least appropriate match (not recommended).

[3] Row spacing: Narrow = 8 to 10 ft; Wide = 11 to 12 ft.

[4] Vine spacing: Narrow = 4 to 6 ft; Wide = 7 to 10 ft.

growth habit. Therefore, a high training system, which allows ample distance for shoots to grow downward, is recommended. On the other hand, European, or vinifera cultivars, have a strong upright growth habit, especially early in the growing season. This growth habit is best managed with a low training system, which allows upward vertical shoot growth.

Common Training Systems (*See centerfold*.)

To date, there are more than a dozen training systems used throughout the world. In the Midwest, training systems used for wine production range from single to divided curtain systems with the High Cordon system being the most common. Although the High Cordon system is commonly used, it is not always the most adequate. A general description of each system and its pros and cons is presented here.

High Bi-Lateral Cordon (*HC*)

The HC or *single curtain* is the most commonly used training system in the Midwest. Two cordons extend along the top wire (5.5 to 6 feet above ground) of the trellis in each direction and meet cordons half way from adjacent vines. The cordons remain as semi-permanent extensions of the trunk, though they may need replacement every five or so years.

A second training wire may be used at 36" to 42" above ground to provide extra support for young and mature vines and minimize breakage from strong winds. This system can be cane- or spur-pruned; however, the latter is more common. Fruiting spurs two- to six-nodes long are spaced along this cordon. Shorter renewal spurs are left to provide fruiting wood for the next season.

The primary advantages of HC are low establishment and production costs and ease of mechanization, including mechanical harvesting and pre-pruning. The high location of the fruit and renewal zones improves sunlight penetration, which thus has the potential to increase yield. Wildlife depredation (deer) and frost injury may also be minimized.

This system is best suited for use under moderate vigor conditions, which are the conditions most common in the Midwest. Most of the Hybrids and American cultivars with procumbent growth habits are adapted to this system.

Umbrella Kniffin

Umbrella Kniffin (UK) used to be the most popular and common system in the Midwest and the East. This system utilizes long canes (10 to 20 buds each) that originate from renewal spurs at or near the top of the trunk. Four to six canes are retained, bent over the trellis wires, and tied securely.

Mechanical damage to the tender buds during the tying process can be a problem, so pruning and tying must be finished before bud swell begins. Other drawbacks of this system include extra time and effort for tying, and difficulty in leaving extra buds to protect against damage from spring frosts (double pruning). Additionally, cane pruning cannot be mechanized. In recent years, UK has been used less in newly established vineyards.

Vertical-Shoot Position

This Vertical-Shoot Position (VSP) system is also called low- or mid-cordon system and is the most commonly used trellis worldwide on vinifera cultivars. Trunks are trained to a low (12") or mid wire (up to 42") with cordons or canes extending along this wire. Shoots are positioned vertically upward between two to three pairs of catch wires.

The first pair of catch wires is positioned about 10" above the cordon wire; the second and third at 12" and 24" above the first catch wires. Shoot positioning is done by either moving catch wires or by manually tucking shoots between fixed catch wires.

The advantage of this system is that the distance between rows can be reduced, allowing more efficient vineyard design and improved productivity. It is also easy to manage and mechanize. This system keeps the fruiting wood close to the ground to allow easy renewal of trunks in case of winter injury.

The disadvantages of VSP are lower light exposure than HC since the fruiting zone is at the base of the canopy; thus, lower yields than HC are expected. Furthermore, the proximity of the fruit zone to the ground makes it more susceptible to wildlife depredation and frost injury.

VSP is normally used under low- to moderate-vigor conditions. This system is most suited to cultivars with upright growth habit, including most vinifera cultivars and some hybrids (*e.g.*, Chancellor, Seyval, and Vignoles).

The Fan System

The Fan System (FS) is often used with cold tender cultivars to assure some live buds each year. This is a *spare-parts* approach in which several trunks of different ages are retained and spread out across a multiple wire trellis. Older trunks are often more susceptible to winter injury than young trunks but are also more fruitful, so trunks of different ages are saved to provide for continuous renewal of fruiting wood.

Fruiting wood is selected from canes on the different trunks. In case of winter injury to one trunk, additional buds are retained on the remaining trunks to balance the bud number. Fruiting wood may be pruned as long canes or short, depending on the degree of winter injury and available buds.

Geneva Double Curtain

As the name indicates, Geneva Double Curtain (GDC) was developed at the New York Agriculture Experiment Station in Geneva, New York, by the late Dr. Shaulis. This system is similar to HC but instead of having a single curtain of shoots, there are two horizontally divided curtains. These curtains are supported by fruiting wires that are separated by cross arms that are usually 4-feet wide.

Since the two curtains extend 2 feet on each side beyond the vine row, row spacing should be wider than other systems. Row spacing of 11 to 12 ft is generally recommended. Vines can be trained either with two cordons (bilateral) on one side of the canopy, or four cordons (quadrilateral), with two on each side of the canopy. At the same vine spacing, the bilateral cordons are twice as long as the quadrilateral cordons.

Field observations indicate that GDC with quadrilateral cordons produces more uniform bud break and shoot growth; cordons have less blind nodes and are quicker to replace in case of disease or winter injury than GDC with bilateral cordons.

The GDC system supports more growth and yields (30% or more, higher than HC) since shoot number and leaf surface areas are doubled (Table 11). Thus, GDC is more suitable under high-vigor conditions where soils are deep and fertile. This system is also suitable to vigorous cultivars such as Concord, Frontenac, Norton, and Traminette and some table grapes.

GDC produces higher fruit quality, higher yields, and less disease incidence than other systems. Although GDC has a high establishment cost due to more trellising materials, the long-term benefits from higher revenues exceed the initial costs. A potential drawback of GDC under a hot climate is excessive fruit exposure to sunlight and heat, which may result in sunburn and may negatively affect flavor components, especially of white varieties.

Table 11. Exposed Canopy Surface Area for Different Training Systems (Smart, 1996).

Trellis System	Surface Area for 12-ft. Row Spacing (m^2/ha)
VSP	8,500
HC	12,500
SH	13,100
SD	13,100
SD – Ballerina	13,700
GDC	20,000

Scott Henry

The Scott Henry (SH) system is similar to VSP, but curtains are vertically divided upward and downward. Vertical curtains are formed by alternating the fruiting zone height. Shoots from the upper canes (or cordons) are positioned vertically upward, while shoots from the lower canes (or cordons) are positioned downward, leaving an open space or window 8" to 10" wide between the two curtains.

SH is best adapted for moderate to high-vigor conditions. The SH trellis system uses 8 wires—two cordon wires, two pairs of catch wires for the upper curtain, and one pair for the lower curtain. Therefore, SH is more labor intensive than the previous trellising systems.

Advantages include higher yields and quality than VSP. Thus, the high establishment and production costs may prove to be worth-while in the long-term. Another significant advantage of SH is reduction in bunch rot, which causes yearly crop losses for several cultivars grown under wet and humid conditions. Cultivars prone to bunch rot, such as Pinots and Vignoles, can benefit from this system.

Originally, Oregon grower Scott Henry developed this system to overcome two problems in his Pinot noir vineyard—excessive vigor and bunch rot. The SH system has promise, but there is limited commercial experience in the Midwest, and more research is needed for long-term evaluation of this system.

Smart-Dyson

This Smart-Dyson (SD) system is similar to SH where curtains are vertically divided. Thus, SD has similar advantages to SH. The only difference with SH is that shoots in SD originate from the same cordon or fruiting zone. Also, SD requires one type of pruning called *spur pruning*, which is easier and less labor intensive than SH. This system is adaptable to machine harvesting, pre-pruning, and leaf removal.

Smart-Dyson Ballerina is a modification of the SD system, with very similar training except that the Ballerina is used more often in cases of retrofitting existing vineyards from VSP in case of excessive vigor.

As with SH, there is limited experience and research with SD, and further evaluation of this system is needed.

Lyre or U-System

The Lyre or U-System (U) is similar to VSP but with two curtains divided horizontally. Thus, this system is adapted to upright growing cultivars and is suitable to moderate and high-vigor conditions. As with other divided canopy systems, yields are increased due to increased shoot number and leaf area per acre.

However, the U system is the most expensive to build among all training systems. Furthermore, this system is difficult to mechanize. Because of the extensive cordon development required, this system is difficult to maintain in areas where cold injury is common. Therefore, this system is generally not recommended in the Midwest.

Other Innovative Pruning and Training Systems

Another trend that has developed in recent years is the use of mechanical pruning, or minimal pruning, techniques. Much work has been done in New York and Arkansas to mechanize all aspects of grape production. Training systems employed are usually High Bilateral Cordon or Geneva Double Curtain. Pruning severity can range from closely approximating hand pruning to only minimal skirting of canes in the lower section of the trellis. These systems are probably best suited for juice grapes, but wine grapes are increasingly being grown using these systems.

More research is needed to evaluate minimal pruning under high disease pressure and extreme low temperature conditions characteristic of the Midwest.

Crop Control and Canopy Management

Concept of Crop Control

Crop control is a vineyard practice that includes the physical adjustment of the vine as needed to balance the amount of fruit with the growth of foliage. This practice adjusts the crop level so there will be sufficient growth of shoots with leaves on each vine, and each shoot will be capable of maturing the fruit retained.

Growers often experience the adverse effects of allowing vines to overproduce and lose vigor. This leads to improper maturation of the crop and causes the vine to enter the winter in a weakened condition. Growers then realize that an effective crop control program for each cultivar must be developed to keep the vineyard productive and healthy over an extended period. As more cold-tender cultivars are planted and the need for high quality increases, growers more than ever must use other methods in addition to balanced pruning to control the crop in a given year.

Crop Control on Young Vines

It has been shown that cropping of young vines can reduce the size of the root system and overall vine vigor. Unless vines are vigorous, fruit should not be retained during the first and second growing season. Remove flowers and fruit early in the season, when shoots are about 12-inches long. If the vines exhibit high vigor, a small amount of fruit can be left during the second season, but it should be only one or two clusters per plant.

Leaving a small amount of fruit helps the grower check for off-type vines early in the life of the vineyard so they can be removed and replaced. Additionally, the presence of fruit on vigorous vines helps slow vine growth in the fall and promotes shoot maturation.

Since the first three seasons are used to establish the vine form, there is usually a considerable amount of fruitful wood retained during the second and third seasons. This can lead to a crop potential that will exceed the capacity of the vine to support the fruit load in the third year.

About one half of a full crop of fruit can be retained during the third season if vine vigor is sufficient. Heavy fruiting of young vines will result in small vine size and reduced yields, and vines may need several years to recover and regain vigor. It is best to be patient and crop vines only after they are well established.

Canopy Management of Mature Vines

With the tremendous vineyard expansion in the Midwest during this decade, production is estimated to increase exponentially in the coming years. Winery owners and managers will be more selective and demand high-quality grapes. Winemakers unanimously agree that quality grapes is the No. 1 criterion.

The recognition of the important role of viticulture in the production of premium wines has led to considerable interest in viticulture practices that can improve wine quality. Among these practices, canopy management has made one of the biggest impacts in world viticulture in the last 20 years.

Therefore, to ensure the production of high-quality grapes, growers in the Midwest should embrace canopy management practices. These practices are usually conducted in fine-wine regions to produce premium fruit and wine. However, they are becoming a routine practice for vineyards seeking maximum wine quality.

In order for the wine industry in the Midwest to continue to be successful, it is critical that high-quality grapes be produced on a consistent basis. Some of the ways to achieve that goal are described here.

Concept

According to Dr. Richard Smart, author of *Sunlight into Wine*: "Canopy management is the practice which results in the modification of position or amount of leaves, shoot, and fruit in space to achieve a desired arrangement."

Vine canopy is the shoot system, which includes the stem, the leaves, and fruit clusters. In the viticulture world, canopy is described by its length, height, width, leaf area, number of leaf layers, and shoot density. Shoot density refers to the number of shoots per foot of row or foot of canopy. Table 12 describes the characteristics of an ideal canopy.

Benefits

Canopy management (CM) has several viticulture advantages, such as maximizing sunlight interception, which means minimizing shading, and very importantly, maintaining a balance between shoot growth and fruit production (Figure 28.) The benefits of CM include:

- Increased air movement, which leads to faster drying time from rain and dew, and thus less disease pressure.
- Improved spray penetration and disease control.
- Improved fruit composition and varietal character.
- Increased bud fruitfulness.
- Improved winter hardiness.

Steps During the Growing Season

There are five major steps or practices that growers should follow and apply to their vineyards. Some grape cultivars require all five steps; others require fewer; and certain cultivars require a repeat of some of the five steps.

The growing season also has a major impact on CM. Dry summers require fewer CM practices than wet summers. Growers have to follow the basics and fine-tune the steps according to cultivar, site, season, and their own experience. The five CM steps are listed

Table 12. Ideal Vine Canopy.

Canopy Characteristic	Optimum Values
Shoot density	4 to 6 shoots per foot of canopy
Number of leaf layers	1 to 1.5
Number of nodes per shoot	12 to 15
Canopy gaps	40% to 50%
Cluster exposure	50% to 75%
Ratio of leaf area to fruit weight (sq. inches per oz.)	44 to 53
Ratio of leaf area to fruit weight (cm^2 per gram)	8 to 12
Vine size (pruning weight in lbs. per ft. of canopy)	0.3 to 0.4
Ratio of fruit produced (lbs.) for each pound of prunings removed.	5 to 12

FIGURE 28. Canopy management enhances sunlight exposure of leaves, clusters, and basal buds which will bear fruit the following year.

here in chronological order of vine development throughout the growing season:

Step 1—Shoot Thinning (Suckering)

***Suckering Trunks and Cordons*:** This consists of removal of suckers (unwanted shoots that grow on the trunk or cordon). One or two suckers are left at the base of the trunk only if a new trunk needs to be trained in second- and third-year vines, or if trunk replacement is deemed necessary due to injury—cold, disease, or mechanical injury. On the cordons, unfruitful shoots are removed first unless they are needed for spur renewal.

Once all shoot thinning is done, shoots should be spaced evenly along the cordon length and have a density of four to six shoots per foot of cordon or canopy. With 8-foot vine spacing, this corresponds to 32 to 48 shoots per vine on a single curtain/high cordon (HC) system, and 64 to 96 shoots per vine on a Geneva Double Curtain (GDC) training system. Note that with a divided canopy (*e.g.*, GDC and Scott Henry), there are two feet of canopy for each foot of row.

***When*:** This is best done early in the season when shoots are about 1 to 3 inches (trunk suckering) to 6 to 12 inches (cordon suckering) long. At this stage, shoots are easily rubbed off; fruit clusters are visible to distinguish between fruitful and unfruitful shoots; and less labor is involved. Suckering may require more than one pass. Growers with frost-prone vineyard sites should plan to thin shoots after the spring frost threat has passed.

Step 2—Shoot Positioning

The best scenario is when shoots grow vertically (parallel to the trunk), either up or down, depending on the training system. In the real world, however, shoots tend to grow sideways and attach to the cordon wire with their tendrils. This is why shoot positioning (Figure 29) is conducted to disallow lateral and horizontal shoot growth. Shoot positioning also allows the spread of shoots to promote an open canopy, improve spray penetration, and adhere to the shape of the given trellis system.

***Combing*:** This is the generic term for positioning shoots downward. Combing is conducted on high training systems such as High Cordon (HC) and Geneva Double Curtain (GDC). Shoots are combed in a vertical downward position.

***Tucking*:** This is the generic term for positioning shoots upward and is used on low training systems such as Vertical Shoot Position (VSP). Shoots are held upright by using two or three pairs of moveable catch wires, 10 to 12 inches apart. Sometimes extra tying with tape is needed in order to keep the shoots upright.

***Combing/Tucking*:** Both practices are required in vertically divided canopies such as Scott Henry and Smart Dyson training systems. The upward growth of both systems is tucked between catch wires, and the downward growth is combed.

***When*:** Timing is critical for reducing the amount of shoot breakage and ease of positioning. Growers should realize that the most important aspect is to reduce shading as soon as possible after bloom as fruit bud development begins about that time and sunlight exposure is critical for bud fruitfulness.

Step 3—Cluster Thinning

Growers are sometimes tempted to take the risk and avoid cluster-thinning altogether for quick vineyard production. Others do cluster thin and have in mind the long-term benefit of this practice for the well-being and life span of the vineyard.

Cluster thinning is a MUST for some cultivars that have very fruitful primary buds and tend to produce three or more clusters per shoot. Examples include Seyval, Chancellor, Vidal, and Chambourcin.

Among these cultivars, some also have fruitful secondary and base buds, which in turn produce several clusters per shoot. Seyval and Chancellor are good examples. These two varieties still produce a normal crop after losing their primary buds to cold injury.

***When*:** There are two periods—before bloom (pre-bloom) and after fruit set (post fruit set).

***Pre-Bloom Thinning*:** This consists of the removal of flower clusters. This practice can be done at the same time as shoot thinning.

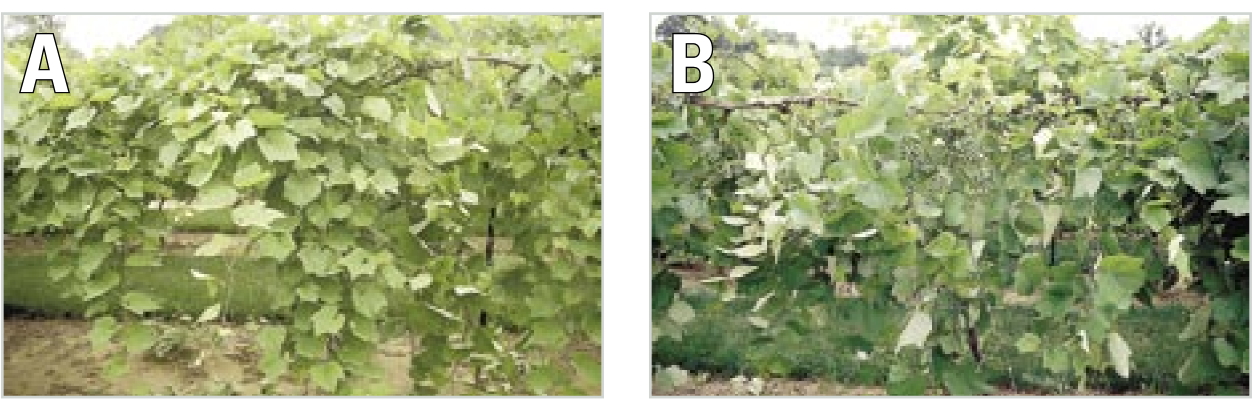

FIGURE 29. Shoot positioning: Canopy before (A) and after (B) combing shoots downward. Note fruit exposure after combing.

The advantage of this timing is that clusters are easy to see; thus, thinning can be done quickly. By removing flower clusters this early, several things happen—berry set is improved (more berries per cluster as a result of less competition with fewer clusters), and berries are bigger at harvest. Other advantages include increased yield, increased sugars and flavors of the fruit, improved vine size and hardiness.

Disadvantages of early thinning include tighter clusters (as a result of increased fruit set and larger berries); thus, bunch rot can be a problem. Seyval produces large and tight clusters and is susceptible to bunch rot. Therefore, thinning before bloom is not recommended for Seyval. However, this practice is beneficial to cultivars that have loose clusters and are not susceptible to bunch rot, such as Chambourcin and Chancellor.

***Post Fruit Set Thinning*:** In this case, berry set is less than that of pre-bloom thinning. There are fewer berries per cluster; thus clusters are looser, and bunch rot incidence is reduced. This practice is more common and recommended for cultivars susceptible to bunch rot, such as Seyval. (See Figure 30.) With this method, yield, sugars, vine size, and hardiness are improved.

This method, however, is more time-consuming, hence more expensive—it is more difficult to see the fruit due to a more developed canopy. At this stage of shoot development, the vine canopy is about 75% formed.

The following rule of thumb for cluster thinning can be used as a general guideline:

- Remove all clusters from shoots less than 12 inches long.
- Leave one cluster per shoot for shoots 12 inches to 24 inches long.
- Leave two clusters per shoot for shoots more than 24 inches long.

FIGURE 30. Post fruit set thinning is recommended for cultivars susceptible to bunch rot, such as Seyval.

***Special Cases*:** In almost all commercial vineyards, there are always some vines that seem to fall behind in growth and production. They look like one- or two-year-old vines in a five-year-old vineyard.

In this case, these undersized vines should be cluster thinned heavily, sometimes completely. This will allow the vines to recover by diverting the carbohydrates to trunks and roots.

Follow the same procedure with vines that have not filled the trellis yet.

Step 4—Leaf Removal (Pulling)

Leaves, and sometimes lateral shoots, are removed in the fruiting zone in order to accomplish two goals. First is to improve air movement and spray penetration, thus reducing bunch-rot infection. This is especially critical for cultivars susceptible to botrytis bunch rot such as Pinot noir, Pinot gris, Pinot blanc, Riesling, Vignoles, and Seyval.

Second is to improve sunlight exposure of fruit and basal buds. This results in better color for red wine varieties, and lower potassium and pH in the juice.

Leaf pulling is done on the *shade* side of the canopy, which is either the east side of a north-south row or the north side of an east-west row. One to three leaves are removed at the base of each shoot and around clusters. (See Figure 31.) Leaf pulling is either minimally done or completely avoided (depending on the canopy thickness) on the *sun* side of a canopy in order to avoid sun burning of fruit.

A disadvantage of leaf pulling is increased bird damage as result of exposed berries.

***When*:** Leaf pulling is first performed after fruit set. One more cleanup pass may be

FIGURE 31. Leaf pulling consists of removing one to three leaves at the base of each shoot and around clusters between fruit set and veraison but not after. Picture taken after veraison of Norton, but leaf pulling was conducted after fruit set.

necessary before veraison by removing old and yellow leaves. Leaf pulling should be avoided at or after veraison as this may lead to fruit sunburn.

Step 5—Shoot Hedging and Skirting

Shoot hedging consists of cutting shoots that grow beyond the allocated space in a given trellis system in order to control shoot length. It is called *hedging* for upward shoot training, such as on a VSP system (Figure 32), and *skirting* for downward shoot training, such as on a high cordon (HC) system.

Shoot hedging may be required for VSP systems and upper canopies of Scott Henry (SH) and Smart Dyson (SD) systems. High cordon (HC) and GDC systems do not usually require skirting unless shoot tips interfere with traffic in row middles. In general, a minimum of 12 to 15 leaves per shoot should be left after hedging in order to mature the fruit and wood.

***When*:** Shoot hedging is performed when shoots grow beyond the trellis space and desired length—about 3.5 feet for VSP and about 5 feet for HC and GDC. The amount of summer rain will determine the number of hedging passes (typically one to three passes). However, do not hedge shoots after veraison, since this may result in delay of fruit maturity and reduces wood maturity and thus winter hardiness.

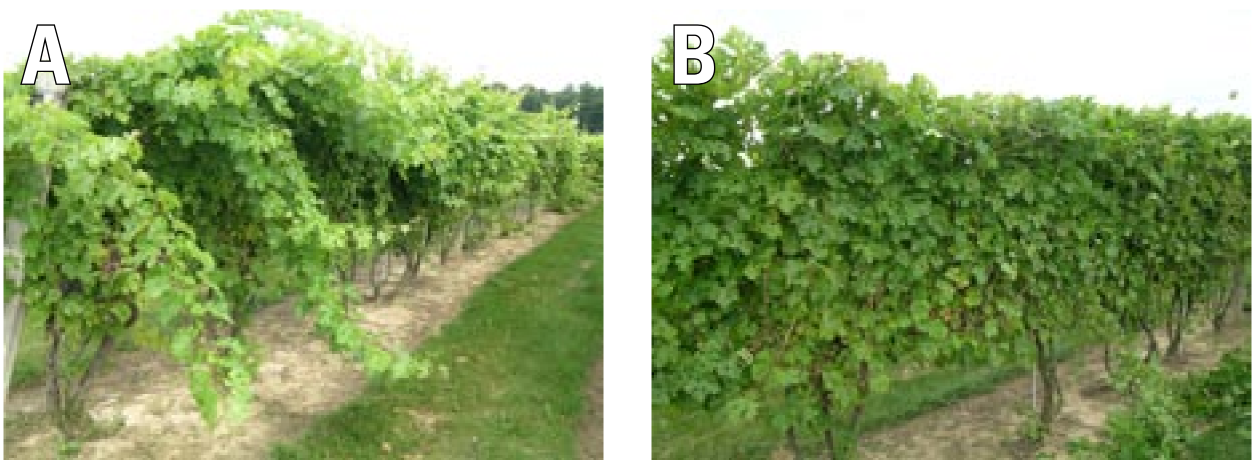

Figure 32. Shoot hedging of VSP-trained vines. Before (A) and after (B) hedging. Note fruit zone is exposed after hedging.

Integrated Management of Grape Diseases

Diseases represent a major threat to the commercial production of grapes in the Midwest. Climatic conditions are conducive to the development of several major grape diseases, including black rot, downy mildew, and powdery mildew. Each of these diseases has the potential to destroy the entire crop under the proper environmental conditions. In addition, there are several other diseases (Phomopsis cane and leaf spot, Botrytis gray mold, Eutypa dieback and crown gall) that can also result in economic loss. It is important to note that most of these diseases can occur simultaneously within the same vineyard during the growing season.

The development and implementation of Integrated Pest Management (IPM) programs for grapes has great potential for improving our current pest control strategies and reducing our use of pesticides in general. Much of the potential for reducing pesticide use will be in the area of insect control. Many of the IPM methods for monitoring and controlling insects give the grower more flexibility in the decision-making process as to whether insecticides are needed, which insecticides to apply, and when to apply them.

Our currently available disease-management programs and recommendations have much less flexibility, and the level to which we will be able to reduce fungicide use is largely limited by the degree of susceptibility of the cultivars being grown and environmental conditions during the growing season (the most important of which is wet rainy weather). The introduction of new fungicide chemistry, such as the sterol inhibitors or SIs (Bayleton, Rubigan, and Nova), and the strobilurin fungicides (Abound, Sovran, and Pristine), as well as new information related to the disease cycles of the various pathogens are providing opportunities for new disease control strategies that can be implemented in IPM programs.

Developing a disease-management program that successfully controls all of the important grape diseases simultaneously presents a unique challenge. In order to accomplish this, all available control methods must be **integrated** into one overall disease-management program. The disease management program should emphasize the integrated use of disease resistance, various cultural practices, knowledge of disease biology, and the use of approved fungicides or biological control agents or products when necessary.

Identifying and Understanding the Major Grape Diseases

It is important for growers to be able to recognize the major grape diseases. Proper disease identification is critical to making the correct disease-management decisions. In addition, growers should develop a basic understanding of pathogen biology and disease cycles for the major grape diseases. The more one knows about the disease, the better equipped one is to make sound and effective management decisions. Color photographs of disease symptoms on grapes, as well as in-depth information on pathogen biology and disease development, can also be found in these publications:

Compendium of Grape Diseases—Published by the American Phytopathological Society, 3340 Pilot Knob Rd., St. Paul, MN 55121. Phone: 612-454-7250, 1-800-328-7560. This is the most comprehensive book on grape diseases available. All commercial growers should have a copy.

Midwest Small Fruit Pest Management Handbook. Bulletin 861, Ohio State University Extension. Can be obtained from Ohio State University Extension, Media Distribution, 2021 Coffey Road, Columbus, OH 43210-1044. Phone 614-292-1607.

A description of symptoms and disease cycles for the most common grape diseases in the Midwest is presented here.

Black Rot

Symptoms and Disease Cycle (Figure 33)

Black rot is caused by the fungus *Guidnardia bidwellii*. The fungus overwinters in mummified fruit on the vine or on the ground. Spring rains trigger the release of airborne ascospores and/or rain splashed conidia from the mummies. Primary infections occur on green tissues if temperatures and duration of leaf wetness are conducive (Table 13). Recent research indicates that the majority of ascospores from mummies on the ground are discharged within a time period from 1-inch shoot growth to two to three weeks after bloom. If mummies are allowed to hang on the vines, they can discharge ascospores and conidia throughout the growing season.

In conventional production systems, black rot is controlled primarily through the use of effective fungicides combined with various cultural practices. Black rot may be particularly important in organic production systems because the organically approved fungicides (copper and sulfur) are not very effective for black rot control. Growers should develop a thorough understanding of the black rot

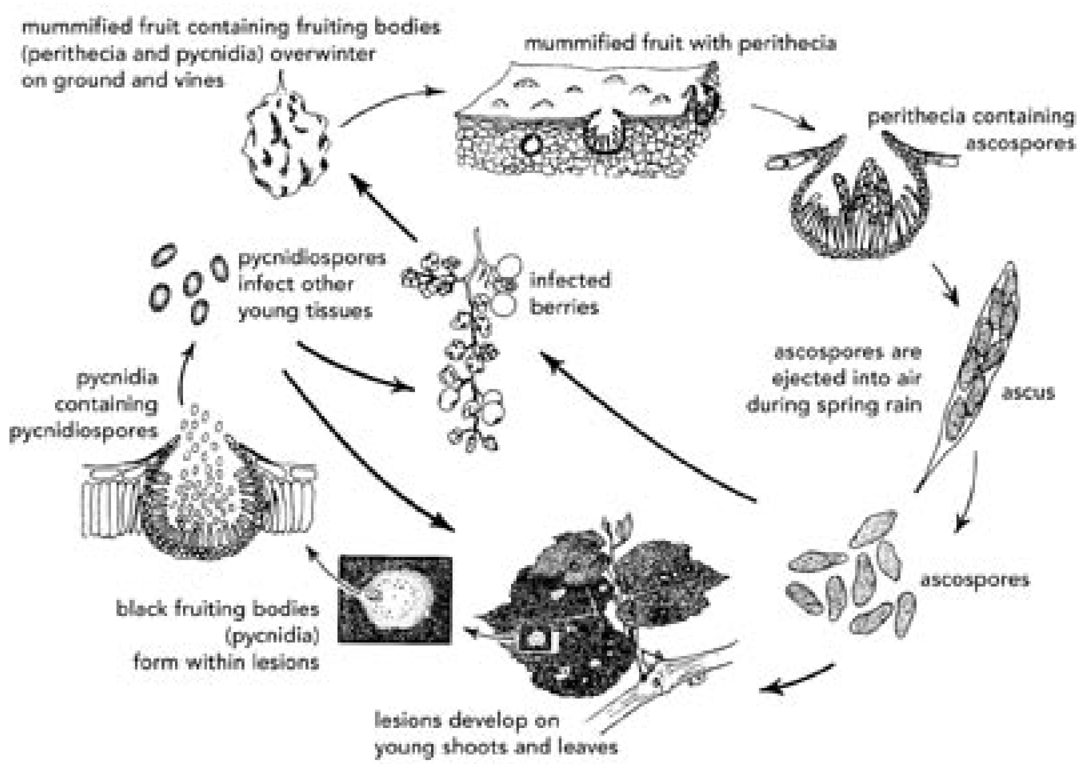

FIGURE 33. Black rot disease cycle. Used with permission of the New York State Agricultural Experiment Station, Cornell University. Figure taken from Grape IPM Disease Identification Sheet No. 4.

Table 13. Grape Black Rot. Leaf Wetness Duration-Temperature Combinations Necessary for Grape Foliar Infection by Black Rot.

Temperature °F	Minimum Leaf Wetness Duration (Hr) for Light Infection
50	24
55	12
60	9
65	8
70	7
75	7
80	6
85	9
90	12

* Data represent a compilation from several experiments with the cultivars Concord, Catawba, Aurora, and Baco noir.

disease cycle and the cultural practices used to control it.

Lesions on canes from the previous season can also produce conidia for a period of at least one month starting at budbreak. Cane lesions are probably most important in mechanically pruned or hedged vineyards that have an abundance of canes in the canopy. All green tissues of the vine are susceptible to infection. Leaves are susceptible for about one week after they reach full size.

Brown circular lesions develop on infected leaves about nine to 11 days after infection (Figure 34). Within a few days, black spherical fruiting bodies (pycnidia) form within the lesions (Figure 35). The pycnidia are often arranged in a ring pattern just inside the margin of the lesion. Each one of these pycnidia can produce a second type of spore (conidium). These conidia are spread by rain splash and can cause secondary infections of leaves throughout the growing season and on fruit through about two to four weeks after bloom.

FIGURE 34. Black rot lesions on grape leaf.

FIGURE 35. Close-up of black rot leaf lesions showing fungal fruiting bodies (pycnidia).

It is important to emphasize that a single ascospore can cause a primary infection (leaf lesion). Within each leaf lesion (primary infection), many pycnidia form. Each pycnidium can produce hundreds of thousands of conidia, each of which can cause another infection (secondary infection) later in the season. Therefore, it is extremely important to control the early season primary infections caused by ascospores. Infection by one ascospore can result in the development of millions of secondary conidia in the vineyard.

Lesions may also develop on young shoots, cluster stems (rachis), and tendrils. These lesions are usually purple to black, oval-shaped, and sunken. Pycnidia also form on these lesions.

The fruit infection phase of the disease can result in serious economic loss (Figure 36). Berries are susceptible to the infection from bloom until shortly after bloom. Older literature reports that berries become resistant when they reach 5% to 8% sugar. Research in New York indicates that berries become resistant to black rot much earlier (three to four weeks after bloom). Therefore, the most critical time to control black rot fruit infections with fungicide is from immediately prior to bloom through three to four weeks after bloom.

An infected berry first appears light brown in color. Soon the entire berry turns dark brown, and then black pycnidia develop on its surface. Infected berries eventually turn into shriveled, hard, black mummies (Figure 37). These mummies also serve as a source of secondary inoculum later in the growing season and are the primary means by which the fungus overwinters.

The Bottom Line for Black Rot Control

Sanitation is critical to successful black rot control. Mummies are the most important overwintering source of the black rot fungus. If all mummies and infected canes are removed

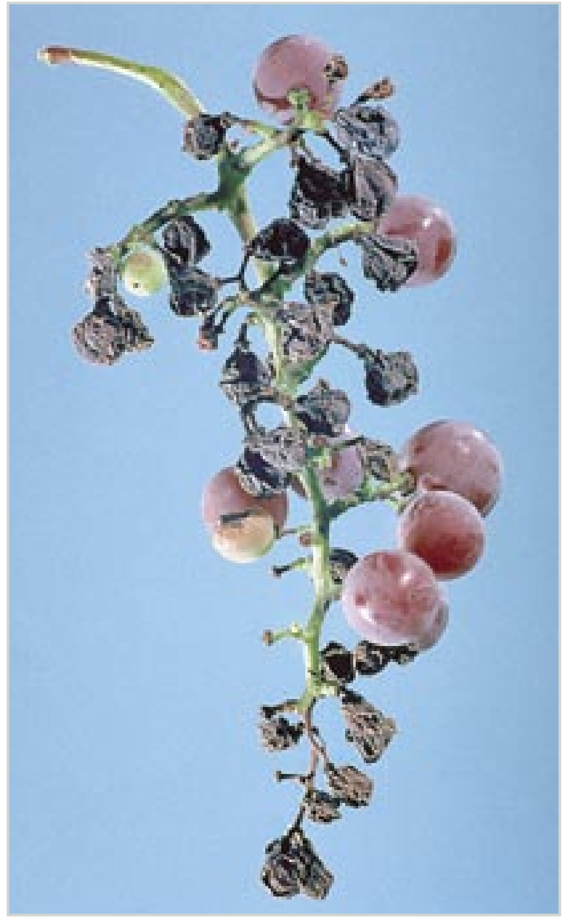

FIGURE 36. Black rot symptoms on berries.

FIGURE 37. Close-up of black rot mummy.

from the vineyard, there is no source of primary inoculum in the spring and, thus, the disease is controlled. Any practice that removes mummies and other infected material from the vineyard will be beneficial to the disease-management program.

If all mummies cannot be removed from the vineyard, it is ***extremely important*** that they are not left hanging in the trellis. As mentioned previously, mummies on the ground appear to discharge their ascospores early in the season, while those hanging in the trellis may discharge ascospores and conidia throughout the growing season. The most critical period to control black rot with fungicide is from immediate prebloom through three to four weeks after bloom.

Powdery Mildew

Powdery mildew is caused by the fungus *Uncinula necator*. If not controlled on susceptible cultivars, the disease can reduce vine growth, yield, quality, and winter hardiness. Cultivars of *Vitis vinifera* and its hybrids (French hybrids) are generally much more susceptible to powdery mildew than are native American cultivars such as Concord (see Table 14 on page 84-85). On susceptible cultivars, the use of fungicides to control powdery mildew is an important part of the disease-management program. Failure to provide adequate control of powdery mildew early in the growing season can result in increased levels of other fruit rots such as Botrytis bunch rot and sour rot.

Symptoms and Disease Cycle (Figure 38)

The fungus can infect all green tissues of the grapevine. Disease losses due to fruit infection can be severe and can result in complete loss of the crop (Figure 39). It was previously thought that the fungus overwintered inside dormant buds of the grapevine. Research in New York

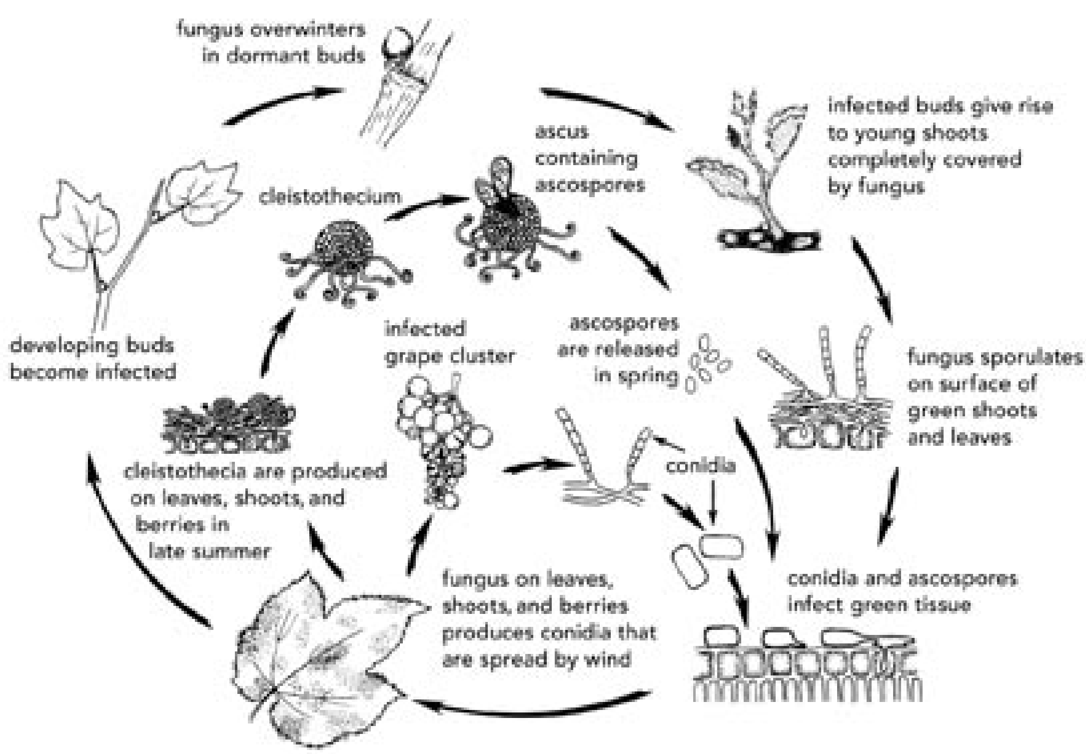

FIGURE 38. Powdery mildew disease cycle. Photo used with permission of the New York State Agricultural Experiment Station, Cornell University. Figure taken from Grape IPM Disease Identification Sheet No. 2.

FIGURE 39. Powdery mildew symptoms on grape berries (top) and Rachis (cluster stem) (bottom).

has shown that almost all overwintering inoculum comes from cleistothecia, which are fungal fruiting bodies that overwinter primarily in bark crevices on the grapevine. In the spring, airborne spores (ascospores) released from the cleistothecia are the primary inoculum for powdery mildew infections.

NOTE: Ascospore discharge from cleistothecia is initiated if 0.10 inch of rain occurs at an average temperature of 50°F. Most mature ascospores are discharged within four to eight hours. These conditions can occur very early in the growing season. Thus, on highly susceptible cultivars, control needs to be initiated early in the growing season.

Ascospores are carried by wind. They germinate on any green surface on the developing vine, resulting in primary infections. The fungus grows and another type of spore (conidium) is formed over the infected area after six to eight days. The conidia and fungal mycelia give a powdery or dusty appearance to infected plant parts (Figure 40). Severely affected leaves may curl upward during hot dry weather. Young expanding leaves that are infected may become distorted and stunted (Figure 41). The conidia serve as secondary inoculum for new infections throughout the remainder of the growing season.

It is important to note that a primary infection caused by one ascospore will result in the production of hundreds of thousands of conidia, each of which is capable of causing secondary infections. Therefore, early season control of primary infections caused by ascospores is necessary. If primary infections are controlled until all the ascospores have been discharged, the amount of inoculum available for causing late-season (secondary) infections is greatly reduced. On young shoots, infections are more likely to be limited, and they appear as dark-brown to black patches that remain as dark patches on the surface of dormant canes.

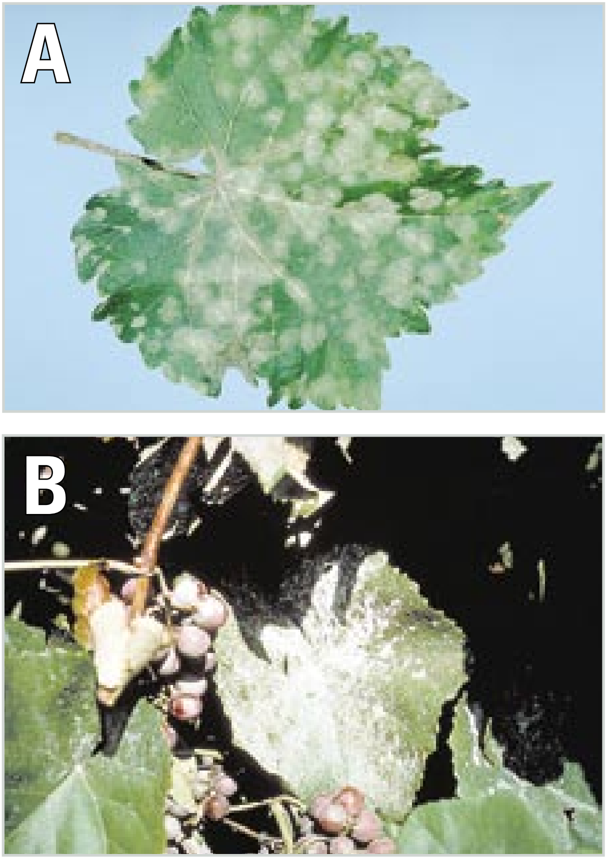

FIGURE 40. Powdery mildew. Primary infections of powdery mildew on grape leaf (A) and powdery mildew covering grape leaf surface (B).

Most economic losses from powdery mildew result from fruit infection. Infected berries often are misshapen or have rusty spots on the surface. Severely affected fruit often split open. When berries of purple or red cultivars are infected as they begin to ripen, they fail to color properly and have a blotchy appearance at harvest. Research in New York has shown that berries are susceptible to infection from bloom through a few weeks after bloom. Berries of Concord grapes are quite resistant within two to three weeks after bloom. Therefore, the most critical time to control fruit infection with fungicide is from immediately prior to bloom through two to four weeks after bloom. Even though the berries become resistant with age, cluster stems (rachis) and leaves remain susceptible throughout the season. Therefore, a full-season fungicide program is generally required for powdery mildew control on susceptible cultivars.

Conditions That Favor Disease Development

Although infection can occur at temperatures from 59° to 90°F, temperatures of 68° to 77°F are optimal for infection and disease development. Temperatures above 95°F inhibit germination of conidia and above 104°F they are killed. High relative humidity is conducive to production of conidia. Atmospheric moisture in the 40% to 100% relative humidity range is sufficient for germination of conidia and infection. Free moisture, especially rainfall, is detrimental to the survival of conidia. This is in contrast to most other grape diseases, such

FIGURE 41. Powdery mildew infections on young grape leaves can result in distortion of the leaves.

as black rot and downy mildew, that require free water on the plant surface before the fungal spores can germinate and infect. Low, diffuse light seems to favor powdery mildew development. Under optimal conditions, the time from infection to production of conidia is only about seven days.

It is important to remember that powdery mildew can be a serious problem during growing seasons when it is too dry for most other diseases, such as black rot or downy mildew, to develop. Thick canopies that retain high levels of relative humidity are highly conducive to infections in the center of the row canopy.

Cleistothecia are formed on the surface of infected plant parts in late fall. Many of them are washed into bark crevices on the vine trunk where they overwinter to initiate primary infections during the next growing season.

Phomopsis Cane and Leaf Spot

For many years, the Eastern grape industry recognized a disease called dead-arm, which was thought to be caused by the fungus *Phomopsis viticola*. In 1976, researchers demonstrated that the dead-arm disease was actually two different diseases that often occur simultaneously. Phomopsis cane and leaf spot is the name for the cane-and-leaf-spotting phase of what was once known as dead-arm. Eutypa dieback is the name for the canker-and-shoot-dieback phase of what was also once known as dead-arm. The name dead-arm has been dropped. Growers should remember that Phomopsis cane and leaf spot and Eutypa dieback are distinctly different diseases and their control recommendations vary greatly.

Disease incidence of Phomopsis cane and leaf spot appears to be increasing in many vineyards throughout the Midwest. Crop losses up to 30% have been reported in some Ohio vineyards in growing seasons with weather conducive to disease development. The most commonly observed symptoms are on shoots where infections give rise to black spots or elliptical lesions that are most numerous on the first three to four basal internodes. Although this phase of the disease can appear quite severe, crop loss due to shoot infections has not been demonstrated. Heavily infected shoots are more prone to wind damage.

Although shoot infections may not result in direct crop loss, lesions on shoots serve as an extremely important source of inoculum for cluster stem (rachis) and fruit infections in the spring. Rachis and fruit infection is the phase of the disease that causes most economic loss.

Symptoms and Disease Cycle (Figure 42)

Phomopsis cane and leaf spot is caused by the fungus *Phomopsis viticola*. The fungus overwinters in lesions or spots on one- to three-year-old wood infected during previous seasons. It requires cool weather and rainfall for spore (conidia) release and infection. Conidia are released from pycnidia (fungal fruiting bodies) in early spring and are spread by rain to developing shoots and leaves. Shoot and leaf infection (Figures 43 and 44) is most likely during the period from bud break until shoots are 6 to 8 inches in length. Lesions appear three to four weeks after infection.

The critical period for fruit and rachis infection (Figure 45) is also early in the season. The rachis and young fruits are susceptible to infection throughout the growing season; however, most infections appear to occur early in the growing season. The fungus does not appear to be active during warm summer months, and most or all of its primary inoculum is probably released and expended early in the growing season. Thus, the critical period to provide fungicide protection for fruit and rachis infection is probably from when the clusters are first exposed until two to four weeks after bloom.

The tiny green fruits that are infected during this critical period may appear to remain

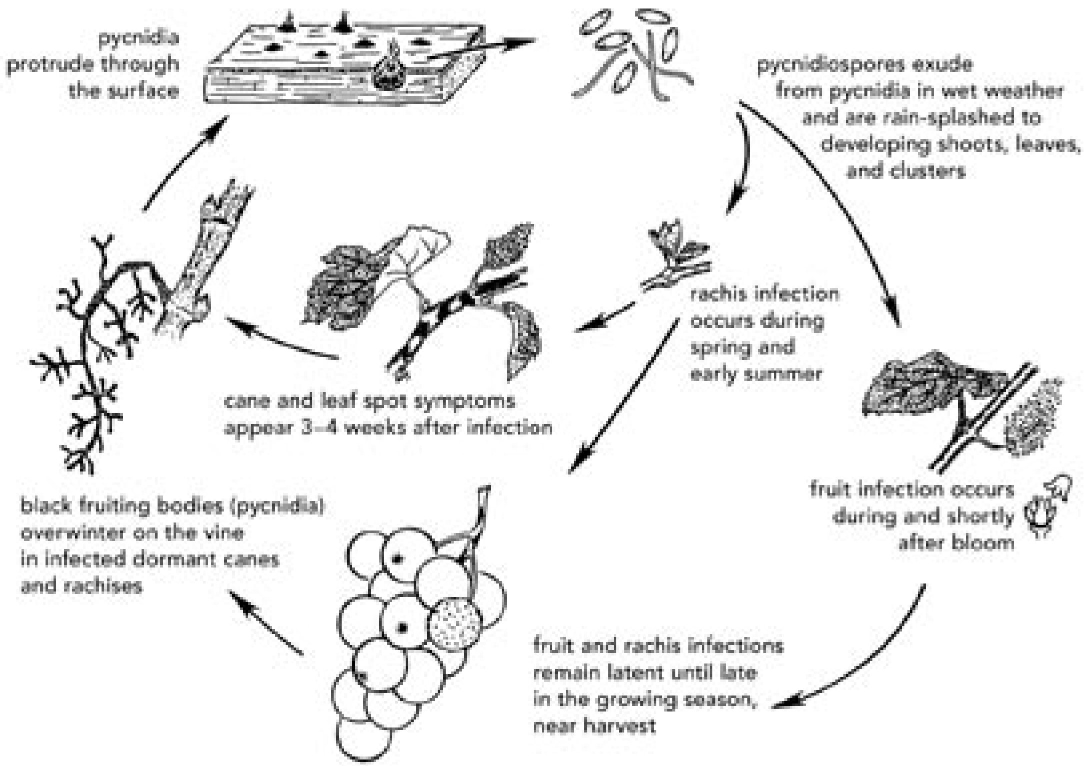

FIGURE 42. Phomopsis cane and leaf spot disease cycle. Used with permission of the New York State Agricultural Experiment Station, Cornell University. Figure taken from Grape IPM Disease Identification Sheet No. 6.

normal. The fungus remains inactive in these fruits as a latent infection. Not until the fruit starts to ripen near harvest does the fungus become active and cause the fruit to rot. Therefore, fruit rot that appears at harvest is probably due to infections that occurred during or shortly after bloom.

Fruit rot first appears close to harvest as a light-brown color. Black, spore-producing structures of the fungus (pycnidia) then break through the berry skin, and the berry soon shrivels.

At this advanced stage, Phomopsis fruit rot can be easily mistaken for black rot. Growers should remember that the black rot fungus does not infect berries late in the growing season, and black rot symptoms develop long before harvest. Berries become resistant to black rot infection by three to four weeks after bloom. Fruit rot symptoms caused by Phomopsis generally do not appear until harvest. Although the fungus does not appear

FIGURE 43. Phomopsis cane and leaf spot symptoms on internodes and rachis.

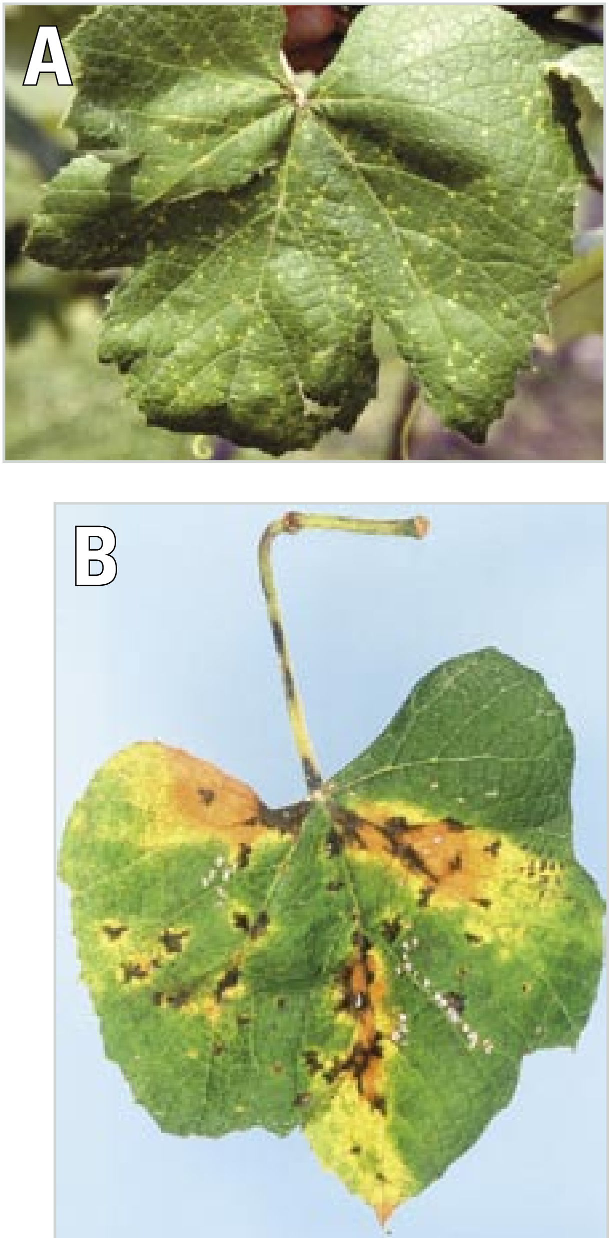

FIGURE 44. Phomopsis symptoms on young grape leaf (A) and old grape leaf (B).

to be active during the warm summer months, it can become active during cool, wet weather later in the growing season.

Downy Mildew

Downy mildew is a major disease of grapes throughout the eastern United States. The

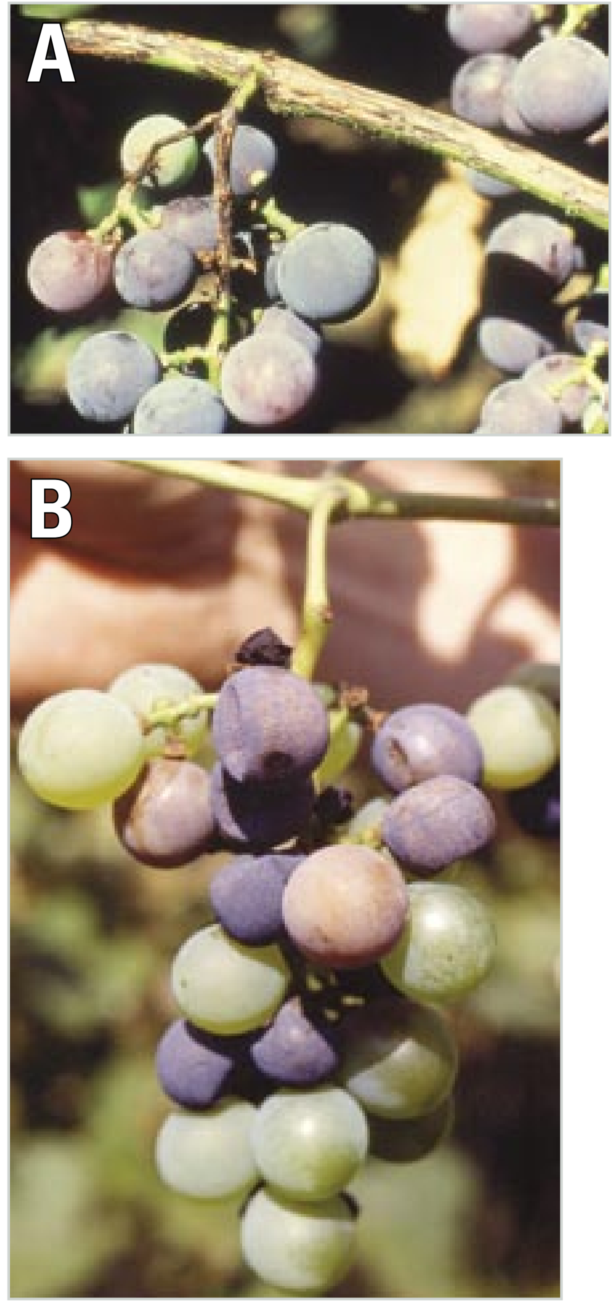

FIGURE 45. Phomopsis rachis infection (A) and fruit rot (B) on grape.

fungus causes direct yield losses by rotting inflorescences, clusters (Figure 46), and shoots. Indirect losses can result from premature defoliation. Premature defoliation is a serious problem, because it predisposes the vine to winter injury. It may take a vineyard several years to fully recover after severe winter injury. In general, vinifera (*Vitis vinifera*) cultivars are

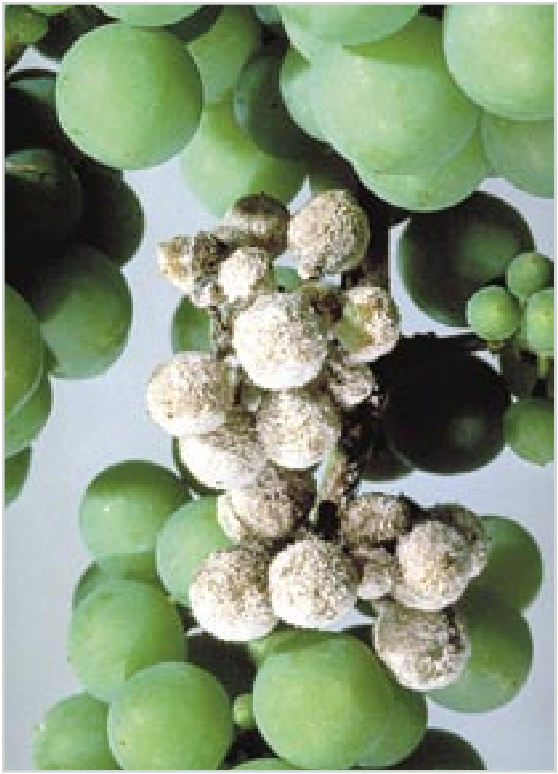

FIGURE 46. Downy mildew fruit infection.

much more susceptible than American types; the French hybrids are somewhat intermediate in susceptibility (see Table 14 on page 84-85).

Symptoms and Disease Cycle (Figure 47)

Downy mildew is caused by the fungus *Plasmopora viticola*. The causal fungus overwinters as tiny oospores in leaf debris on the vineyard floor. In the spring, the oospores serve as primary inoculum and germinate in water to form sporangia. The sporangia liberate small swimming spores, called zoospores, when free water is present. The zoospores are disseminated by rain splash to grape tissues where they swim to the vicinity of stomata and encyst. Stomata are tiny pores through which the plants exchange air, and transpiration occurs. Stomata are concentrated on the underside of the leaves. Encysted zoospores infect grape tissues by forming germ tubes that enter stomata and from there invade inner tissues of the plant. The fungus can

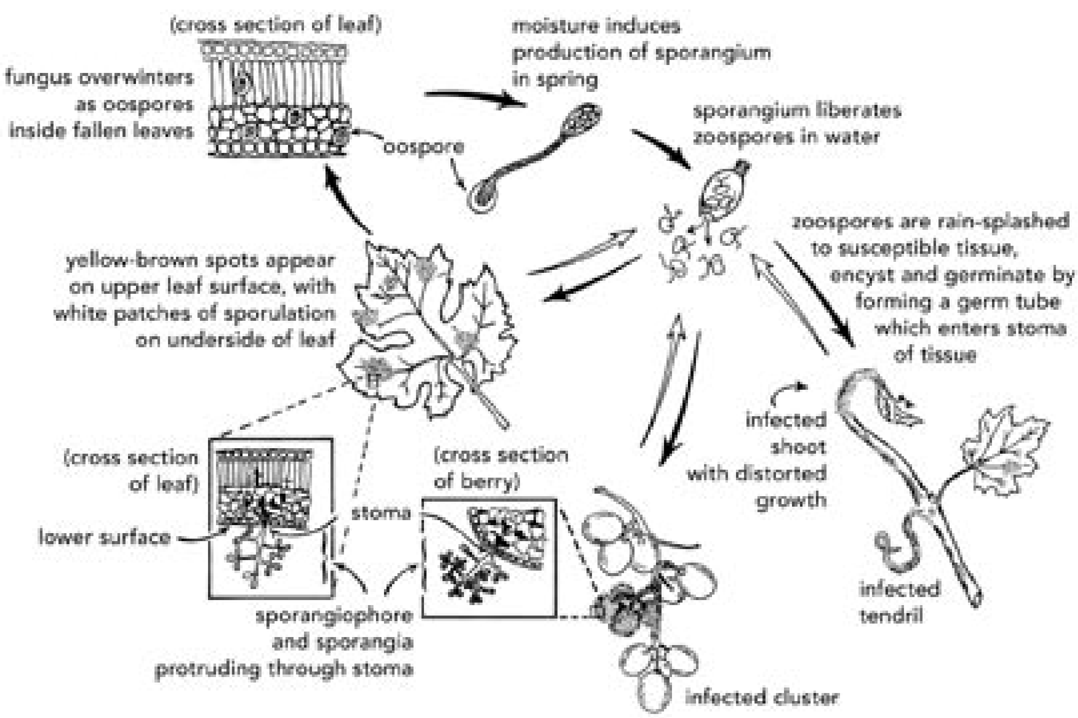

FIGURE 47. Downy mildew disease cycle. Used with permission of the New York State Agricultural Experiment Station, Cornell University. Figure taken from Grape IPM Disease Identification Sheet No. 5.

infect all green, actively growing parts of the vine that have mature, functional stomata.

Infected leaves develop yellowish-green lesions on their upper surfaces (Figure 48) seven to 12 days after infection. As lesions expand, the affected areas turn brown, necrotic, or mottled (Figure 49). At night, during periods of high humidity and temperatures above 55°F, the fungus sporulates by forming sporangia on numerous branched structures, called sporangiophores, that protrude out through stomata on the undersides of the leaf. Sporulation only occurs on plant surfaces that contain stomata, such as the underside of leaves, and it gives the surface of the lesion its white, downy appearance, which is characteristic of the disease (Figure 50). The sporulation (downy growth) generally occurs directly below the yellowish-green spots that develop on the upper surface of the leaf.

Sporangia are disseminated by wind or rain splash. On susceptible tissue they liberate zoospores into water films formed by rain or

FIGURE 48. Downy mildew symptoms on upper leaf surface.

FIGURE 49. Downy mildew-affected areas turn brown, necrotic, or mottled with age later in the growing season.

FIGURE 50. Downy mildew symptoms on lower leaf surface. The patches of downy growth are usually directly beneath the yellowish-green spots observed on the upper leaf surface.

dew. These zoospores initiate secondary infections, which can occur in as little as two hours of wetting at 77°F or up to nine hours at 43°F. Infections are usually visible as lesions in about seven to 12 days, depending on temperature and humidity. The number of secondary infection cycles depends on the frequency of suitable wetting periods that occur during the growing season and the presence of susceptible grape tissue. In general, Catawba, Chancellor, Chardonnay, Delaware, Fredonia, Ives, Niagara, White Riesling, and Rougeon are highly susceptible cultivars (see Table 14 on page 84-85).

Severely infected leaves may curl and drop from the vine. The disease attacks older leaves in late summer and autumn, producing a mosaic of small, angular, yellow to red-brown spots on the upper leaf surface. Lesions commonly form along leaf veins, and the fungus sporulates in these areas on the lower leaf surface. When young shoots, petioles, tendrils, or cluster stems are infected, they frequently become distorted, thickened, or curled. White, downy sporulation can be abundant on the surface of infected areas. Eventually, severely infected portions of the vine wither and die.

Infected green fruit turn light brown to purple, shrivel, and detach easily. White, cottony sporulation is abundant on these berries during humid weather. The fruits remain susceptible as long as stomata on their surfaces are functional. After that, new infections and sporulation do not develop.

Recent research indicates that fruit become resistant to infection by downy mildew about three to four weeks after bloom. Although fruit become resistant shortly after bloom, cluster stems (rachis) and leaves remain susceptible throughout the growing season. Later in the season, some berries that were infected earlier in the growing season may turn dull green to reddish purple, remain firm, and are easily distinguished from non-infected ripening berries in a cluster. Infected berries are easily detached from their pedicels leaving a dry stem scar.

Throughout most of the Midwest, downy mildew symptoms often do not appear until after bloom. This is why we often refer to it as a late-season disease. The role of oospores in causing early season primary infections is not clearly defined. Although we emphasize the use of fungicides for downy mildew control after bloom, early season fungicide applications are very important. Especially on highly susceptible cultivars, the early season fungicide program should contain a fungicide effective against downy mildew. As with black rot and powdery mildew, the period from immediate prebloom through three to four weeks after bloom is critical for controlling fruit or cluster infections by downy mildew.

Botrytis Bunch Rot

Botrytis bunch rot (gray mold) is caused by the fungus *Botrytis cinerea*. The fungus causes blight of leaves, shoots, and blossom clusters and occurs throughout the viticultural world. The fungus causing the disease grows and reproduces on senescent or dead plant tissue. Botrytis bunch rot is especially severe in grape cultivars with tight, closely packed clusters of fruit. Botrytis is also responsible for storage losses of grapes picked for fresh market.

Symptoms

Botrytis infection of leaves begins as a dull, green spot, commonly surrounding a vein, which rapidly becomes a brown necrotic lesion. The fungus may also cause a blossom blight or a shoot blight, which can result in significant crop losses. However, the most common phase of this disease is the infection and rot of ripening berries (Figure 51).
Fruit rot can spread rapidly throughout the cluster. Infected berries of white cultivars often become brown and shriveled, and those of purple cultivars develop a reddish color. Under proper weather conditions, the

FIGURE 51. Botrytis bunch rot of grape.

FIGURE 52. Close-up showing the Botrytis fungus sporulating on infected berries.

fungus produces a fluffy, gray-brown growth containing spores (Figure 52).

Botrytis Bunch Rot Disease Cycle (Figure 53)

The fungus overwinters on debris in the vineyard floor and on the vine. The fungus produces small, dark, hard, resting structures called sclerotia. Sclerotia are resistant to adverse weather conditions and usually germinate in spring. Germinated sclerotia produce conidia, which spread the disease. Sporulation may also occur on debris left on the vine during the previous growing season, such as cluster stems remaining after mechanical harvest or mummified fruit.

The fungus usually gains a foothold by colonizing dead tissue prior to infection of healthy tissue. Tissue injured by hail, wind, birds, other diseases or insects is readily colonized by *Botrytis.* Ripe berries that split because of internal pressure or because of early season infection by powdery mildew, are especially susceptible to infection by *Botrytis. Botrytis* conidia are usually present in the vineyard throughout the growing season. Moisture in the form of fog or dew and temperatures of 59°F to 77°F are ideal for conidia production and infection. Rainfall is not required for disease development, although periods of rainfall are highly conducive to disease development.

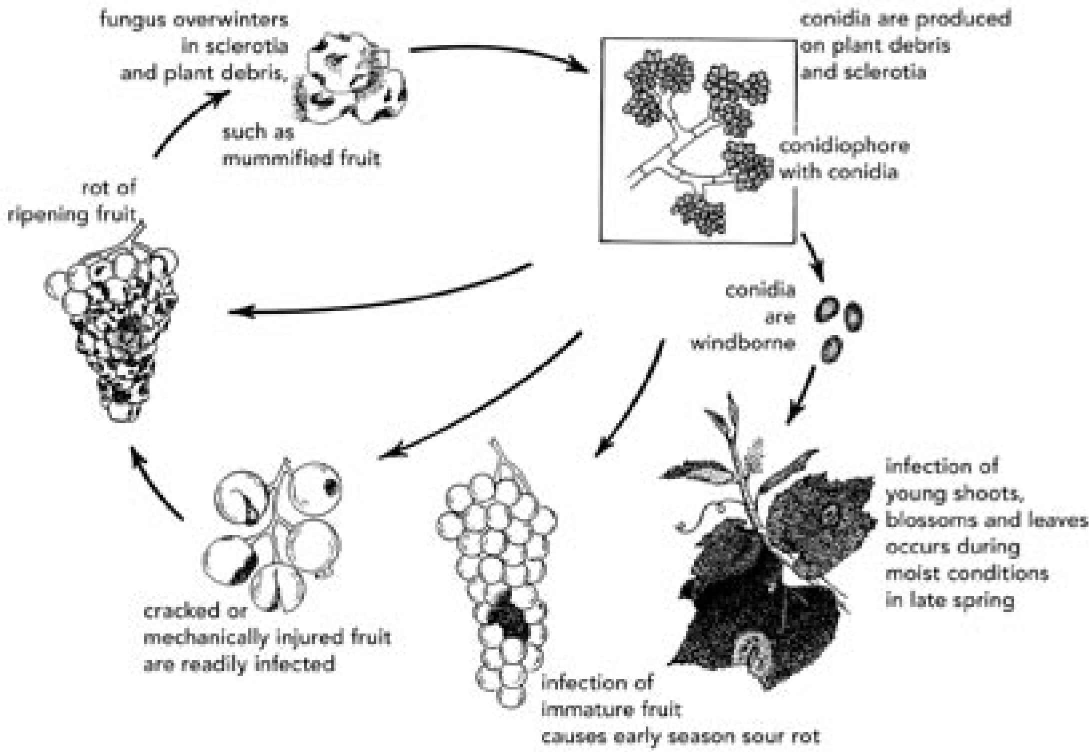

FIGURE 53. Botrytis bunch rot disease cycle. Used with permission of the New York State Agricultural Experiment Station, Cornell University. Figure taken from Grape IPM Disease Identification Sheet No. 3.

Eutypa Dieback

Eutypa dieback is caused by the fungus *Eutypa lata.* Eutypa dieback is the name for the canker-and-shoot-dieback phase of what was once known as dead-arm. The name dead-arm should be dropped.

Symptoms

The earliest symptom to develop is a canker that generally forms around pruning wounds in older wood of the main trunk (Figure 54). These cankers usually are difficult to see because they are covered with bark. One indication of a canker is a flattened area on the trunk. Removal of bark over the canker reveals a sharply defined region of darkened or discolored wood bordered by white, healthy wood. Cankers may be up to three-feet long and extend below the soil line (Figure 55).

FIGURE 54. Canker on Eutypa-infected vine.

When the trunk is cut in cross-section, the canker appears as darkened or discolored wood extending in a wedge shape to the center of the trunk (Figure 56).

The most striking and obvious symptoms of Eutypa dieback are the leaf-and-shoot symptoms (Figure 57), which may not develop for two to four years after the vine was first infected. These symptoms are most obvious in spring, when healthy shoots are 12- to 24-

FIGURE 55. Eutypa canker extending the entire length of the trunk.

FIGURE 56. Eutypa-infected trunk cut in cross section.

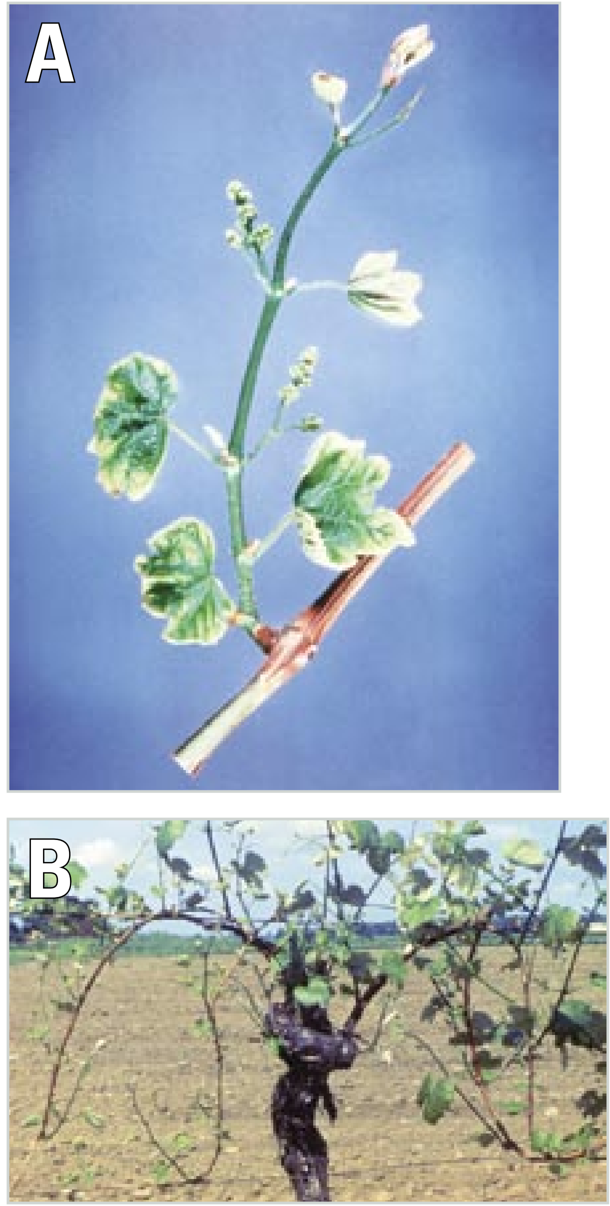

FIGURE 57. Close up of Eutypa symptoms on grape leaves (A); leaf symptoms on a Eutypa-infected grape vine (B). Note that symptoms may occur on some shoots, while others appear normal.

inches long. Spring shoot growth on diseased canes is weak and stunted above the cankered area. Leaves are at first smaller than normal, cupped, distorted, and yellow. These leaf and shoot symptoms may not be as obvious later in the season (mid July). Leaf and shoot symptoms are more pronounced each year until the affected portion of the vine finally dies.

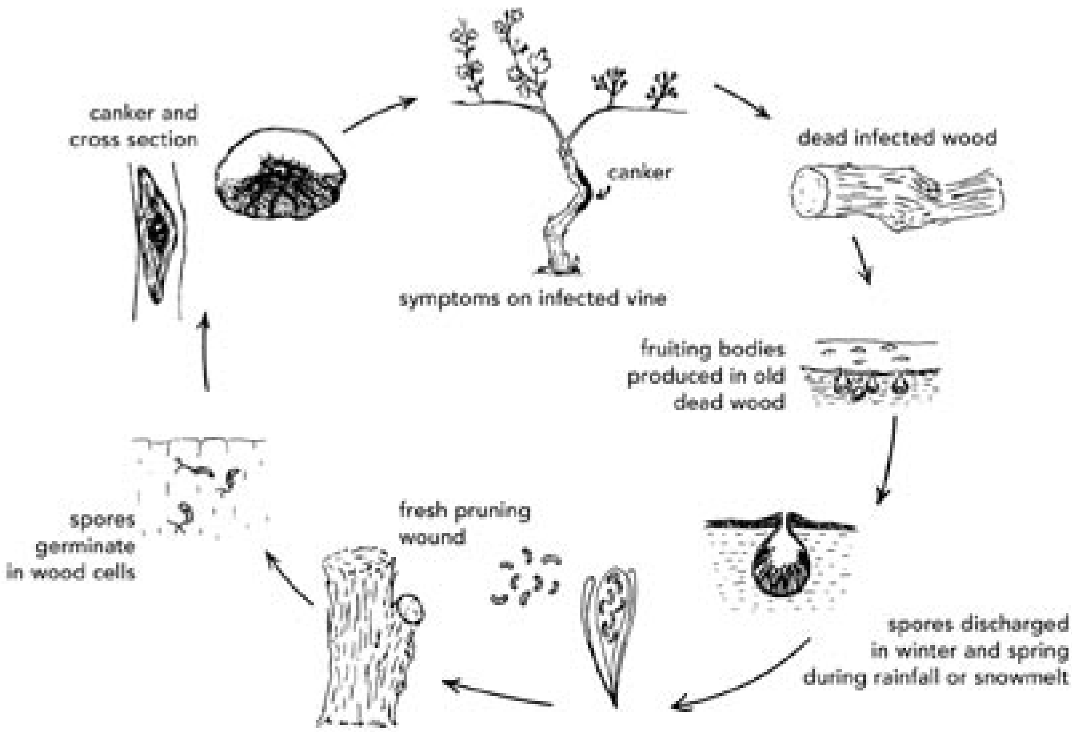

FIGURE 58. Eutypa dieback disease cycle. Photo used with permission of the New York State Agricultural Experiment Station, Cornell University. Figure taken from Grape IPM Disease Identification Sheet No. 1.

Eutypa Dieback Disease Cycle (Figure 58)

The fungus survives in infected trunks for long periods, whether as part of the in-place vine or as old, dead grape wood in the vineyard. The fungus is generally present in older wood, such as vine trunks, but generally not in younger wood, such as one- or two-year-old prunings.

The fungus eventually produces reproductive structures (perithecia) on the surface of infected wood. Spores (ascospores) are produced in these structures and discharged into the air. Ascospore discharge is initiated by the presence of free water (rainfall or snow melt). Most spores appear to be released during winter or early spring; few are released during the summer.

Unfortunately, most spores are released at about the same time pruning is being conducted. Air currents can carry the ascospores long distances to fresh wounds on the trunk. Pruning wounds are by far the most important points of infection. The ascospores germinate when they contact the newly cut wood, and a new infection is initiated. Stunted shoots and small, cupped leaves appear two to four years after infection. After approximately five years, the fungus produces perithecia and ascospores in the dead wood on cankers.

Control of Eutypa Dieback

The primary control method is removal of infected trunks from the vineyard. The vine must be cut off below the cankered or discolored wood. If the canker extends below the soil line, the entire vine must be removed. If the canker does not go below the soil line, the stump can be left and a new trunk formed. The best time to identify and remove infected vines is in early spring (May and June) when leaf and shoot symptoms are most obvious. In addition, large wounds are less susceptible to infection at this time of year, and fewer ascospores are present to cause reinfection. If trunks cannot be removed in the spring, they should be marked for easy identification and removal later in the growing season.

Sanitation is critical. All wood (especially trunks and stumps) from infected plants must be removed from the vineyard and destroyed (either buried or burned) as soon as possible. An old infected stump or trunk lying on the ground may continue to produce spores for several years.

The double trunk system of training, where each trunk is pruned to carry half the number of buds, may help reduce crop loss caused by Eutypa dieback. If a diseased trunk must be removed, the remaining trunk can be pruned to leave the full number of buds until a new second trunk can be established.

Fungicide recommendations currently are not available for control of this disease.

Anthracnose

Anthracnose of grape was first detected in the United States in the mid 1800s. The disease was probably introduced into this country by grape plant material imported from Europe. It quickly established in American vineyards and became a significant disease of grape in rainy, humid, and warm regions of the United States. Anthracnose reduces the quality and quantity of fruit and weakens the vine. Once the disease is established in a vineyard, it can be very destructive.

Symptoms

All succulent parts of the plant, including fruit stems, leaves, petioles, tendrils, young shoots, and berries, can be attacked, but lesions on shoots and berries are most common and distinctive. Symptoms on young, succulent shoots first appear as numerous small, circular, and reddish spots. Spots then enlarge, become sunken, and produce lesions with gray centers

FIGURE 59. Anthracnose symptoms on grape cane.

and round or angular edges (Figure 59). Dark reddish-brown to violet-black margins eventually surround the lesions. Lesions may coalesce, causing a blighting or killing of the shoot.

A slightly raised area may form around the edge of the lesion. Infected areas may crack, causing shoots to become brittle. Anthracnose lesions on shoots may be confused with hail injury; however, unlike hail damage, the edges of the wounds caused by the anthracnose fungus are raised and black. In addition, hail damage generally appears on only one side of the shoot, whereas anthracnose is more generally distributed. Anthracnose on petioles appears similar to that on the shoots.

Leaf spots are often numerous and develop in a similar manner to those on shoots. Eventually, they become circular with gray centers and brown to black margins with round or angular edges. The necrotic center of the lesion often drops out, creating a shot-hole appearance (Figure 60). Young leaves are more susceptible to infection than older leaves. When veins are affected, especially on young leaves, the lesions prevent normal development, resulting in malformation or complete drying or burning of the leaf. Lesions may cover the entire leaf blade or appear mainly along the veins.

On berries, small, reddish circular spots initially develop. The spots then enlarge to an

FIGURE 60. Anthracnose symptoms on grape leaf.

average diameter of 1/4 inch and may become slightly sunken. The centers of the spots turn whitish gray and are surrounded by narrow reddish-brown to black margins (Figure 61). This typical symptom on fruit often resembles a bird's eye, and the disease has been called bird's eye rot. Acervuli (fungal fruiting structures) eventually develop in the lesions. A pinkish mass of fungal spores (conidia) exudes from these structures during prolonged wet weather.

Causal Organism

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

Another type of spore, called an ascospore, is produced within sexual fruiting bodies and

FIGURE 61. Anthracnose symptoms on grape berry. Note that the lesion resembles a bird's eye.

may also form on infected canes and berries left on the ground or in the trellis from the previous year. The importance of ascospores in disease development is not clearly understood.

Conidia are by far the most important source of primary inoculum in the spring. In early spring, when free moisture from rain or dew is present, conidia germinate and infect succulent tissue. Conidia germinate and infect at temperatures ranging from 36°F to 90°F. The higher the temperature, the faster disease develops. Disease symptoms start to develop approximately 13 days after infection occurs at 36°F and at four days after infection occurs at 90°F. Heavy rainfall and warm temperatures are ideal for disease development and spread.

Lesions may extend into the pulp and cause the fruit to crack. Lesions on the rachis and pedicels appear similar to those on shoots. Clusters are susceptible to infection before flowering and until veraison.

Once the disease is established, asexual fruiting bodies called acervuli form on diseased areas. These acervuli produce conidia during periods of wet weather. These conidia are the secondary source of inoculum and are responsible for continued spread of the fungus and the disease throughout the growing season.

Disease Management

1. Sanitation is very important. Prune out and destroy (remove from the vineyard) diseased plant parts during the dormant season. This includes infected shoots, cluster stems, and berries. This should reduce the amount of primary inoculum for the disease in the vineyard.

2. Eliminate wild grapes near the vineyard. The disease can infect wild grapes, and infected wild grapes have been observed near diseased vineyards in Ohio. Wild grapes provide an excellent place for the disease to develop and serve as a reservoir for the disease. It is probably impossible to eradicate wild grapes from the woods, but serious efforts should be made to at least remove them from the fence rows and as far away from the vineyard as possible. Remember, the spores are spread over relatively short distances by splashing rain and should not be able to move over long distances by wind into the vineyard.

3. Cultivars differ in their susceptibility. In Ohio the disease has been observed on Vidal and Reliance. Vinifera and French Hybrid cultivars may be more susceptible than American grapes, such as Concord and Niagara.

4. Canopy management can aid in disease control. Any practice that opens the canopy to improve air circulation and reduce drying time of susceptible tissue is beneficial for disease control. These practices include selection of the proper training system, shoot positioning, and leaf removal.

5. Fungicide use. Where the disease is established, especially in a commercial vineyard, the use of fungicides is recommended. Fungicide recommendations for anthracnose control consist of a dormant application of Liquid Lime Sulfur in early spring, followed by applications of foliar fungicides during the growing season.

Crown Gall

Crown gall is caused by the bacterium *Agrobacterium tumefaciens.* The disease infects more than 2,000 species of plants. Crown gall of grape is a major problem in cold climate regions. Wounds are necessary for infection to occur. Observations suggest that freeze injury wounds are highly conducive to infection. The disease is particularly severe following winters that result in freeze injury on cold-sensitive cultivars, such as those of *Vitis vinifera.*

Crown gall is characterized by galls or overgrowths that usually form at the base of the trunk. Galls form as high as 3-feet or more up the trunk (aerial galls). Galls generally do not form on roots. The disease affects all grape cultivars. Vines with galls at their crowns or on their major roots grow poorly and have reduced yields. Severe economic losses result in vineyards where a high percentage of vines become galled within a few years of planting.

Symptoms

The disease first appears as small overgrowths or galls on the trunk, particularly near the soil line. Early in their development, the galls are more or less spherical, white or flesh-colored, and soft. Because they originate in a wound, the galls at first cannot be distinguished from callus. However, they usually develop more rapidly than callus tissue. As galls age, they become dark brown, knotty, and rough (Figure 62).

When galls are numerous on the lower trunks or major roots, they disrupt the translocation of water and nutrients, which leads to poor growth, gradual dieback, and sometimes death of the vine. In some cases, infected vines appear stunted and as if they are suffering from nutrient deficiency.

FIGURE 62. Crown gall symptoms on grape trunk.

Life Cycle

The causal organism, a bacterium, is soil borne and persists for long periods in plant debris in the soil. Fresh wounds are required to infect and initiate gall formation. Wounds that commonly serve as infection sites are those made during pruning, machinery operations, freezing injury, or any other practice that injures the vine.

In addition to the primary galls, secondary galls may also form around other wounds and on other portions of the plant, even in the absence of the bacterium. Crown gall bacteria also survive systemically within grapevines and probably are most commonly introduced into the vineyard on or in planting material.

Control of Crown Gall

Examine new plants before planting and discard any that have galls. Wounding by freeze injury appears to be important in the development of crown gall. If winter injury is controlled, crown gall may not be an important problem. Prevent winter injury to vines. Practices, such as hilling or burying vines of cold-sensitive cultivars, is beneficial.

Proper pruning practices and proper crop loads for maximum vine vigor will result in stronger plants that are less susceptible to winter injury. Controlling other diseases, such as downy and powdery mildew, is also important in preventing winter injury and crown gall.

The double-trunk system of training, in which each trunk is pruned to carry half the number of buds, may help reduce crop loss caused by crown gall. If a diseased trunk must be removed, the remaining trunk can be pruned, leaving the full number of buds until a second trunk is established. Galls on arms or the upper parts of the trunk can be removed by pruning.

There are no current chemical or biological control recommendations for crown gall on grapes.

Use of Resistant Cultivars for Grape Disease Management

In an integrated disease-management program where emphasis is placed on reducing overall fungicide use, it is essential that any available disease resistance be identified and used. If resistance is not available, we should at least identify and **avoid** those cultivars that are highly susceptible to important diseases.

A few grape cultivars have high levels of resistance to most diseases. Norton (Cynthiana) is a cultivar that has great potential for organic production in the southern portion of the Midwest. It has good resistance to most diseases, and in several commercial plantings, growers rarely apply fungicides. It is hoped that new cultivars with improved levels of disease resistance will be introduced in the near future.

Unfortunately, resistance to most of the major diseases is not available in most commercially grown grape cultivars in the Midwest. Thus, the disease-management program must rely heavily on the use of cultural practices and efficient use of approved fungicides or biocontrol agents or products. Whereas resistance is generally not available for most diseases, some grape cultivars are known to be much more susceptible to certain diseases than others (Table 14). For example, the cultivar Chancellor is highly susceptible to downy mildew, whereas downy mildew is seldom a serious problem on Concord and several other cultivars.

Growers should consider disease susceptibility before establishing the vineyard. Segregating highly susceptible cultivars into blocks that can be easily treated separately allows growers to apply more fungicide or other control agents when needed for highly susceptible cultivars while reducing their use on less susceptible cultivars. In addition, cultivars differ greatly in their sensitivity to copper and sulfur fungicides. When planting the vineyard, it is important to isolate blocks of sensitive cultivars from those that will be sprayed with these materials.

Cultural Practices for Disease Control in Grapes

The use of any practice that reduces or eliminates pathogen populations or creates an environment within the planting that is less conducive to disease development should be used. Certain diseases, such as viruses, Eutypa dieback, and crown gall, cannot be directly controlled with pesticides at the present time. Therefore, cultural practices are the major means for their control. When fungicides or other control agents are required, any practice that opens the plant canopy, such as shoot thinning, leaf removal, berry and cluster thinning, and pruning and shoot positioning, can greatly increase the efficacy of the fungicide program by allowing better spray penetration and coverage. These practices also have a direct effect on vine microclimate.

Vine Microclimate

Vine microclimate refers to the climate within the leaf canopy of the vineyard. In relation to disease management, the most important elements of the vine microclimate are relative humidity, ventilation, the temperature of the air and of vine tissues, and the intensity and quality of light. In general, factors that increase relative humidity also increase fungal diseases. Factors that increase ventilation (air movement) of the vine canopy generally reduce disease incidence and severity by lowering the humidity, shortening periods of leaf and fruit wetness, and aiding spray penetration and coverage. Cultural practices should be carefully considered and implemented into the disease management program whenever possible. Here are some cultural practices to consider.

Use Virus-Indexed Planting Stock

Always start the planting with healthy virus-indexed nursery stock from a reputable nursery. The importance of establishing plantings with virus-indexed nursery stock cannot be overemphasized, since the selection of planting stock and planting site are the only actions a grower can take to prevent or delay the introduction of most virus diseases. Plants obtained from an unknown source or a neighbor may be contaminated with a number of major diseases that reputable nurseries work hard to avoid.

Table 14. Relative Disease Susceptibility and Sulfur and Copper Sensitivity Among Grape Cultivars.

Cultivar	BR	DM	PM	Bot	Phom	Eu	CG	ALS	Susceptible or Sensitive to S[1]	C[2]
Aurore	+++	++	++	+++	+	+++	++	+++	No	++
Baco noir	+++	+	++	++	+	++	+++	++	No	?
Cabernet Franc	+++	+++	+++	+	?	?	+++	?	No	?
Cabernet Sauvignon	+++	+++	+++	+	+++	+++	+++	?	No	+
Candice	+++	++	+	++	?	?	++	++	?	?
Cascade	+	+	++	+	++	++	+	?	No	?
Catawba	+++	+++	++	+	+++	+	+	+	No	++
Cayuga White	+	++	+	+	+	+	++	++	No	+
Chambourcin	+++	++	+	++	?	?	++	?	Yes	?
Chancellor	+	+++	+++	+	+++	+	+++	+++	Yes	+++
Chardonel	++	++	++	++	?	?	++	++	No	?
Chardonnay	++	+++	+++	+++	+++	++	+++	++	No	+
Chelois	+	+	+++	+++	+++	+++	++	+++	No	+
Concord	+++	+	++	+	+++	+++	+	+	Yes	+
Cynthiana/Norton	+	++	+	+	+	?	+	?	Yes	?
DeChaunac	+	++	++	+	+++	+++	++	+++	Yes	+
Delaware	++	+++[3]	++	+	+++	+	+	+	No	+
Dutchess	+++	++	++	+	++	+	++	+	No	?
Elvira	+	++	++	+++	+	+	++	++	No	++
Einset Seedless	+++	++	+++	+	?	?	+	?	?	?
Fredonia	++	+++	++	+	++	?	+	+	No	?
Frontenac	++	+	++	++	+	?	?	?	No	?
Gewurztraminer	+++	+++	+++	+++	?	?	+++	+	No	+
Himrod	++	+	++	+	?	?	?	+	No	?
Ives	+	+++	+	+	?	++	+	+	Yes	?
Jupiter	++	+	+++	+	+	?	?	?	?	?
LaCrosse	+++	++	++	+++	++	?	?	?	?	?
Leon Millot	+	++	+++	+	+	+	?	?	Yes	?
Limberger	+++	+++	+++	+	?	+++	+++	?	No	?
Maréchal Foch	++	+	++	+	?	+++	?	+	Yes	?
Marquis	+	+++	+	+	+++	?	?	?	?	?
Mars	+	+	+	+	+	?	+	?	?	?
Melody	+++	++	+	+	?	?	?	?	No	?
Merlot	++	+++	+++	++	+	+++	+++	?	No	++
Moore's Diamond	+++	+	+++	++	?	++	?	?	No	?
Muscat Ottonel	+++	+++	+++	++	?	+++	+++	?	No	?

Table 14 (Continued). Relative Disease Susceptibility and Sulfur and Copper Sensitivity Among Grape Cultivars.

Cultivar	BR	DM	PM	Bot	Phom	Eu	CG	ALS	Susceptible or Sensitive to S[1]	C[2]
Niagara	+++	+++	++	+	+++	+	++	+	No	+
Pinot gris	+++	+++	+++	++	?	+++	+++	?	No	?
Pinot Meunier	+++	+++	+++	+++	?	+++	+++	?	No	?
Pinot blanc	+++	+++	+++	++	?	?	+++	?	No	+
Pinot noir	+++	+++	+++	+++	?	?	+++	+	No	+
Reliance	+++	+++	++	+	++	?	?	?	No	?
Riesling	+++	+++	+++	+++	++	++	+++	+	No	+
Rosette	++	++	+++	+	++	++	++	++	No	+++
Rougeon	++	+++	+++	++	+++	+	++	+++	Yes	+++
Saint Croix	?	++	++	++	?	?	?	?	?	?
Sauvignon blanc	+++	+++	+++	+++	?	?	+++	?	No	+
Seyval	++	++	+++	+++	++	+	++	++	No	+
Steuben	++	+	+	+	?	?	+	++	No	?
Traminette	+	++	+	+	?	?	++	?	?	?
Vanessa	+++	++	++	+	+	?	+	?	?	?
Ventura	++	++	++	+	+	?	+	+++	No	?
Vidal blanc	+	++	+++	+	+	+	++	+	No	?
Vignoles	+	++	+++	+++	++	++	++	++	No	?
Villard noir	?	+	+++	+	?	?	?	?	?	?

Key to susceptibility or sensitivity: BR = black rot; DM = downy mildew; PM = powdery mildew; Bot = Botrytis; Phom = Phomopsis; Eu = Eutypa; CG = crown gall; ALS = angular leaf scorch; S = sulfur; C = copper.

Key to ratings: + = slightly susceptible or sensitive; ++ = moderately susceptible or sensitive; +++ = highly susceptible or sensitive; No = not sensitive; Yes = sensitive; ? = relative susceptibility or sensitivity not established.

[1] Slight to moderate sulfur injury may occur even on tolerant cultivars when temperatures are 85°F or higher during or immediately following the application.

[2] Copper applied under cool, slow-drying conditions is likely to cause injury.

[3] Berries not susceptible.

Select the Site Carefully

Site selection can have a direct effect on vine microclimate. A site that provides for maximum air drainage, which promotes faster drying of foliage, can substantially reduce the risk of black rot and downy mildew. In the northern hemisphere, north-facing slopes receive less light than south-facing slopes. Therefore, vineyards on north-facing slopes may dry more slowly and be at a higher risk for disease development.

Avoid planting the vineyard adjacent to woods that will prevent sunlight from reaching the vines during any part of the day. Woods act as a windbreak that may be beneficial in preventing shoot breakage in high winds, but woods may also reduce air movement (ventilation) in the vineyard which results in prolonged wetting periods. Close proximity to woods can also increase the risk of introducing certain diseases and insect pests into the vineyard.

Planting rows in a north-south row orientation should be the grower's first choice for maximum light penetration. However, rows planted in the direction of prevailing winds will promote better air movement, which results in faster drying of foliage and fruit. Rows should never be planted parallel to a steep slope where erosion could be more of a problem than pests.

Good soil drainage is also extremely important. Avoid sites that are consistently wet during the growing season. These soils may have an impervious subsoil or other drainage problems. Such sites will usually result in unsatisfactory vine growth and yields, in addition to providing a humid microclimate that is conducive to disease development. In some situations poor drainage can be corrected by tiling prior to planting.

If nematodes have been a problem in previous crops or nematodes are suspected to be a problem on the site, a soil analysis to determine the presence of harmful nematodes should be conducted. Nematodes are most likely to be a problem on lighter (sandy) soils. Nematode sampling kits and instructions for taking samples can be obtained through your county Extension office.

Avoid Excessive Fertilization

Fertility should be based on soil and foliar analysis. The use of excessive fertilizer, especially nitrogen, should be avoided. Sufficient fertility is essential to produce a crop, but excessive nitrogen can result in dense foliage that increases drying time in the plant canopy.

Control Weeds in and Around the Planting

Good weed control within and between the rows is essential. From a disease control standpoint, weeds in the planting prevent air circulation and result in the fruit and foliage staying wet for longer periods. For this reason, most diseases caused by fungi are generally more serious in plantings with poor weed control than in those with good weed control.

Manage the Canopy

Any cultural practice that alters vegetative growth and canopy density has an effect on vine microclimate. Most cultural practices are chosen primarily to enhance yield or fruit quality rather than to influence the microclimate. However, practices, such as shoot thinning, pruning, and positioning, have a direct impact on vine microclimate. Increasing cluster thinning and decreasing pruning stimulates vegetative growth and hence reduces light exposure and ventilation within the canopy.

Shoot thinning, leaf removal, and summer pruning are frequently done specifically to reduce canopy density, so as to increase fruit exposure to light, improve ventilation, and aid spray coverage. Leaf removal in the fruiting zone of the canopy is important for optimal control of Botrytis bunch rot. This is a common practice in California vineyards and has been shown to be effective in Midwest vineyards as well. Shoot positioning is usually done to ensure canopy separation of divided canopies or to enhance light exposure of the renewal zone of the vine; it also decreases vegetative growth and canopy density and increases light exposure of fruit.

Avoid Winter Injury

Wounding by freeze injury is important in the development of crown gall. If winter injury is reduced, crown gall may not become an important problem. Practices such as hilling or burying vines of cold-sensitive cultivars are beneficial. Proper pruning practices and proper crop loads for maximum vine vigor will result in stronger plants that are less susceptible to winter injury. Controlling other diseases, such as downy and powdery mildew, is also important in preventing winter injury and crown gall.

Practice Sanitation (Removal of Overwintering Inoculum)

Vineyard sanitation is an extremely important part of the disease-management program. Most pathogens overwinter (survive from one season to the next) in old diseased plant material, such as mummified fruit, leaves, and infected canes or trunks, within the vineyard. Removal of old, infected wood, tendrils, and clusters with mummified berries from the vines and wires greatly reduces overwintering inoculum of several diseases.

Wild grapes in nearby woods and fence rows also are sources of disease inoculum and insects. Removal of these wild hosts is beneficial to the disease-management program. This especially applies to abandoned vineyards adjacent to managed sites with respect to contamination from powdery and downy mildews.

Using Fungicides for Controlling Grape Diseases

Fungicides are an important part of the grape disease-management program. Due to the lack of disease resistance in most of our currently grown cultivars combined with our environmental conditions (abundant moisture) that are highly conducive to disease development, successful commercial grape production in the Midwest is highly unlikely without the use of at least some fungicide.

While fungicides are important, growers need to recognize that they are only one part of the overall integrated disease-management program. The effectiveness of the fungicide program is greatly influenced by use of the various cultural practices described previously and the level of disease susceptibility of the cultivars being grown. For example, given a poorly pruned (dense canopy) vineyard of Chancellor grapes (highly susceptible to downy mildew) planted on a poor site (little air circulation) and with poor weed control, the chance of any reasonable fungicide program providing an acceptable level of downy mildew control is highly unlikely.

To use any fungicide effectively, consider the following points:

Identify the Disease Correctly

If you do not know what disease or diseases are present in the vineyard, you cannot choose the most effective fungicide or fungicides for their control. Correct disease identification is essential for selecting the proper fungicide or fungicide combinations to use in the vineyard.

Select the Proper Fungicide

Fungicides differ greatly in their spectrum of activity (which fungi they can control). Selection of the wrong fungicide for use on a specific disease can result in financial loss and no control. For example, if a grower misidentified downy mildew for powdery mildew and sprayed Nova or Bayleton to control it, neither of these fungicides would have any effect on the downy mildew, although they would provide excellent control of powdery mildew.

Time the Application Properly

For most diseases it takes at least a week from the time the fungus enters the plant until the symptoms appear. In the case of Phomopsis fruit rot, the fungus enters the fruit during bloom, and symptoms do not appear until the fruit begins to ripen (harvest). Depending upon the weather, it may take two weeks for black rot symptoms to appear. Once symptoms appear, it is too late to control the disease; therefore, proper timing of the application is critical. The fungus must be controlled before or shortly after it enters the plant.

Cover All Susceptible Plant Parts Thoroughly

If the fungicide is not on or in susceptible plant parts, it cannot control the fungus. Cultural practices that open the plant canopy greatly improve fungicide coverage. Proper calibration and use of the sprayer is also critical to good coverage.

Fungicide Use Strategies for Grapes

Unfortunately, there are not many options to choose from when one considers our current fungicide-use strategies. The current options are:

Do Not Use Fungicides

This is always an option, but it is not recommended for commercial plantings. This option should not be confused with organic production. Grape growers in organic production systems will most probably use sulfur or copper to some extent for disease control. Sulfur, lime-sulfur, and copper are fungicides. Growers who choose not to use fungicides must rely completely on cultural practices and disease resistance for disease control.

Use a Protectant Fungicide

In a protectant program, fungicides are used to form a protective barrier on the plant surface. This chemical barrier prevents the fungus from entering the plant. It works much like paint on a piece of wood to keep out water. Protectant fungicides are not systemic and cannot move into plant tissues. Once the fungus penetrates into the plant, protectant fungicides will not control it. As the protective barrier breaks down or new foliage is produced, additional applications are required to maintain the protective barrier.

Protectant fungicide programs have been and still are very effective; however, they generally result in a fairly intensive use of fungicides. Protectant fungicides are usually applied on a 7- to 10-day schedule early in the growing season and on a 10- to 14-day schedule later in the season. Obviously, maintaining a protective barrier on the plant surface throughout the growing season requires many applications.

Use a Post-Infection or Curative Fungicide

The development and introduction of new systemic fungicides allows the use of a post-infection or curative fungicide-use strategy. In a post-infection program, fungicides are applied only after infection periods occur. The systemic properties of the fungicide allow it to move into plant tissues where it stops further development of the fungus after it has penetrated the plant. In the post-infection program, the fungicide is applied after the initiation of an infection period, but before symptoms develop. Thus, the fungicide must be applied within three to four days (72 to

96 hours) after the initiation of an infection period in order to be effective.

The sterol-inhibiting (SI) fungicides (Bayleton and Nova) have excellent post-infection activity against black rot and powdery mildew. Ridomil and Aliette have excellent post-infection activity against downy mildew. In dry growing seasons, with few or no infection periods, a post-infection program should result in reduced fungicide use.

There are several important points to remember about the post-infection program. In order to use a post-infection program, you must:

- Monitor the environment to determine when infection periods occur. If growers do not have the capability to accurately monitor the environment, they should not use a post-infection program.
- Know what an infection period is for a specific disease. This requires a great deal of knowledge about the biology of the pathogen. At present, we have this information for black rot (Table 13 on page 64). There are also predictive capabilities for powdery mildew and downy mildew, and Botrytis bunch rot. Predictive programs are currently being developed and evaluated for these diseases.
- Timing is critical. Post-infection applications must be made as soon as possible, but no later than three to four days (72 to 96 hours) after the initiation of an infection period and before symptom development. In most situations, once symptoms develop, the damage is done.

If these criteria cannot be met, growers should use a protectant fungicide spray program.

Fungicides for Controlling Specific Grape Diseases

Specific fungicide recommendations cannot be made in this publication because of constantly changing regulations and recommendations regarding their agricultural use. For specific fungicide recommendations, consult your local Extension service. Most Midwestern states have a small fruit and grape spray guide that is revised annually. General information about fungicides that were available at the time this bulletin was published is presented here.

Fungicides for Controlling Black Rot

Protectants

Mancozeb, Ferbam, and **Ziram** are all highly effective against black rot (Table 15 on page 96). Because these fungicides are strictly protectants, they must be applied before the fungus infects or enters the plant. They protect fruit and foliage by preventing spore germination. They will not arrest lesion development after infection has occurred.

Mancozeb provides an excellent foundation for a protectant spray program for grapes in the Midwest. It is a good protectant fungicide that will provide good to excellent control of downy mildew and Phomopsis cane and leaf spot in addition to black rot. The major problem with Mancozeb is a 66-day preharvest interval (PHI) on grapes. It cannot be applied within 66 days of harvest. Mancozeb is available under many trade names and formulations. Some common trade names are Manzate 200, Penncozeb, Dithane M45, Dithane F45, and Dithane Rainshield DF.

Some food processors may not accept Mancozeb-treated fruit or may have special restrictions on its use. This also applies to Captan. Prior to initiating a control program in the spring, growers need to know where they will sell their fruit and if the buyer has any restrictions on pesticide use.

Ziram is similar in efficacy to Ferbam. It is highly effective against black rot and provides moderate control of downy mildew and Phomopsis cane and leaf spot.

Growers of processing grapes who cannot apply Mancozeb past the initiation of bloom could use Ziram during this period. Ziram can be applied up to 21 days before harvest.

Ferbam will provide excellent control of black rot but is not highly effective against the other grape diseases. In addition, there are restrictions on the number of applications that can be used. Always read and understand the label before using or purchasing a pesticide.

Captan and **copper fungicides** (fixed copper or Bordeaux mixture) are only slightly to moderately effective against black rot and will probably not provide adequate control under heavy disease pressure.

Sterol Inhibiting (SI) Fungicides

The locally systemic fungicides, Bayleton, Nova, Elite, and Procure, are also highly effective against black rot and will provide some post-infection (curative) activity of the disease if applied at the higher labeled rates within 72 to 96 hours after the initiation of an infection period. Post-infection or curative control must be achieved prior to symptom development on leaves or fruit. Once the symptoms are present, these fungicides will not eradicate or burn out the fungus. Bayleton, Nova, Elite, and Procure also appear to provide good protectant activity against black rot if applied at the lower labeled rates in a protectant program. These fungicides also have excellent activity against powdery mildew as well.

Rubigan is another SI fungicide that is registered for use on grapes and will provide moderate control of black rot if applied in a protectant program. This fungicide is in the same general class of fungicides as Bayleton, Nova, Elite, and Procure; however, it does not provide adequate curative or post-infection control of black rot. Nova, Elite, Procure, or Bayleton are the preferred SI fungicides for black rot control.

Strobilurin Fungicides

Abound, Sovran, Flint, and Pristine are locally systemic fungicides that are all highly effective for control of black rot. They do differ in their efficacy against some of the other important grape diseases.

***Note*:** Flint or Pristine cannot be applied on Concord grapes or phytotoxicity (damage) could occur. Always read the fungicide label carefully.

Fungicides for Powdery Mildew

Protectants

Sulfur is highly effective against powdery mildew if used in a protectant program with a minimum of seven to 14 days between applications (see Table 15 on page 96). There are many formulations of sulfur (wettable powders, dusts, dry flowables, and flowables). The flowable formulations appear to be most effective and result in much less applicator exposure when preparing sprays.

***Note*:** On sulfur-tolerant cultivars that are susceptible to powdery mildew (Table 14), sulfur will probably be a major component of the fungicide program. On highly susceptible cultivars, spray intervals shorter than 14 days (7 to 10 days) will probably be required with sulfur. Although sulfur is highly effective for powdery mildew control, it has little or no effect on the other grape diseases (Table 15). It is important to remember that sulfur will cause severe injury on some grape cultivars. Sulfur should only be used on cultivars known to be sulfur tolerant (Table 14).

***Note*:** Chancellor, Concord, DeChaunac, Foch, Norton, and Rougeon grapes are highly sensitive to sulfur. Sulfur injury may occur even on sulfur-tolerant cultivars when temperatures of 80 to 85°F or higher are experienced during or immediately after application.

Copper fungicides (fixed coppers or Bordeaux mixture) have been rated moderately effective against powdery mildew; however, care must be taken when using copper due to the danger of foliage injury (phytotoxicity). Grape cultivars differ in their sensitivity to copper fungicides (Table 14). Under heavy disease pressure, copper fungicides may not provide adequate control. Copper is not the preferred fungicide for powdery mildew control. However, if copper is applied for downy mildew control, it will provide some protection against powdery mildew. On less susceptible cultivars, such as Concord, copper fungicides may provide satisfactory control.

Sterol Inhibiting (SI) Fungicides

Nova, Elite, Procure, and **Rubigan** are locally systemic and highly effective for control of powdery mildew. They will also provide good to excellent control of black rot, but they will not control downy mildew. Bayleton was highly effective against powdery mildew when it was first introduced; however, due to development of fungicide-resistant strains of the powdery mildew fungus, Bayleton is no longer recommended for powdery mildew control.

Strobilurin Fungicides

Abound, Sovran, and **Flint** are locally systemic, and all were good to excellent for control of powdery mildew when they were first introduced. Fungicide resistance development in powdery mildew has been observed in strobilurin fungicides. At present, it may be necessary to combine the strobilurin fungicides with a fungicide of different chemistry with activity against powdery mildew in order to achieve acceptable control.

Pristine 38WG Fungicide is a combination of pyraclostrobin (a strobilurin fungicide) and Boscalid (Endura). The addition of Boscalid (Endura) gives Pristine activity against strains of the powdery mildew fungus with resistance to the strobilurins (Abound, Sovran, and Flint).

***Note*:** Flint or Pristine cannot be applied on Concord grapes or phytotoxicity (damage) can occur. Always read the fungicide label carefully.

Other Fungicides For Powdery Mildew Control

Endura 70WG Fungicide is new fungicide chemistry and is highly effective for control of powdery mildew and provides good control of Botrytis bunch rot. It is different chemistry from the sterol-inhibiting and strobilurin fungicides; therefore, it is an excellent material to use in rotation with these materials in a fungicide resistance management program.

Quintec 2.08SC is new fungicide chemistry that is very effective for control of powdery mildew, but it has no activity against the other grape diseases. It is a protectant fungicide so it must be applied before infection occurs. It does not have curative activity. It is registered for use at the rate of 3 to 4 fluid ounces per acre on a seven- to 14-day schedule. Because it is new chemistry (not related to other fungicides), it will control strains of the powdery mildew fungus that are resistant to the strobilurin fungicides (Abound, Sovran, Flint, and Cabrio) and the sterol-inhibiting fungicides (Nova, Elite, Procure, and Rubigan). Quintec has a 12-hour re-entry interval and a 14-day preharvest interval.

JMS Stylet-Oil is a highly refined petroleum distillate that is registered for use on grapes in the United States. It has provided excellent powdery mildew control in fungicide tests in Ohio and New York and is currently being used rather extensively by California grape growers for powdery mildew control. It is registered for use at the rate of 1 to 2 gallons oil per 100 gallons water (1% to 2% concentration). The label states on grapes: "Make first application pre-bloom and continue sprays every two to three weeks depending on level of disease pressure. Use higher rates and shorter spray interval when disease conditions are severe."

Although this fungicide has not been used on grapes extensively in the Midwest or northeastern United States, it appears to have good potential as an alternative fungicide for powdery mildew control on grape.

***Note*:** One potential problem with stylet oil is that it removes the "bloom" or waxy coating from the grape berry. This apparently has no effect on quality of wine or juice grapes, but it does affect the appearance of the berry and probably should not be used for fresh-market table grapes.

***Note*:** DO NOT use CAPTAN or SULFUR within two weeks after applying JMS STYLET-OIL. Mixing Captan or Sulfur with oil could result in severe damage to the vine. In addition, repeated use of oil during the growing season has been shown to be phytotoxic to vines.

Potassium Salts

Armicarb 100 (potassium bicarbonate) and Nutrol (manopotassium phosphate) have been reported to provide fair control of powdery mildew on grape but provide no control of the other grape diseases. It is assumed that they provide control through limited eradication and antisporulant activity. They do not provide protectant activity.

Fungicides for Phomopsis Cane and Leaf Spot

At present, **Mancozeb, Captan,** or **Ziram** are the fungicides recommended for control of this disease (Table 15). They are ranked as moderately to highly effective.

Fungicide test results indicate that the sterol inhibitors are not effective and the strobilurins only provide moderate control. Copper and sulfur fungicides appear to be ineffective.

***Note*:** Especially where Phomopsis is a problem or a concern, Mancozeb, Captan, or Ziram should be included in the early-season fungicide program.

Fungicides for Downy Mildew

Protectant Fungicides

Mancozeb, Captan, and Copper fungicides (fixed coppers and Bordeaux mixture) are highly effective for control of downy mildew (Table 15). Ziram is moderately effective. All of these fungicides are effective only when used in a protectant spray program. They will not provide post-infection or curative activity and will not eradicate or burn out the fungus after symptoms appear.

Of the protectant fungicides currently available, **Mancozeb** is an excellent choice. Mancozeb is highly effective against downy mildew, black rot, and Phomopsis cane and leaf spot. One problem with Mancozeb is that it cannot be applied within 66 days of harvest. Even with this restriction, Mancozeb is an excellent protectant fungicide for early-season disease control and can also be used on later-maturing cultivars for post-bloom disease control (prior to 66 days of harvest).

Captan is also excellent for downy mildew and Phomopsis cane and leaf spot but is weak for controlling black rot. A good approach to using Mancozeb and Captan for downy mildew control is to use Mancozeb early in the season then switch to Captan within the 66-day preharvest interval for Mancozeb. Currently Captan does not have a preharvest interval for grapes.

***Note*:** Although Captan has no preharvest interval on grapes, it does have a three-day reentry restriction. The following information is taken from the Captan label: "Do not allow persons to enter treated areas within four days following application unless a long-sleeved shirt and long pants or a coverall that covers all parts of the body except the head, hands, and feet, and chemically resistant gloves are worn. Conspicuously post reentry information at site of application." Remember, always read the label.

Ziram is similar in efficacy to Ferbam. It provides only moderate control of downy mildew, and excellent control of black rot and Phomopsis cane and leaf spot. Under heavy disease pressure, Ziram may not provide adequate control of downy mildew.

Locally Systemic Fungicides

Ridomil Gold MZ and **Ridomil Gold/Copper** are by far the most efficacious fungicides available for control of downy mildew. Ridomil is locally systemic and has good post-infection or curative activity. If used in post-infection control programs, it should be applied as soon as possible, ***but within*** two to three days after the initiation of an infection period. Ridomil **should not be** applied after symptom development (sporulating lesions). Use of Ridomil in this manner (as an eradicant) will probably lead to a rapid buildup of Ridomil-resistant strains of the downy mildew fungus in your vineyard. If resistance develops in the vineyard, the use of Ridomil as a tool for downy mildew control is lost.

Ridomil also has excellent protectant activity against downy mildew. It should provide at least two weeks of protection, and in some tests in Ohio, it has provided up to three weeks of protection.

As mentioned previously, Ridomil Gold has a strong potential for fungicide resistance development by the downy mildew fungus. For this reason, the manufacturer (Syngenta) has registered its use only as a ***Package Mix*** with a protectant fungicide. The two formulations available for use on grapes are Ridomil Gold MZ (4% Ridomil and 64% Mancozeb) and Ridomil Gold/Copper (5% Ridomil and 60% copper hydroxide). The purpose of the package mix (at least in theory) is to delay the development of strains of the downy mildew fungus with resistance to Ridomil. Both formulations are equally effective for controlling downy mildew. The Ridomil Gold MZ formulation should be used on copper sensitive cultivars.

Although Ridomil is very effective, the current label use recommendations restrict the timing of its use on grapes. Ridomil Gold MZ cannot be applied within 66 days of harvest, and Ridomil Gold/Copper cannot be applied within 42 days of harvest. Based on these long preharvest intervals, Ridomil will be of limited use for late season downy mildew control in the Midwest.

In seasons when downy mildew is a problem and on highly susceptible cultivars, pre-bloom and post-bloom applications of Ridomil will aid greatly in disease control. However, additional fungicide protection may be required within the 66-day preharvest interval on late-harvested, highly susceptible cultivars. The alternative fungicides for use during this period are Captan, copper fungicides, phosphorus acid fungicides, or the strobilurin fungicides Abound or Pristine.

Strobilurin fungicides are also locally systemic, and some have good to excellent activity against downy mildew. Whereas the strobilurins (Abound, Sovran, Flint, and Pristine) all have good to excellent activity against black rot and powdery mildew, they vary greatly in their efficacy against downy mildew. Abound and Pristine have excellent activity and are the most effective for downy mildew control. Sovran is moderately effective if used at the highest labeled rate, and Flint is registered for "suppression" of downy mildew, not control.

Phosphorous Acid (Agri-Fos, ProPhyt, Phostrol)

Several products containing phosphorous acid (PA, also called phosphite or phosphonate) are sold as nutritional supplements and plant conditioners. Several of these materials have been registered in the United States as fungicides for control of downy mildew on grape. In multiple New York trials, PA has provided excellent control of downy mildew but has not controlled any other grape disease.

Australian experience suggests that PA provides most control on *foliage* when it is applied within a few days after the start of an infection period, providing only a few days of additional residual (protective) activity. Experience in New York suggests that spray timing is less critical for control of downy mildew on *fruit*, perhaps because this highly mobile chemical (which is exempt from residue tolerances) accumulates in these organs. When applied in a seven- to 10-day protectant program, they appear to provide good to excellent control of downy mildew.

Copper fungicides are highly effective against downy mildew and are moderately effective against powdery mildew. Copper fungicides are weak for controlling black rot. A major concern with the use of copper fungicides is the potential they have for phytotoxicity or vine damage. Grape cultivars differ in their sensitivity to copper fungicides (Table 14).

***Note*:** Certain food processors, such as the National Grape Cooperative, will not accept grapes treated with Mancozeb past the initiation of bloom, and the use of Captan is not permitted at any time. If growers cannot use Mancozeb or Captan, alternatives for downy mildew control include Ridomil Gold/Copper, copper fungicides, a phosphorous acid fungicide, or a strobilurin fungicide. Thus, copper may be an important fungicide for producers of processing grapes that have these fungicide use restrictions.

Botrytis Bunch Rot

Vangard, Elevate, Endura, Scala, and Rovral all have excellent activity against Botrytis bunch rot on grapes and are the fungicides of choice for control of Botrytis bunch rot. The strobilurins are moderately effective against Botrytis. Botrytis bunch rot is most commonly a problem on tight-clustered French hybrids and *Vitis vinifera* cultivars.

Proper timing and thorough spray coverage are essential for good control. Make at least two applications:

- When the disease is first observed or when the first berries reach 5°Brix (5% soluble solids/sugars), which ever comes first.
- Fourteen days after the first application. A third spray may be necessary on late cultivars, *e.g.*, White Riesling, if the interval between the second spray and harvest is greater than four weeks.

Field experience suggests that effectiveness of the fungicide is reduced following a heavy prolonged rainfall. If such conditions occur after the last intended spray has been made, an additional application may be necessary. If only one application can be made, wait until the crop average is 5°Brix. Direct the spray toward the fruit; use a minimum of 100 gal/acre of water.

The importance of bloom sprays for control of Botrytis bunch rot is not clear; however, during seasons with wet conditions during bloom, fungicide application during bloom is probably beneficial. Research in New York has shown that the strobilurin fungicides have moderate to good efficacy for Botrytis control. The use of a strobilurin fungicide during the bloom period may be beneficial for Botrytis control, especially on highly susceptible cultivars. In addition, a strobilurin fungicide such as Abound or Pristine during bloom will provide excellent control of black rot, powdery mildew, and downy mildew as well.

***Note*:** Growers in Europe and Canada have experienced loss of disease control due to the development of fungicide resistance when more than three sprays per year of Rovral were applied over a period of three to five years. It is, therefore, strongly recommended that the use of Rovral, Endura, Vangard, Scala, or Elevate be limited to a maximum of two to three applications per year to reduce the probability of developing strains of *Botrytis* that are resistant to this material. In addition, alternating these fungicides during the growing season or from season to season should be helpful in fungicide-resistance management.

Note**:** Removal of leaves around clusters on mid- or low-wire cordon-trained vines before bunch closing has been shown to reduce losses caused by Botrytis due to improved air circulation and improved spray penetration and coverage.

Post-Harvest Applications

On cultivars highly susceptible to downy mildew and powdery mildew, some post harvest application may be required to protect foliage and prevent premature defoliation. This is especially true on early harvested cultivars in southern regions of the Midwest.

Fungicide Resistance Management

The development of strains of the powdery mildew fungus with resistance to the sterol-inhibiting (SI) fungicides (Bayleton, Nova, Procure, and Rubigan) or the strobilurin fungicides (Abound, Sovran, and Flint) is a serious threat to their continued use for powdery mildew control on grapes. There is good evidence that strains of the fungus with resistance to Bayleton and reduced sensitivity to other SI fungicides have developed in several areas.

Other grape diseases (fungi) and fungicides that are at high risk for fungicide resistance development include Botrytis bunch rot (Vangard, Elevate, Rovral, Endura, and Scala) and downy mildew (Ridomil Gold, Abound, Sovran, and Pristine). In order to prevent or delay the development of fungicide resistance, these fungicides should not be used alone for season-long control and should be used as little as possible. This means another fungicide with good activity against the disease should be incorporated into the spray program at some point during the growing season.

A good strategy for resistance management is to use one or two spray blocks of different fungicides. For example, a grower could start the season with two applications of a sterol-inhibiting fungicide, then switch to a strobilurin fungicide for two sprays. Other materials, such as a protectant fungicide, can be used in an alternating program such as this. The important thing is not to use one material season-long. Check with your local Extension service for the most current fungicide recommendations.

Table 15. Effectiveness of Fungicides for the Control of Grape Diseases.

Fungicide	Phomopsis Cane and Leaf Spot	Black Rot	Downy Mildew	Powdery Mildew	Botrytis Rot
Abound	+	+++	+++	+++	++
Bayleton	0	+++	0	+++	0
Captan	+++	+	+++	0	+
Elevate	0	0	0	0	+++
Elite	0	+++	0	+++	0
Endura	0	0	0	+++	++
Ferbam	+	+++	+	0	0
Fixed Copper and Lime	+	+	+++	++	+
Flint	+	+++	+	+++	++
JMS Stylet Oil	0	0	0	+++	?
Mancozeb	+++	+++	+++	0	0
Nova	0	+++	0	+++	0
Phosphorous acid	0	0	+++	0	0
Potassium salts	0	0	0	++	0
Pristine	++	+++	+++	+++	++
Procure	0	+++	0	+++	0
Quintec	0	0	0	+++	0
Ridomil Gold MZ	+	++	+++	0	0
Ridomil Gold Copper	+	+	+++	0	0
Rovral	0	0	0	0	+++
Rubigan	0	++	0	+++	0
Scala	0	0	0	0	+++
Sovran	+	+++	++	+++	++
Sulfur	+	0	0	+++	0
Vangard	0	0	0	0	+++
Ziram	++	+++	++	0	0

+++ = highly effective, ++ = moderately effective, + = slightly effective, 0 = not effective, ? = activity unknown.

Note: These ratings are intended to provide the reader with an idea of relative effectiveness. They are based on published data and/or field observations from various locations. Ratings could change based on varietal susceptibility and environmental conditions for disease development, or changes in fungal sensitivity to specific fungicides.

Grape Insect Pests

Many of the same insect and mite species that damaged grapes late in the 1800s continue to cause economic injury today. Damage is direct to the berry clusters or indirect to vines, shoots, roots, or leaves. In this section, the life histories of 10 of the most damaging arthropod (insect and mite) pests of Ohio grapes are described, including a new pest—the multicolored Asian lady beetle. Growers should keep in mind there are more than 50 insect and mite pests of grapes, and some can cause significant injury. Many of the pests are found only in certain regions; others only occasionally reach damaging population levels. Periodic vineyard inspections for grape pests will reduce the risk of arthropod damage.

For accurate identification of grape pests, growers should obtain a copy of *Insect and Mite Pests of Grapes in Ohio*, Bulletin 730, Ohio State University Extension. This bulletin has 76 photos of the most common pests of Ohio grapes and includes descriptions of pest life cycles and damage. There is a charge for this publication, which is available from Ohio State University Extension, Media Distribution, 2021 Coffey Road, Columbus, OH 43210-1044. Current pesticide recommendations and spray schedules in Ohio are available from Ohio State University Extension.

Insects That Attack Grape Buds

Grape Flea Beetle

***Altica chalybea*, Order Coleoptera, Family Chrysomelidae**

Description and Life Cycle

The grape flea beetle is a dark metallic greenish-blue or steel-blue beetle about 3/16-inch long (Figure 63). It is occasionally a serious pest of grapes in the Midwest, feeding on grape buds in the early spring.

FIGURE 63. Grape flea beetle adult.

Female beetles lay eggs mainly under loose bark of the grapevine. Larvae hatch and crawl to the developing grape leaves, where they feed. Adult beetles and larvae also feed on the foliage, but the injury they cause usually is negligible.

Newly hatched larvae of the grape flea beetle are dark blackish purple and approximately 1/16-inch long. As they grow, their color lightens and they reach a length of almost 1/3 inch (Figure 64). The head is black, and there are six or eight shining black dots on each of the other segments of the body, each dot emitting a single brownish hair. The under surface is paler than the dorsum. Its legs, six in number, are black, and there is a fleshy, orange-colored proleg on the terminal segment.

When they are fully developed, the larvae drop to the soil, burrow one inch or less, and pupate. They emerge later as adults. There may be a partial or full second generation each year.

FIGURE 64. Flea beetle larva feeding on leaf. Note damage.

FIGURE 65. Flea beetle damage to a swollen bud early in the season.

Damage Symptoms

Flea beetles cause two types of damage—feeding directly on the buds and feeding on the foliage. The most serious damage occurs in the spring as the adults emerge from overwintering sites and feed on slightly swollen grape buds (Figure 65). They chew holes in the sides and ends of the newly developing buds, damaging primary and occasionally secondary and tertiary buds.

If all three growing points are destroyed, no grapes will be produced. If secondary or tertiary buds are not destroyed, a partial crop may develop, allowing subsequent clusters to form. These beetles do not cause major damage once the buds have surpassed a half inch in length. Both larvae and adults feed on the upper and lower leaf surfaces, causing some damage, although this injury is usually of little consequence.

Management/Control

The adult beetles eat the contents of the buds, destroying foliage and fruit that normally would develop. Fortunately, the beetle attacks usually are confined to limited areas of the vineyard. If growers are aware of these infestations, they can make an early-season insecticide application the following year to keep populations in check. Another application of spray in June, when larvae are feeding on the grape foliage, may help to control an outbreak the following year.

Wood lots and wasteland areas near cultivated vineyards are a possible source of flea beetles and should be cleaned up if possible. This will help to reduce overwintering sites for the beetles. Cultivating between rows may contribute to control by exposing the delicate pupae to desiccation and death. Cultivating helps but does not completely eliminate emerging beetles from under the trellis and adjoining wood lots.

Grape bud damage caused by the grape flea beetle is often concentrated in vineyard borders near wooded areas. Early vineyard monitoring and past history of beetles in the vineyard will help determine the need for an early-season application of insecticide. Scouting of the vineyard for grape flea beetle should begin in April and continue until bud development is past the critical stage.

These shiny metallic beetles are easily spotted on grape canes and buds on warm, sunny days in the spring. Scouting for adult beetles should be conducted along the vineyard perimeter, on all sides, and near the center of the vineyard. At least 25 vines should be surveyed at each of the five locations.

If bud damage averages 4% or more, one should apply an insecticide to prevent further bud damage. Timing is critical. For specific insecticides used in the control of the grape flea beetle, see annual recommendations.

Insects That Attack Grape Flower Clusters and/or Berries

Grape Berry Moth

***Endopiza viteana*, Order Lepidoptera, Family Tortricidae**

Description and Life Cycle

This is the major insect pest of grape berries in the eastern United States and Canada. When vineyards are left unmanaged, up to 90% of the fruit often is destroyed by the larvae and accompanying diseases facilitated by the damage inflicted upon the fruit. Infestations vary greatly from vineyard to vineyard, from year to year, and within a vineyard. However, vineyards bordering wooded areas are most vulnerable to infestation.

The adult is a mottled brown-colored moth with some bluish-gray on the inner halves of the front wings (Figure 66). The larvae of this small moth are active, greenish to purplish caterpillars about 3/8-inch long when fully grown. Grape berry moths overwinter in cocoons within folded leaves in debris on the vineyard floor and within adjacent woodlots.

After emerging in the spring, the adults mate and the females lay eggs on or near flowers or berry clusters. Newly hatched larvae feed upon the flowers and young fruit clusters. Larvae that hatch in June make up the first generation of grape berry moth and will mature from mid- to late July or August.

After mating, females lay eggs on developing berries, and this second generation matures in August or September. Larvae of the second generation, after completing their development, form cocoons in which they overwinter. A third generation occurs commonly in the southern range of the pest and occasionally in the northern tier of states.

FIGURE 66. The adult grape berry moth is mottled brown with bluish-gray on front wings.

Damage Symptoms

First-generation larvae web small flower buds or berries together in early June and feed externally on them or on tender stems. Larvae that attack grape bunches during this time are difficult to see.

Second generation larvae tunnel directly into the green berries and feed internally. Conspicuous reddish spots develop on the berries at the point of larval entry. Berries affected in this manner are known as stung berries (Figure 67).

The second generation is more damaging than the first. A single larva may destroy two to six berries in a cluster, depending on berry size, and several larvae frequently inhabit a single cluster. At veraison the damage is easiest to see on white grapes.

FIGURE 67. Stung berries have a reddish color where the larvae tunnel directly into the green berries and feed internally. Stung berries are easy to spot.

At harvest, severely infected bunches may contain many larvae, and most of the berries may be completely hollowed (Figure 68). In many cases, bunches are covered with bunch rot fungi and infested with Drosophila fruit flies and often have an unhealthy appearance.

Management

An insecticide may be needed to prevent damage in areas heavily infested by grape berry moth. The number of spray applications depends on the infestation level and the type of production—wine, juice, or table grapes. Table grapes that are inspected by consumers in the market place require more attention than grapes grown for juice.

Corrective measures are usually suggested if more than 5% of the clusters are injured. To determine the percentage of clusters damaged, randomly inspect 100 clusters along the perimeter of the vineyard and 100 clusters toward the center of the vineyard. This method will tell you if treatment of the entire vineyard is necessary. Treatment of perimeter rows may be all that is necessary to control this pest. Control of second generation larvae in mid- to late July is particularly important.

Cultural controls can be used to kill the overwintering pupae in leaves. Leaves can be gathered and destroyed in the fall, or leaves

FIGURE 68. Berries may be completely hollowed.

can be buried within the soil in the spring, two weeks before bloom, by rototilling or cultivating.

An alternate method of control using pheromone rope ties to disrupt the males of the grape berry moth was approved by the EPA in 1990. Following that sprayable pheromones were tried with some success. However, the sprayable pheromone must be applied several times in order to eliminate the threat. Neither of these approaches is being practiced at present.

Monitoring Male Moths

Pheromone traps are available to monitor the emergence of male grape berry moths during the season. This information may be useful for optimal spray timing; sprays should target egg hatch and young larval activity, which occurs shortly after the first moths are trapped.

A minimum of three traps for monitoring a single block of approximately 10 to 15 acres is recommended. Traps hung from the top wire of the trellis should be placed around the perimeter of the vineyard before bloom and should be at least 100 feet apart. Sticky trap bottoms should be checked weekly for moths, and pheromone caps should be changed monthly to obtain accurate flight information.

Every vineyard location is unique, and growers should not rely entirely on pheromone trap data especially from other vineyards for timing insecticide sprays. Visual inspection of flower and grape clusters should be conducted throughout the season in order to be aware of any stung berries.

Control

Pheromone traps should be used in vineyards with a history of grape berry moth problems. Trapping of adult male moths indicates the beginning of flight activity. Mating and egg laying will occur over a two- to three-week period following the first detection of flight activity. A protective cover spray may be required during this period to prevent egg laying and hatch. Early-season control of this pest may prevent it from becoming well established within the vineyard and may eliminate the need for control later in the season.

It should be noted that the second flight activity period occurring in late July and August is the most important. These adult moths in late summer produce the eggs that hatch into larvae capable of causing major damage to the maturing fruit. One should not depend solely upon a pheromone trap for detecting this late-season threat. Scouting should be implemented on a weekly basis after bloom.

If berry cluster damage reaches 6% in grapes used for processing or 3% in those grown for fresh market, a protective cover spray should be applied. Most growers are using a pyrethroid insecticide with very good results in this situation. Remember that pyrethroids have a short residual, usually no longer than seven to 10 days, and reapplication may be necessary, especially if above-average precipitation occurs.

Studies indicate that vineyards in close proximity to external berry-moth sources, such as wood lots, may require an application of insecticide in addition to the pheromone applications. Growers using the grape berry moth pheromone should continue to scout their plantings in the same manner as previously mentioned. If thresholds are reached, the decision to apply an insecticide should be considered.

Rose Chafer

Macrodactylus subspinosus, Order Coleoptera, Family Scarabaeidae

Description and Life Cycle

Rose chafer adults attack grapes at bloom as the chafers emerge from the soil. Not only do they destroy the fruit at blossom, they also frequently skeletonize the leaves, leaving only the large veins intact. This insect is especially abundant in areas of light, sandy soil where beetles may appear suddenly as grapes begin to bloom.

The ungainly beetles have a straw-colored body, reddish-brown head and thorax with a black undersurface. The adult rose chafer is about 1/2 inch in length with long, spiny, reddish-brown legs that gradually become darker near the tip (Figure 69). As they age, hairs are worn off the head and thorax with normal activity, revealing the black color below. Thus they become mottled in color as they mate and move around in the flower clusters, making it possible to distinguish newly emerged adults from older specimens.

FIGURE 69. Adult rose chafer.

Females frequently lose more hairs, particularly on the thorax, in the mating process.

Eggs of the rose chafer are oval, white, shiny in appearance, and about 1/20 inch long and 1/30 inch in width. Larvae are C-shaped white grubs about 1/12 inch long and 1/8 inch wide when fully grown. Mature larvae have three distinct pairs of legs, a brown head capsule, and a dark rectal sac visible through the integument. Larvae are found in sandy soil, feeding on roots of grasses and other weeds, and can be identified by a distinctive rastral pattern. The pupae are light yellowish-brown in color and have prominent legs. They measure about 1/2 inch in length.

Adult rose chafers become active in northeastern North America from late May to early June. The adults appear all of a sudden. It seems as though the entire population reaches maturity practically at the same time, and multitudes of beetles suddenly make their appearance. Beetles feed and mate soon after emerging from the soil. It is common to see mating pairs in the newly formed grape clusters.

Females deposit eggs singly a few centimeters below the soil surface. Mating and egg laying occur continuously for about two weeks, with each female depositing 24 to 36 eggs. The average life-span of the adult is about three weeks.

Approximately two weeks after being deposited, eggs hatch into tiny, white, C-shaped grubs. The larvae feed on the roots of grasses, weeds, grains, and other plants throughout the summer, becoming fully developed by autumn. However, it is not easy to collect the larvae of rose chafer. They have been found occasionally on the roots of orchard grass but never in proportion to the numbers found in adjacent grapes.

Larvae move downward in the soil as soil temperatures decline and form an earthen cell in which they overwinter. In the spring, larvae return to the soil surface, feed for a short time, and pupate in May. After two weeks in the pupal stage, the adults emerge and crawl to the soil surface to begin their cycle again. There is only one generation per year.

Damage Symptoms

Despite its common name, the rose chafer attacks the flowers, buds, foliage, and fruit of numerous plants including grape, rose, strawberry, peach, cherry, apple, raspberry, blackberry, clover, hollyhock, corn, bean, beet, pepper, cabbage, peony, and many more plants, trees, and shrubs.

Adults emerge about the time of grape bloom and often cause extensive damage. Blossom buds are often completely destroyed, resulting in little or no grape production (Figure 70). Feeding activity on various plants may continue for four to six weeks. Damage can be especially heavy in sandy areas, the preferred habitat for egg-laying.

FIGURE 70. Blossom buds destroyed by the rose chafer.

Monitoring

Scouting for this pest within your vineyard should begin in late May and continue through late June. Newly emerged adults may be found feeding primarily on newly formed grape clusters. If numbers reach two beetles per vine, control methods should be considered.

Monitoring may also be conducted by using the attractant developed for rose chafer. Traps should be placed around the perimeter as well as diagonally across the vineyard. The traps used for this purpose are Japanese beetle traps. For monitoring purposes, these traps may be spaced every 100 feet and should be checked daily for newly emerged chafers to let you know when beetle activity has begun. In addition, these traps remove beetles from the population.

If you have areas where the rose chafer is particularly troublesome, it would be a good idea to sample pastures or other grassy areas in the neighborhood to see if the grubs are in the vicinity and might be controlled. In order to distinguish the grubs of scarab beetles, the raster pattern is used (Figure 71).

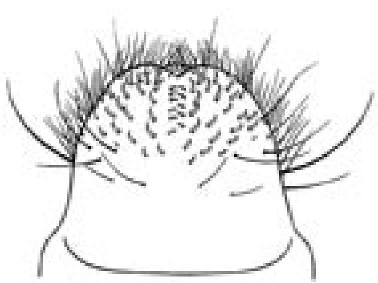

FIGURE 71. Use the rastral pattern to distinguish grubs of scarab beetles. Rose chafer larvae can be identified by a distinctive rastral pattern, shown here.

Management/Control

Adult chafers begin emerging in late May and early June at the time of grape bloom. When only a few beetles are present, one may handpick them from the plant and destroy them. Where populations are large and pose a threat to the grape crop, massive trapping may be a safe alternative to applying insecticide.

An alternative method to chemical control has been developed by the Department of Entomology at Ohio State University for this pest. A lure using a new powerful attractant is placed in a Japanese beetle trap. Results have been very positive. The desired effect of mass trapping, which is to bring the beetle population to below threshold level, is usually achieved after a couple years of trapping.

An application of insecticide may be required in combination with the trapping effort if the population is extremely high. It is our experience that it takes a couple years of intensive trapping to reduce the population within a heavily infested vineyard to the point that chemicals are no longer needed to control this pest.

In addition, it should be kept in mind that the pupal stage is extremely vulnerable to disturbance; therefore, cultivating between rows may be effective in destroying a good number of chafers. However, it has been our experience that growers with numbers of beetles sufficient to inflict economic damage will not be able to control this pest by this cultural method alone.

Chemical control methods should be used when beetle pressure exceeds the threshold. To determine the number of beetles per vine, one should randomly survey 25 vines at all four corners of the vineyard and 25 in the center of the vineyard. If this average is above two beetles per vine, then treatment is recommended.

It should be noted that with this survey method, one can determine if the chafer infestation is present throughout the vineyard or localized in a specific area. If the area is localized, spot treatment of the infestation may be all that is required. Treatment with an insecticide should be when the first newly emerged beetles are detected in adequate numbers to pose concern. A second application may be required if pressure is severe and rainfall is frequent.

Protection of the young grape cluster is critical and should be maintained throughout June. For control of rose chafer, see the *Commercial Small Fruit and Grape Spray Guide* for your state. These recommendations are updated annually.

Multicolored Asian Lady Beetle

Harmonia axyridis, Order Coleoptera, Family Coccinellidae

Description of Life Cycle

Adults are oval, about 5/16 inches long and 1/4 inch wide (Figure 72). There are many different color forms ranging from pale yellow-orange to bright red-orange, with or without black spots on the wing covers. The head, antennae, and mouthparts are generally straw colored but are sometimes tinged with black. The pronotum is white with up to five black spots or with lateral spots usually joined to form two curved lines, a W- or M-shaped mark, or a solid trapezoid. The wing covers are generally yellow-orange in unspotted beetles.

FIGURE 72. Adult Multicolored Asian Lady Beetle.

Eggs are bright yellow, laid in clusters of about 20 on the leaves and stems of host plants (Figure 73). Larvae are elongate, somewhat flattened, and adorned with strong tubercles and spines. The mature fourth-instar larva is strikingly colored—the overall color is mostly black to dark bluish-gray, with a prominent bright yellow-orange patch on the sides of abdominal segments one to five (Figure 74).

The life cycle from egg to adult requires about a month or so, depending mostly on temper-

FIGURE 73. Lady beetle eggs hatch in three to five days.

FIGURE 74. Lady beetle larval stage.

ature. Eggs hatch in three to five days. The larval stage lasts up to 14 days, during which time they consume large numbers of aphids, scale insects, or other soft-bodied insects. Pupation lasts five to six days (Figure 75), followed by adult emergence.

The adults are rather long lived, with some lady beetles living up to three years. At least two generations, with a partial to complete third generation, occur each growing season.

In the fall when the host plants, such as soybeans, begin to dry and cooler weather approaches, adult lady beetles begin to seek overwintering sites. They are attracted to vertical walls or cliffs where they seek shelter in cracks and crevices. Once one lady beetle

FIGURE 75. Lady beetle pupation.

FIGURE 76. Multicolored Asian lady beetles on damaged fruit.

lands, many others may follow in their aggregating behavior.

Damage Symptoms

Lady beetles are normally considered as beneficial insects. However, at grape harvest, the multicolored Asian lady beetle is now considered a foe. At harvest there may be a huge increase in the presence of lady beetles in many vineyards in the Midwest. Entomologists in the region attribute this population explosion to the sudden arrival of the Chinese soybean aphid. As soybeans mature and dry in late summer, the lady beetles disperse, at which time mature grapes, especially those with damaged clusters, become very attractive to the lady beetles. Beetles remain on the grapes and feed for several weeks, especially where ripe fruit is left in the field late in the season.

In many instances, 10 or more beetles may be found per cluster on the damaged fruit (Figure 76). The lady beetles seldom cause primary damage biting through the skin of the grapes with their mandibles. However, they do take advantage of breaks in the skins caused by yellow jackets, hornets, birds, raccoons, as well as diseases.

The amount of physical damage they cause is minimal. However, the lady beetles are a menace to grapes due to a substance they produce when touched or squeezed, causing reflex bleeding. When harvesting infested grapes, the beetles inadvertently end up in the crusher and thus contaminate the juice with their special aroma.

The hemolymph or blood of the insect is a protective mechanism to keep birds and other predators away. They exude the musty/basement-like odor from the joints of their legs. The detrimental effect is that this hemolymph taints the juice and is able to persist all the way through the process of fermentation into the wine.

Management

Since the multicolored Asian lady beetle is not a native species, few diseases or parasites have been associated with this beetle. However, adult beetles have been found to vector fungal diseases, and therefore their aggregating nature may be favorable to the dissemination of bunch rot and other diseases from one grapevine to another.

Due to the adverse habits of this predatory beetle, some form of cultural or chemical control has become necessary. However, controlling these beetles in grapes at harvest poses a problem. Harvest restriction intervals must be considered.

Insects That Attack Grape Foliage

Japanese Beetle

Popillia japonica, Order Coleoptera, Family Scarabaeidae

Description and Life Cycle

The adult beetles feed on the foliage, fruits, and flowers of more than 250 kinds of plants, but grape is one of their preferred hosts. The larvae are C-shaped grubs found in the soil and are serious pests of grass roots. The distinguishing character of the grubs of scarab beetles is the rastral pattern (Figure 77). The adult beetle has a shiny, metallic-green head and thorax, and coppery-brown wing covers. Tufts of white hairs are located along the sides of the body (Figure 78). Adult beetles are about 1/2-inch long.

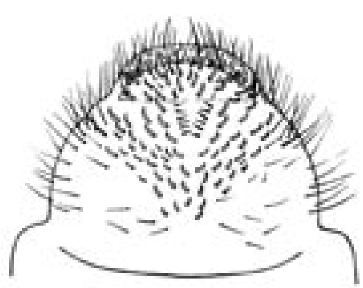

FIGURE 77. The rastral pattern is the distinguishing characteristic of the Japanese beetle. Note the V-shaped formation of hairs on the raster of the grub.

Larvae feed principally on grass roots and other organic matter. During late spring, larvae move closer to the soil surface and complete their development.

Adult beetles emerge from the ground in late June through July and begin feeding upon foliage. Mating occurs at this time, and eggs are laid in the ground. Eggs hatch in about 10

FIGURE 78. Note tufts of white hair alongside the body of the Japanese beetle.

days, and young grubs begin feeding on plant roots. They overwinter as larvae below the soil surface. Grubs continue to feed and grow until cold weather drives them down, at which time they tunnel down from 3 to 12 inches to make overwintering cells. In the spring when the soil begins to warm, grubs move toward the surface where additional feeding may occur before pupation in late spring. There is only one generation per year.

Damage Symptoms

The adults feed on the leaves of both wild and cultivated grapevines (Figure 79). Beetles prefer foliage exposed to direct sunlight and often are seen clustered together, feeding on tender vegetative parts. Vines with thin, smooth leaves, such as French hybrids, are preferred over those with thick, pubescent leaves, such as Concord. Concord vineyards rarely need special control sprays for Japanese beetles. On the other hand, French hybrids and other thin-leaved cultivars require frequent inspection to prevent damage. Damaged leaves have a laced appearance, and severely affected leaves will drop prematurely.

Management

There is no economic threshold on the number of beetles or amount of damage that

FIGURE 79. Adult Japanese beetles feeding on grape leaves.

requires treatment. If a susceptible cultivar is being grown and growers previously have experienced high populations of Japanese beetles, an insecticide should be applied when beetles emerge and thereafter as needed.

Monitoring

A Japanese beetle lure and trap is available for monitoring this pest; however, these beetles are easily detected while walking through the vineyard. If skeletonizing of leaves becomes evident, thin-leaved cultivars may need to be protected with an application of insecticide. The usual threshold for making a spray application is about 15% of the leaves consumed.

Control

Insecticide is usually applied when feeding is apparent on most vines and skeletonized leaves are found. Spot treatment is adequate in some cases. An insecticide with long residual activity is needed when beetle populations are high. Repeated applications may be needed to control new beetles flying in from surrounding areas.

A microbial insecticide is available to control Japanese beetle grubs in turf, although it is slower acting and more expensive than conventional insecticides. This bacterial insecticide causes milky spore disease within the grub stage of development. This microbial insecticide cannot be relied upon to protect grapes from Japanese beetles due to the mobility of the beetles.

To control Japanese beetle and other fruit insects, get a copy of the latest recommendations from your local Extension agent.

Grape Phylloxera

Daktulosphaira vitifoliae, Order Homoptera, Family Phylloxeridae

Description and Life Cycle

Phylloxera is one of the most destructive grape pests worldwide. This small aphid-like insect has a complex life cycle that involves survival on the roots throughout the year and on the leaves during the growing season. The insect forms galls on the leaves and roots of grapevines. The vine will die if its roots become heavily infested with phylloxera (Figure 80). If leaves become heavily infested, premature defoliation and retarded shoot growth may result.

The life cycle is different for the foliar and root forms of this insect. The foliar form survives the winter as an egg under the bark of the grapevine. Asexual, wingless forms hatch in the spring and crawl to tiny new leaves, where they develop galls.

FIGURE 80. Roots heavily infested with phylloxera.

Young crawlers settle on the upper surface of immature leaves, causing galls to form on the under surface of the leaves (Figure 81). The only opening in a gall is to the upper leaf surface. Once mature, the female begins to lay eggs within the gall. Nymphs hatching from these eggs crawl to new leaves at shoot tips, settle on the leaves, and form new galls.

In the case of the root form of grape phylloxera, the insects overwinter as immature forms on the roots (Figure 82). These forms mature in the spring and produce eggs that hatch into nymphs. The nymphs then start new galls on the roots.

FIGURE 81. Phylloxera galls are found on the undersurface of leaves.

FIGURE 82. Phylloxera overwinters as immature forms on roots.

Winged forms develop in the spring, summer, or fall and emerge from the soil to lay eggs on stems. These eggs hatch and produce the true sexual forms that produce the overwintering eggs laid under the bark. Several generations of each form of phylloxera may occur each season. Although the two forms behave differently, both belong to the same species.

Management

In many areas of the world, susceptible cultivars are grafted onto resistant rootstocks to prevent damage by the root form. However, the foliar form still may occur in such cases. There are some natural predators that feed upon the foliar form of grape phylloxera, but none of these provide adequate control of the pest. There is no known completely successful chemical control for the root form of grape phylloxera. Eastern growers usually do not have a problem with the root form of the phylloxera.

Monitoring

Phylloxera is usually spotty in Ohio vineyards, so identifying these areas within your vineyard is important. Spot treatment may be all that is required to control this pest.

To identify the location and extent of phylloxera within a vineyard, one should begin scouting for infested leaves after shoot length has reached five inches. Young galls will be forming on the underside of the terminal leaves; they are not easily noticed early in the season without taking the time to inspect the leaves closely.

These galls should not be confused with grape tumid galls, commonly called the grape tomato gall. Tumid galls have a smooth outer surface and take on a reddish tomato-like appearance. The grape phylloxera gall is green in appearance except early in the season, when some cultivars tend to have more of a reddish cast to them. The gall itself has a rough-looking surface rather than the smooth surface of the tumid gall. Tumid gall is present but not a problem in Midwestern vineyards.

Control

Among the cultivated American grapes, many tend to have resistance to the foliar form of the grape phylloxera, whereas French hybrids and vinifera grapes are usually very susceptible, and control of phylloxera on these cultivars is recommended. One cannot usually completely eradicate phylloxera from a vineyard that is already infested, but one can take measures to keep the infestation at a tolerable level.

Control of the foliar form of phylloxera may be achieved by applying insecticide at bloom and again 10 to 14 days later. Late-season treatment of grape phylloxera is not effective and seems to be a waste of time and money. Early-season control of this pest is critical. Currently we are fortunate to have a pyrethroid insecticide labeled for controlling the foliar form of grape phylloxera. Some compounds are known to be phytotoxic to certain cultivars. Consult the latest control recommendations for EPA-approved insecticides.

Leafhoppers

Potato Leafhopper

***Empoasca fabae*, Order Homoptera, Family Cicadellidae**

Description and Life Cycle

The potato leafhopper (Figure 83), a sucking insect, feeds sporadically on foliage of grapes, strawberries, and many other plants. The adult leafhopper is pale to bright green, wedge-shaped, and about 1/8 inch long. The adults are very active, jumping, flying, or running when disturbed. The immature forms, or nymphs, are pale green and wingless. They run forward, backward, or sideways rapidly when

FIGURE 83. The potato leafhopper feeds on foliage.

threatened. The potato leafhopper feeds on more than 200 plant species.

The potato leafhopper does not generally overwinter in areas north of the Gulf States. Each year large numbers of potato leafhoppers are carried to northern areas by warm spring air currents. Injury to grapes occurs when the adults fly into vineyards and feed on the leaves. Toxins injected while feeding cause leaves to cup and be misshapen (Figure 84). These leaves are most often observed in the top of the vine and are quite obvious, especially at the end of the growing season.

FIGURE 84. Toxins injected during potato leafhopper feeding causes leaves to cup and be misshapen.

Grape Leafhoppers

Eastern Grape Leafhopper, *Erythroneura comes*
Three-Banded Leafhopper, *Erythroneura tricincta*
Virginia Creeper Leafhopper, *Erythroneura ziczac*

Description and Life Cycle

Three of the most common leafhoppers found on grapes in Ohio are the Eastern Grape Leafhopper, *Erythroneura comes* [Say]; the Three-Banded Leafhopper, *Erythroneura tricincta* Fitch; and the Virginia Creeper Leafhopper, *Erythroneura ziczac* Walsh. These three species vary in their coloration and markings.

The adults of these leafhoppers are about 1/8-inch long. *Erythroneura comes* is pale yellow or white with yellow, red, and blue markings (Figure 85). Overwintering adults are often nearly all red. *E. tricincta* is brown and black with touches of orange on the wings (Figure 86). *E. ziczac* is pale yellowish or white with a zigzag stripe down each wing and cross veins are distinctly red.

FIGURE 85. The Eastern Grape Leafhopper is pale yellow or white with yellow, red, and blue markings.

FIGURE 86. The Three-Banded Leafhopper is brown and black with touches of orange on the wings.

The biology of these three species is similar. They overwinter as adults in sheltered places such as the remains of old plants. During the first warm spring days the leafhoppers become active, and they feed on the foliage of many different plants until grape leaves appear. Eggs are deposited under the leaf epidermis and hatch in about two weeks. The immature leafhoppers, or nymphs, are wingless (Figure 87); they remain and feed on the leaves where they hatch. Nymphs molt five times, then transform into adults. There are two or three generations of leafhoppers each season.

Damage Symptoms

Adults and nymphs feed on leaves by puncturing the leaf cell and sucking out the

FIGURE 87. Immature leafhoppers, or nymphs, are wingless.

contents. Each puncture causes a white blotch to appear on the leaf (Figure 88). In heavy infestations, the leaves turn yellow or brown, and many fall off prematurely. Feeding by these leafhoppers may reduce the photosynthetic capacity of the plant, and the quality and quantity of the fruit may be affected.

FIGURE 88. Each puncture from a leafhopper causes a white blotch on the leaf (left). The leaf on the right is normal.

Grapevines can tolerate populations of up to 15 insects per leaf with little or no economic damage. However, heavy leafhopper feeding may result in premature leaf drop, lowered sugar content, increased acid, and poor coloration of the fruit.

The sticky excrement (honeydew) of the leafhoppers affects the appearance and supports the growth of sooty molds. Severely infested vines may be unable to produce sufficient wood the following year. Damage to the vine can be serious if infestations are allowed to persist unchecked for two or more years.

Management

Weeds and trash in and around a vineyard are a source of leafhoppers. If this material is removed before spring, the adults lose their protection and feeding sites, although in areas with extensive agriculture, this practice has less value as the adults will just move to an adjacent crop or weedy area.

Certain cultivars are likely to suffer higher leafhopper populations than others. Wine and table grape varieties fit this criteria. Moreover, late-producing cultivars are more likely to favor leafhoppers than early maturing cultivars.

Monitoring

Vigorous vines are preferred by leafhoppers. The heaviest populations are normally found on end vines and on outside rows. This is partly because these vines are usually the most vigorous and therefore the most attractive. It also is partly because of the border or boundary effect. Vigorous vines fortunately can tolerate the highest populations.

Sampling for leafhoppers should be done at 10 days post-bloom, the third week in July, and again the third to fourth week of August. This is approximately the same time one should be assessing grape berry moth risk, and both surveys may be conducted simultaneously.

Ten Days Post-Bloom—Only adult leafhoppers are present at this time of the year, so it is not necessary to count them. If leafhoppers are present, you should see stippling damage on the lower sucker leaves and interior leaves of the grape canopy. By shaking the vines, adult leafhoppers, if present, will fly around the vine. If stippling damage is present throughout the vineyard, an application of insecticide is recommended to prevent later damage from occurring.

Early-season damage may indicate that populations may potentially build up to damaging levels later in the season. In vineyards that are at high risk for grape berry moth, insecticide is usually applied at this time, so scouting for leafhoppers at this time is not necessary.

Third Week in July—From mid- to late July, first generation nymphs are present and feeding on the undersides of grape leaves. At this time, the need to apply an insecticide for leafhopper control should be determined on a block-by-block basis. Sampling for grape berry moth and leafhoppers can be done with a single pass through the vineyard.

The first step in evaluating leafhopper damage is to look for stippling on leaves while you are doing counts of grape berry moth damage. Most damage will be found on the first seven leaves from the base of the shoot. If no stippling or minimal stippling is visible on the leaves, there is no point in counting how many leafhoppers are present.

If moderate to heavy stippling is visible, then it is necessary to do counts of leafhopper nymphs to determine if damage levels warrant treatment. The sampling procedure for leafhoppers requires counting all leafhoppers on the undersides of the third through seventh leaves of one shoot on each of five vines. Sampling for leafhoppers should take only a few minutes per vineyard.

Late August—In years when leafhoppers do build up to damaging levels in vineyards, it is most common for them to do so in late August. Vineyards with greater than 10 leafhoppers per leaf should be treated at this time. If there is very little visible stippling, sampling will not be necessary. Vineyards that had insecticides applied to them earlier in the season will probably not need treatment at this time. In Ohio we experience more of a problem with leafhoppers on the islands in Lake Erie and in vineyards near Lake Erie.

Control

Leafhoppers have few natural enemies. Cold and wet weather conditions in spring and fall are damaging to leafhopper populations, as are wet winters. Cultivation and cleanup of adjacent weedy land in the fall will eliminate favorable overwintering sites in and near a vineyard.

When high populations of leafhoppers are encountered, an application of an insecticide may be required. In order to obtain good control of leafhoppers, complete coverage of the undersides of the leaves is important. Coverage of the fruit is of secondary importance.

For control of leafhoppers, see the *Commercial Small Fruit and Grape Spray Guide* for your state. These recommendations are updated annually.

Insects That Attack the Roots and Crown

Grape Root Borer

***Vitacea polistiformis*, Order Lepidoptera, Family Sesiidae**

Description and Life Cycle

Larvae of the grape root borer attack the larger roots and crown of grapevines (Figure 89). They tunnel into these parts of the plant and feed internally. The feeding and boring of the larvae will weaken and may eventually kill the vine.

FIGURE **89.** Grape root borer larvae attack the larger roots and crown.

The adult is a clearwing moth, with brown forewings and clear hind wings with brown borders. The body mimics that of a wasp, brown with yellow markings. Male moths (Figure 90) measure about 5/8 of an inch in length, while the female (Figure 91) is larger, about 3/4-inch long.

FIGURE 90. Grape root borer, male moth.

FIGURE 91. Grape root borer, female moth.

The moths emerge from the soil during July and August. Eggs are deposited individually on grape leaves or weeds, or dropped on the ground close to the trunk. The larvae hatch and burrow into the soil, find their way to the roots and crown, and feed on them. Larvae continue to feed within the vine's root system for about 22 months (Figure 92). A fully developed larva is about 1/2-inch long and white with a brown head capsule.

FIGURE 92. Grape root borer.

Mature larvae move to places just under the surface of the soil and pupate in earthen cells. Adults start emerging in July and continue to emerge through August (Figure 93).

Damage Symptoms

Larvae attack the roots and crown of grapevines. They tunnel into the roots or crown and feed internally. Feeding and boring weaken the grapevine and may eventually kill it. Larvae also provide entry points for disease organisms. Vines that are severely infested may wilt under stress; sometimes only part of the vine will show stress.

Management

Weed control is important in managing this insect pest. Weed control decreases the number of oviposition sites and provides an area under the trellis suitable for applying an insecticide. Researchers in North Carolina also have achieved good control of root borers with polyethylene mulch; this technique can be easily accomplished at planting. It works well in the short term, but the mulch must be maintained over the years in order to be successful.

An alternative method of control is to use pheromone rope ties to disrupt the ability of the males to locate the female grape root borer. This method has been successful in some cases.

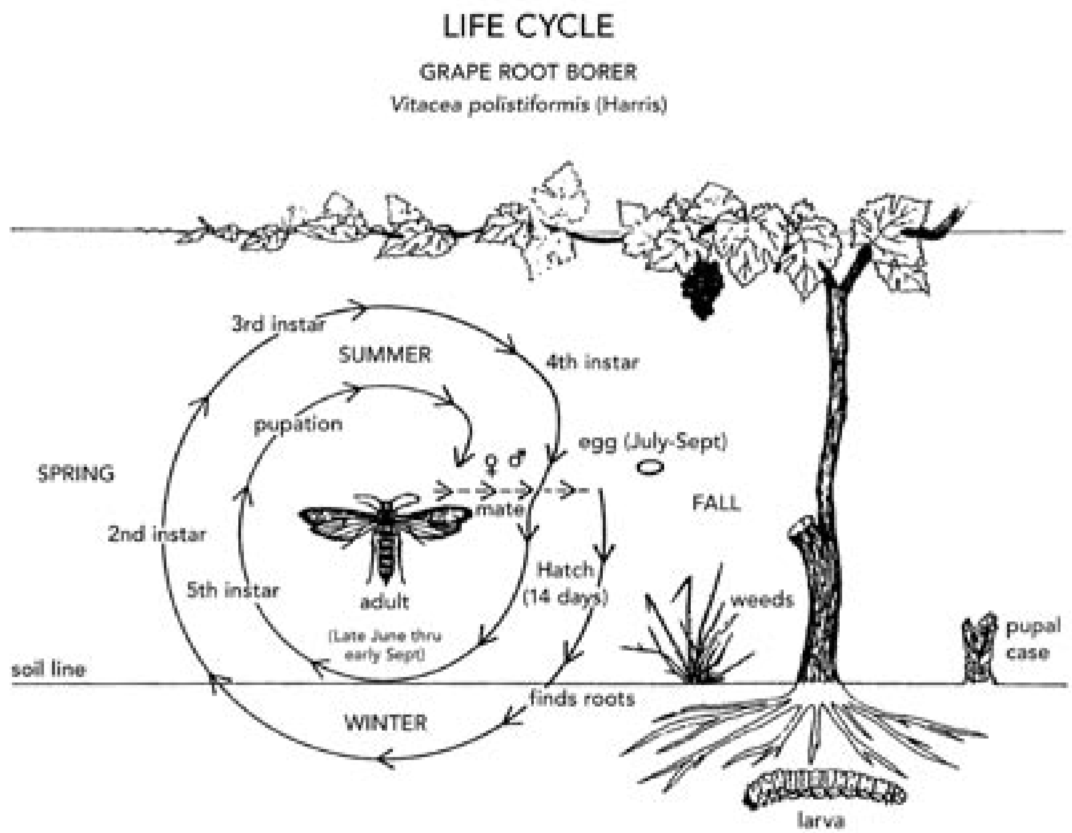

FIGURE 93. Grape root borer adults emerge in July and August.

This method prevents the male root borers from locating the female borers and mating, thus reducing the number of fertile root borer females in a treated vineyard.

Ties are dispensed manually at a rate of 100 ties per acre. They should be placed on the top trellis wire every six or seven vines. Results from these trials look promising, but bringing the borer population down to acceptable levels requires several years.

Another method of using the grape root borer pheromone for control is being studied at two southern Ohio vineyards. This method uses the sex pheromone and 1C Pherocon traps. Traps baited with the pheromone are placed throughout the vineyard in an attempt to reduce the number of males available for mating. Three years of study has shown that the male population is continuing to decline where the pheromone is utilized.

External wood lots containing wild grapes are a good source of grape root borers. Such areas adjacent to vineyards should be considered as possible reservoirs when trying to manage this pest. Extermination of wild grapes from within these areas should help to reduce root borer pressure.

Chemical control of this pest is difficult due to its cryptic nature. Other management strategies are being evaluated at Ohio State University. One of these utilized parasitic nematodes that attack the larvae of the grape root borer. This method of control is showing promise. However, a little more research is needed to confirm its utility.

Monitoring

Pheromone traps are the only means to easily monitor this pest. Response by male root borers to this sex pheromone is strong. A minimum of three pheromone traps should be placed transecting the vineyard in a diagonal manner. Traps should be in place by late June and checked on a weekly basis thereafter. A single pheromone cap within a trap will last the entire season.

Control

Trapping-out uses the sex pheromone placed within 1C Pherocon sticky traps. This method is still experimental at this time but certainly appears to be working. Traps are placed around the vineyard perimeter in late June at 35- to 50-foot intervals. These traps should be checked on a weekly basis. Where infestations are high, many borers will be trapped, resulting in the need for removal of some of the trapped adults or replacement of the trap bottoms. This method requires a continued effort year after year to reduce pressure in subsequent years.

Chemical control of emerging adults or entering newly hatched larvae will give some assistance if repeated over a wide area.

See the *Commercial Small Fruit and Grape Spray Guide* for your state for recommendations.

Mites That Attack Grapes

European Red Mite

Panonychus ulmi, Order Acari, Family Tetranychidae

Description and Life Cycle

The European red mite causes considerable damage to apples in some orchards; it also becomes a problem in vineyards from time to time.

The adult female of the European red mite is dark red to reddish-brown, has eight legs, and is about 1/50-inch long (Figure 94). Adult male mites are smaller and have a pointed abdomen; they are usually dull green to brown.

Eggs, which are globe-shaped and red, are laid on the undersides of leaves in the summer. The eggs are tiny and require a magnifying glass to be seen. During late summer and early fall, eggs are laid around cane nodes, where they overwinter (Figure 95). Several generations occur each season.

FIGURE 94. Adult female European red mite.

FIGURE 95. Red mite eggs are laid around cane nodes where they overwinter.

Damage Symptoms

The adults and nymphs of this species feed on the undersurfaces of leaves, and in heavy infestations, the leaves turn a bronze color. If bronzing occurs early enough in the season, a negative effect on fruit ripening may occur as feeding may interfere with the normal photosynthetic process of the leaves.

Management

Growers should apply miticide sprays before bronzing occurs. In some vineyards, this pest is kept at low levels by naturally occurring predatory mites and predaceous insects.

Monitoring

Monitoring for European red mite can be accomplished by looking at the underside of the leaves for their presence at the same time you are scouting your vineyard for leafhoppers and grape berry moth. You may also keep a close eye out for bronzing while traveling through the vineyard on your tractor. This can be done at the same time you are applying fungicide sprays to the vineyard.

Control

Some chemicals reduce leafhopper and/or spider mite populations while allowing predaceous mites to maintain control of the latter. Ideally, treatments should be applied so that mites are reduced below economic levels without killing predaceous mites or reducing their food source to the extent that they starve.

For a list of miticides available for controlling mites in the Midwest, see the *Commercial Small Fruit and Grape Spray Guide* for your state.

Wildlife Management

Birds

Crop damage in wine grape vineyards due to bird depredation appears to be more pronounced in recent years (Figure 96). This may be due in part to the increasing acreage of highly palatable wine grape cultivars being grown.

Several Midwest wine grape growers have found that birds are attracted to the early ripening varieties such as Marechal Foch, Leon Millot, Pinot gris, and Baco noir. There is commonly an increase in bird activity in vineyards as the berries near veraison. This is a critical time to persuade the birds to move elsewhere or try to prevent them from reaching the mature berries.

FIGURE 96. Bird damage to winegrape clusters.

Birds that are commonly observed in Midwestern vineyards are European starling, American robin, Northern mockingbird, Northern oriole, and Common grackle. Other birds such as House finch, Cardinal, Cedar waxwing, Gray catbirds, and American goldfinch have also been observed in vineyards at various times. Migrating or local flocks of birds will begin testing grape berries at veraison.

Several types of management measures have been implemented in vineyards to deter birds from feeding, including bird netting; visual, sound, and chemical repellents; and birds of prey.

Physical Barriers

Growers have often tried to exclude birds from the grape canopy by draping bird netting over each individual trellis row (Figure 97). Netting is usually rolled out between the rows and pulled over each trellis and fastened together to prevent netting from blowing off. This provides a good barrier to feeding birds. Mechanical rollers to lay out and take up bird netting are available commercially. Netting must be in place by early veraison to assure that no fruit is damaged or lost.

Visual Repellents

Some of the most frequently used visual devices include scare-eye balloons, Mylar tape, tin pans, streamers, and other shiny and fluttering objects. The effectiveness of these visual deterrents has been limited. Birds are very capable of adjusting to new objects in a relatively short period of time. This type of deterrent should only be used in a limited time frame and, more appropriately, should be included in an integrated bird-management system.

FIGURE 97. Bird netting draped over grape canopy using a net applicator.

Birds of Prey

Some growers have tried to set up nesting poles to encourage falcons and hawks to nest in vineyards. When large avian predators are active in the vineyard, fruit-eating birds will tend to stay away from the area. Locating artificial owls and other birds of prey in vineyards has not been effective.

Sound Repellents

Propane cannons have been randomly placed in vineyards and set to go off at designated time intervals. Alarm systems that imitate bird distress sounds can also be located in the vineyard and will sound on a preset time schedule. Some of the more sophisticated systems can produce distress calls from different bird species, alternating the sound and length of time of each. The loud or distress noise will generally induce a panic in the birds, and they take flight to avoid a perceived danger.

As with the sight deterrents, birds often become acclimated in time to new sounds introduced into the vineyard. These devices should be used selectively with other control measures. The devices should be moved around the vineyard to reduce bird familiarity and avoid annoying neighbors living near the vineyard. Growers have resorted to shooting a shotgun or pyrotechnic pistols to create noise to scare birds from vineyards.

Chemical Repellents

This type of bird control requires the application of a chemical compound to grapes. Birds find fruit treated with a chemical agent to be distasteful. Different chemicals have been tested as repellents to reduce bird depredation in fruit crops.

Methyl anthranilate, a naturally occurring compound in Concord grapes, was found to reduce bird feeding, but a noticeable *foxy flavor* appeared in wine produced from Vinifera and French hybrid grapes treated with this chemical. Sucrose (disaccharide) has been used to reduce bird depredation in fruit crops. Research conducted at Cornell University showed that birds were less likely to consume blueberries sprayed with sucrose.

Wild Turkey

Wild turkeys are appearing with ever increasing numbers in vineyards. As more vineyards are planted, wild turkeys tend to move through these areas in flocks looking for food and shelter. Unless preventative measures are taken to restrict their entry into a vineyard, there is little that can be done to prevent them from decimating a grape crop.

Wild turkeys, unlike domestic turkeys, can take flight and are often seen roosting in surrounding trees and brush. As with other birds, turkeys do not like loud and/or distressing sounds.

Physical Barriers

Standard bird netting can be used, although turkeys are more powerful and may tear the netting trying to get the fruit. High fencing can be used to turn back the turkeys.

Sound Repellents

Propane cannons will have some effect for the short term, but turkeys, as with other fruit-eating birds, become accustomed to the sound and within a few days may pay little attention. Shotgun and pyrotechnic guns may provide some means of distraction to wild turkeys, so they are less likely to settle in the vineyard.

Deer

Deer, like other wildlife, pose a serious threat to Midwestern vineyards. Many times deer have been observed foraging on young succulent grapevine shoots in early spring and continuing this feeding behavior into early summer. Food sources are scarce during budbreak, and deer are naturally attracted to any green tissue that emerges. Several different kinds of approaches have been used to mitigate the damage that deer cause in vineyards.

Chemical Repellents

Chemical repellents should be used with caution on fruit crops. Some repellents are not labeled for use on any food crop, and others can only be used during dormancy or when there is no fruit present. Be sure to read and follow label directions when considering the application of a repellent.

Odor Repellents

Materials—human hair, dog hair, and soap—that are commonly used to deter deer are used because they smell unnatural or have the smell of a predator. These materials can be used effectively to prevent deer from entering vineyards.

There is some interest in using coyote hair to create a negative environment for deer. Coyotes are the main predators of white-tail deer in Ohio, and it has been reported that deer do not like to come near feeding areas that have been baited with coyote hair. As with the bird populations, deer can acclimate very quickly, and they can become familiar with a new odor. However, deer appear to avoid the area baited with coyote hair for several weeks, even when the bait is removed, according to APHIS research scientists.

Sound Repellents

Deer can be startled by unfamiliar sounds, and they are less likely to stay in an area in which strange, unnatural sounds are emanating. Propane cannons and distress signals can be used to send deer to flight. Moving the noise-makers around the inside and outside of the vineyard can help to dissuade the deer from entering the vineyard and make the situation somewhat less familiar. This should keep the deer on edge and less interested in foraging on the tender vegetation of the vines.

Physical Barriers

Grow tubes and mesh vinyl screens can be quite effective in protecting young vines from foraging deer. The cost will vary depending on the number of tubes and screens you purchase. They can be easily placed around the plants to protect the newly emerging tissue. One problem is that these devices only protect plants when first established in the vineyard. The vines will quickly grow out of the tubes and mesh screen, and then deer are able to reach shoots growing out of the top.

Fencing is one of the best means of preventing deer from entering a vineyard (Figure 98). The expense for some owners can be cost prohibitive. Poly Tape electric fence, commonly used to keep horses and cattle in pasture, is being used to control deer from entering vineyards. Some producers are using this in place of standard single-strand electrical fence.

It has been observed that deer will not enter pasture with this type of fence surrounding it. The Poly Tape (1–1/2-inches wide) works well at a height of 5 to 6 feet, with four to five strands from top to bottom. Generally, only the first through third strands from the ground are charged.

Peanut butter on aluminum foil placed on the electrical wire is used to bate the deer. T-Posts are used to fasten the tape in place within the fence row. With any electric fence, grass and weeds must be kept under control or the fence could short out. Weed whacker or burndown herbicides can be used to control vegetation (Figure 99).

FIGURE 98. Deer exclusion from the vineyard using an eight-foot fence.

FIGURE 99. Integrated wildlife management using netting (background) for birds and two-wire electric fence (foreground) for raccoons.

Weeds and Weed Control

Growers agree that weeds must be controlled to maintain a productive vineyard; however, the success achieved varies considerably. Whether you are establishing a new vineyard or attempting to reduce weed problems in one that already exists, choices and actions made along the way will determine the outcome. Weed control fails most often because growers do not understand the biology of weeds nor the tools they are using to gain control.

Weeds can cause tremendous problems in the vineyard. Besides competing with the grapevine for nutrients, light, and moisture, weeds provide shelter and food for other pest problems. Dense weed growth impairs air circulation in the vineyard, creating an environment where grape diseases can flourish. Weed growth may interfere with fungicide and insecticide applications.

Because each weed species may require a slightly different or a vastly different control method, the successful grower must be able to identify weeds. Once the weeds in the vineyard have been identified, a control program that considers biology, tools, economics, and the environment can be planned and implemented. Therefore, weed identification is the first skill set that should be learned.

To get started with weed identification, obtain an identification manual, preferably one with good photographs and line drawings of weeds at both seedling and mature stages. One book we have found particularly useful is *Weeds of the Northeast*. Once you are ready, remember that separating different weeds into sensible categories will help you identify one from the other and also help decide on the appropriate control. Categories most useful are grasses vs. broadleafs and annuals vs. perennials (grasses and broadleaf weeds may be either annual or perennial).

Most weeds can be categorized as annuals or perennials. Annual weeds complete their life cycle, from emergence to setting seed and dying, in less than 12 months (Figure 100). Summer annuals (common lambsquarters, pigweed, green foxtail, for example) emerge in the spring or early summer and complete the cycle by fall. Winter annuals (such as shepherd's purse, red dead nettle, annual bluegrass) may germinate anywhere from mid-summer until freeze-up (depending on the species), overwinter as a rosette, and resume growth in spring, typically setting seed and dying by May or June. With annuals, destroying the top growth usually kills the entire plant and prevents further seed production.

Perennials (*e.g.*, quackgrass, Canada thistle, poison ivy) may live for several years. Most perennials (Figure 101) survive the winter as vegetative propagules, including below-ground rhizomes (*e.g.*, quackgrass), tubers (*e.g.*, Jerusalem artichoke), budding rootstocks (*e.g.*, Canada thistle), budding taproots (*e.g.*, dandelion), or above-ground stolons (*e.g.*, ground ivy). Although most produce seed, new growth in spring usually is from the under- or above-ground vegetative propagules. Perennials are more difficult to control than annuals, because the propagules are protected by soil, foliage, and debris.

Annual weeds are best controlled around the time of seedling germination and emergence. Perennial weeds, other than those emerging from seed, are best controlled either after a few weeks of growth in the spring, or after fall rains when growth has resumed. Some perennials are most sensitive to herbicides at or just before blooming. These critical differences in strategy for annuals and perennials determine the success or failure of control and can only be fully appreciated by understanding the biology of weeds.

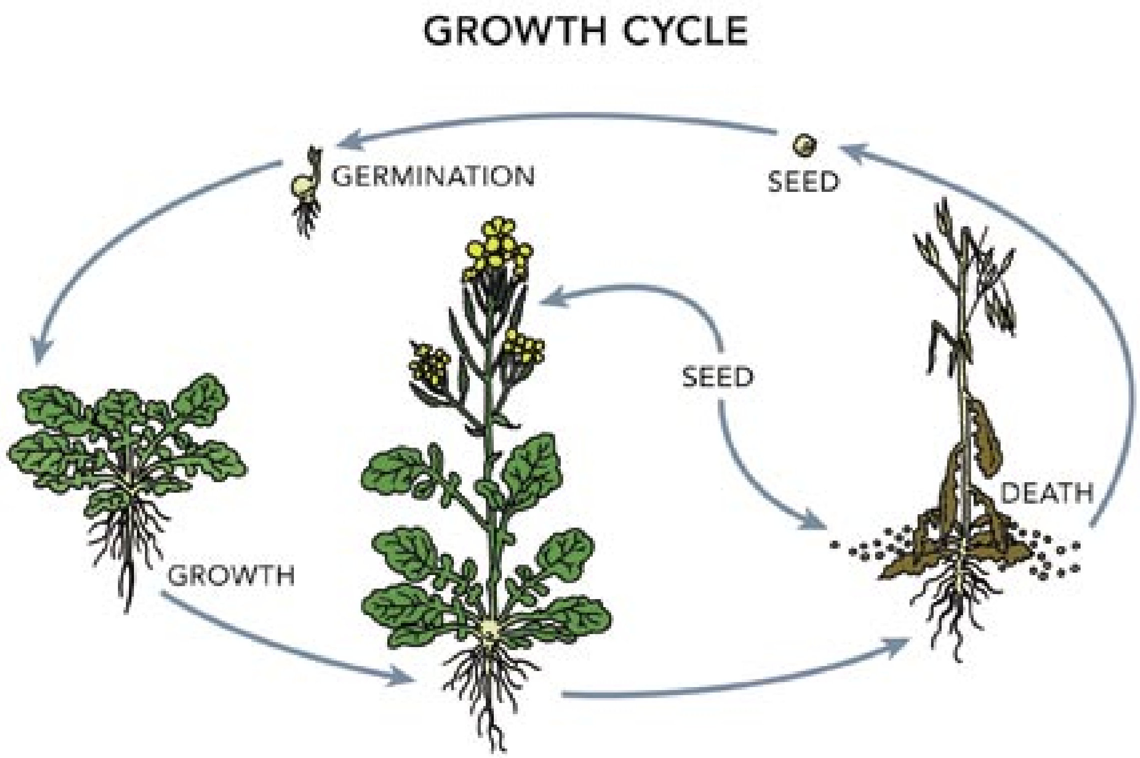

FIGURE 100. Annual weeds complete their life cycle in less than 12 months.

FIGURE 101. Most perennials survive the winter as vegetative propagules. A. Canada thistle; B. Quackgrass.

Annuals are most sensitive at, or shortly after, germination because food reserves in the seed have been depleted, and the young seedling is not yet producing its own food. Also, at emergence, seedlings are most sensitive to the damage caused by herbicides or by cultivation, and the desiccating effects of wind and sun.

Beyond the 2- to 4-leaf stage, annual weeds become much more difficult to control; leaves develop cuticles that resist herbicide absorption, and root systems penetrate deeply into the soil where they are protected from herbicides applied to the soil. Because annuals persist only by producing seeds, anything you do to prevent seed production will reduce future costs of weed control.

In contrast to annual weeds, killing young foliage and shoots of perennials in early spring has little effect on the vegetative propagules. Cultivation or application of herbicides at this stage of growth merely causes the propagules to resprout, and the problem quickly returns. Wait until the correct growth stage of each species before applying systemic herbicides.

When a perennial reaches the correct growth stage for herbicide application, food reserves in the rhizome are depleted, photosynthesis is in full-swing, and the plant is starting to rebuild root reserves by translocating sugars downward into the rhizome or root-system. Systemic herbicides applied at this stage translocate, along with sugars, from the foliage to the vegetative propagules, and complete control can usually be achieved (Figure 102).

For most perennial grasses, the sensitive stage is reached after a few weeks of growth, typically when there are 6 to 8 inches or more of new growth. For broadleaf perennials such as Canada thistle and field bindweed, the sensitive stage is later, just before or at the time

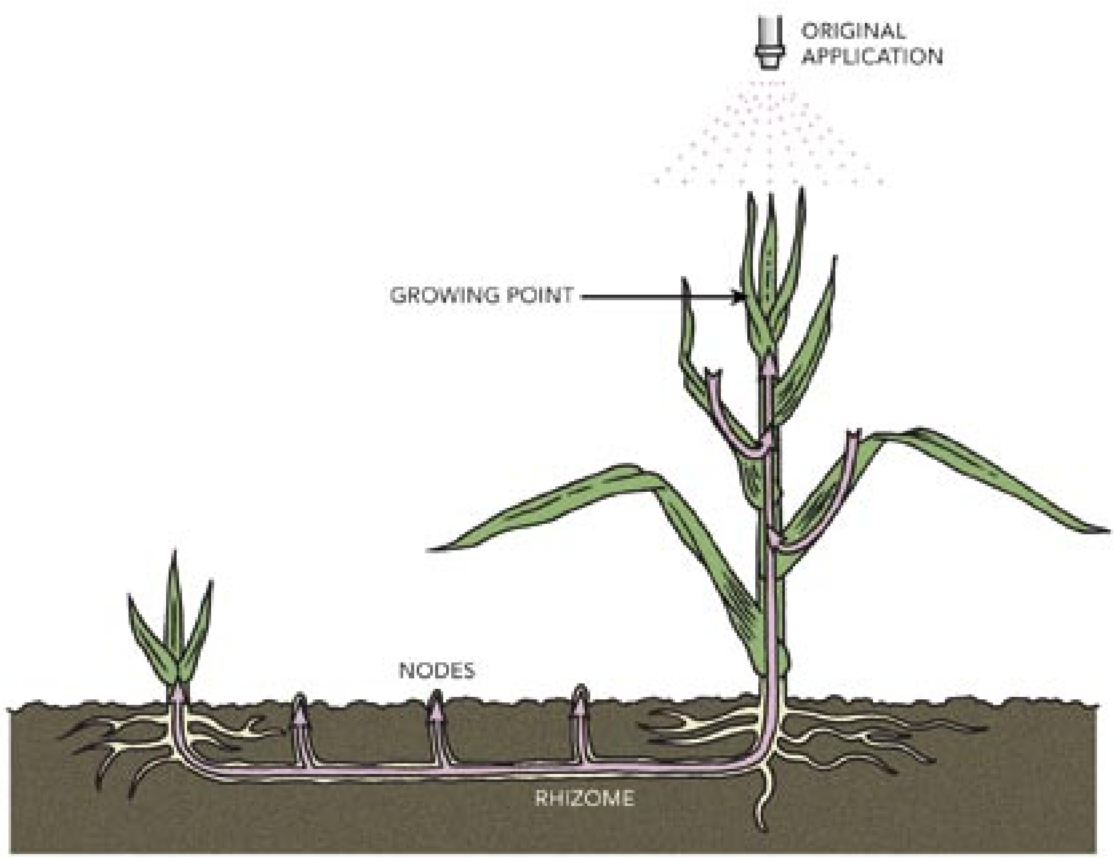

FIGURE 102. Systemic herbicides translocate downward to vegetative propagules.

of flowering. Nearly all grass and broadleaf perennials can be controlled with fall-sprays of systemic herbicides, as the weeds are actively building root-reserves at that time.

Understanding how the tools of weed control work is as important as understanding the biology of weeds. Cultivation kills by breaking and shearing individual plants and exposing them to the drying effects of sun and wind. When annual weeds get beyond a few inches high, cultivation becomes more difficult and much less effective, because weeds can tolerate some drying and can recover from the physical damage.

Cultivation also stimulates germination of more weed seeds. Growers can use this behavior to their advantage by planning ahead. Cultivate the surface to stimulate seed germination and then kill young seedlings soon after emergence with more cultivation. The second cultivation will, in turn, cause more seed germination, and the cycle can be repeated.

The cycle of cultivation, weed emergence followed by more cultivation, is called *summer fallow*. The cycle can be repeated many times in a single spring or growing season and is a very effective strategy to reduce the number of weed seeds in the soil and thus the need for weeding after planting grapevines.

Herbicides kill weeds by interfering with various physiological processes occurring within their tissues. Typical symptoms of herbicide use are malformed growth, discolored or dead tissue, and stunting. Young seedlings are more sensitive to these effects than older plants.

Terms used when discussing herbicides are listed here and are useful in understanding the important differences between the various herbicide products.

- **Selective Herbicides**

  Herbicides are either selective or non-selective. A *selective herbicide* affects some plants but not others. A *non-selective herbicide* will kill any plant it contacts.

- **Contact Herbicides**

  Contact herbicides affect only the tissue sprayed. They do not move within the plant. Only above-ground tissues that are directly sprayed will be affected. Contact herbicides (*e.g.*, Gramoxone) are useful for controlling small annuals and for temporarily reducing growth of perennials.

- **Systemic Herbicides**

  Systemic, or translocated, herbicides, are those that move within the plant. Systemic herbicides applied to the soil (*e.g.*, Karmex) are absorbed by roots and translocated to leaves where they inhibit physiological processes such as photosynthesis. Systemic herbicides applied to the foliage (*e.g.*, Roundup) translocate to the root system, provided the herbicide is applied at the correct growth stage.

- **Residual Herbicides**

  A residual herbicide or persistent herbicide (*e.g.*, Princep) is one applied to the soil (may also be applied to leaves) where it slowly breaks down over time but continues to control germinating weeds for some time after application. Some residual herbicides may persist long enough to damage crops planted a year or more after application. Residual herbicides may or may not be selective, and they may or may not be systemic.

The more you understand about the biology of the weeds you need to control and the tools available, the better decisions you will be able to make about control; however, an extensive review of these topics is beyond the scope of this publication. Fortunately, many excellent sources of detailed information on weed biology, herbicides, cultivation implements, and other control tools are available on the Internet and in local libraries.

Now that you have mastered some basic concepts of weed biology and control techniques, you should plan a weed-control program. A weed-control program is simply a pre-planned schedule of activities based on the weeds you have identified, the age of your vineyard, and economic and environmental considerations.

Developing a new vineyard, nurturing one that is newly planted, or cleaning up an established weed-infested site all require different approaches. The best time to implement a weed-control program is before planting. This is when perennial weeds can be eradicated. Once a vineyard is established, perennials are much more difficult to control. While specific perennial weeds may require specific controls, the guidelines presented here will apply in most instances.

Establishing New Vineyards

The practices recommended prior to planting are referred to as site preparation. Start site preparation the year before planting. Land that is in sod should be treated with a non-selective systemic herbicide after new growth reaches a height of about 8 inches. Plow and disk within one to two weeks of herbicide application, even if control is not obvious.

Systemic herbicides work slowly, and control symptoms take time to develop. Delaying tillage until after symptoms are obvious can result in reduced control. After tillage is a good time to take soil samples for nutrient and pH analysis (see *Vineyard Establishment*). Practice summer fallow until late May by allowing weeds to regrow until they are a maximum of 1-inch high and then cultivate.

Land that has been in annual crops, such as corn and soybeans, may be relatively free of perennials. Such land should be tilled in early spring, sufficiently to stimulate weed emergence, and then summer fallowed as recommended for sod ground. If perennials are obvious prior to tillage, then treat the field as if it is in sod. In June plant a cover crop of oats, buckwheat, or annual ryegrass to build organic matter and suppress weed growth.

Oats and ryegrass can be treated with a selective, systemic broadleaf weed herbicide to kill germinating annuals (see *Weed Control Guide for Ohio Field Crops*, Ohio State University Extension Bulletin 789). Plow the cover crop before it goes to seed. If significant annual weeds germinate in late summer, after plowing-under, consider additional summer fallow. Do not let late summer weeds go to seed.

When fall rains resume, surviving vegetative propagules of perennials will sprout and emerge. Late September through October is a good time to apply a final treatment of a non-selective systemic herbicide to kill remnants of perennial weeds. Apply the herbicide to actively growing weeds when the foliage is 6- to 8-inches high. Annuals co-emerging will also be killed. The site can be re-seeded in as little as four days after the last systemic herbicide application.

Cultivate (only if needed to prepare an adequate seedbed) and plant a cover crop of companion grass (see the section on *Soil Management*) if a permanent sod is required for the row middles. Otherwise, plant fall rye or winter wheat (rye can be established throughout November, depending on latitude and prevailing weather) if bare row-middles are needed. Remember too that winter wheat can be underseeded with a permanent sod species that will persist after the wheat dies. Cover in the row areas can be killed in the spring by spraying new growth (wait until it is 6- to 8-inches high) with a systemic herbicide.

Nurturing a Newly Planted Vineyard

Scout the vineyard for emerging weeds at the same time as scouting for insects and diseases, and map their location in the vineyard at the individual species level. Record the distribution of each species as:

GENERAL = found throughout the field.
LOCAL = found in a small portion of the field.
SPOTTY = found in just a few places.

Also record the density of each species as either:

1 = SCATTERED, just a few weeds.
2 = SLIGHT, 1 weed per 6 feet of row.
3 = MODERATE, 1 weed per 3 feet of row.
4 = SEVERE = more than 1 weed per 3 feet of row.

Take samples of unknown weeds for later identification. Hopefully, perennial weeds were eradicated before planting as outlined previously. If not, it is not too late to start but don't expect control to be as good as the outcome of a correctly implemented site preparation program.

Perennial grasses in the row can be treated whenever they occur with selective, systemic herbicides such as Select, Fusilade, or Poast. These herbicides will not affect broadleaf weeds or grapevines, even if directly sprayed. Grass control will take time, but with persistence, perennial grasses will be largely eliminated.

In the meantime, mow the sod between grape rows to discourage growth of broadleaf weeds and to prevent any seed production. Install grow tubes on young vines. With grow tubes correctly installed, *i.e.*, with the bottom of the tube buried about 1 inch in the soil, non-selective herbicides can be used under the trellis.

Contact herbicides such as Gramoxone and Rely (glufosinate) will control annuals up to 4-inches high. Systemic herbicides (Roundup) will control annuals and perennials. For persistent broadleaf perennials, such as Canada thistle, wait until the bud stage is reached and then spray with a systemic herbicide.

Perennials requiring herbicide treatment must not be allowed to grow higher than the grow tube or sprays cannot be used. Tall weeds can be gently bent to the ground and then thoroughly sprayed with a systemic, or alternatively, wiped with a topical application of a systemic herbicide. Weeds under the trellis should be controlled into late fall until winter-hilling takes place. Grow tubes should be removed prior to winter.

Remember that annual weeds under the trellis can be controlled with cultivation. However, trellis wires and location of vines and posts often limit the type of cultivation equipment that can be used. Nevertheless, several implements, generally operated hydraulically, have been used to work the area under the trellis. An example is the grape hoe.

Hand hoeing is sufficient for smaller plantings. Invariably, weeds are controlled only by repeated cultivations which can be costly and laborious. Missing just one timely cultivation may result in weed seeds being returned to the soil. With cultivation there is a significant risk of injuring trunks and root systems of vines.

Several soil-applied residual herbicides including Devrinol, Surflan, and Prowl can be used in the transplant year to prevent annual weeds. Herbicides typically lead to more vigorous vine growth and higher yields because they do not injure the crop's root system. Plastic and organic mulches can effectively control weeds. Their use is described in the section *Vineyard Establishment*.

Maintaining Weed Control and Clean-Up Practices in Established Vineyards

Additional herbicides are registered for use in older vineyards. In late March through April, apply a residual herbicide such as Karmex or Princep (three-year-old vines with these herbicides) to the soil under the trellis. Most residual herbicides only kill germinating weeds, thus they must be applied early before weed emergence.

Contemplate applying two or more micro-rate applications rather than a single application at the maximum rate. Micro-rates are simply a fraction of the maximum one-time application rate, applied to coincide with flushes of weed emergence whenever that occurs, provided the total used is no more than the annual maximum application rate. For instance, if the single maximum application rate is 3 lbs per acre, three micro-rate applications of 1 lb per acre could be applied.

The advantage of the micro-rate approach is generally better weed control with less herbicide. The disadvantages include a requirement for more careful management, more time and labor, and potentially more soil compaction because of repeated trips across the vineyard.

Watch for *escapes* (escapes are weeds in the treated area that have been missed or have survived the treatment) when scouting for insects and diseases. Typical escapes following application of a residual herbicide such as Karmex or Princep are old witchgrass and large crabgrass. Annual grasses tolerate these herbicides, and their populations quickly build up if the same residuals are used year after year. This buildup of tolerant species is known as a *weed shift*. To prevent weed shifts, do not depend on just one herbicide or on herbicides that work the same way (*e.g.*, herbicides that inhibit photosynthesis) every year. Instead, rotate herbicides with different modes of action and selectivity on a yearly basis. When grasses occur in the vineyard, they can be treated with a systemic herbicide such as Poast. Poast and similar herbicides can be used several times during the growing season on an as-needed basis.

Be vigilant for the return of perennials and other invasive weeds and eradicate them, preventing seed production, whenever they occur. Invasion of the vineyard is an on-going problem as weed seeds enter in soil, wind, and water and on machinery and animals, etc. In mid- to late summer, an application of a residual soil-active herbicide will prevent establishment of winter annual weeds, such as shepherd's purse and groundsel. The exception to this guideline would be vinifera, when there is an intention to establish a winter cover crop under the trellis after hilling.

Guidelines for Weed Control with Herbicides

- Start site preparation weed control the year before planting. Eradicate perennial weeds and reduce weed seed numbers in the soil.
- Learn to identify weeds. Herbicides are *species specific*, only controlling those species listed on the label, when they are treated at the correct growth stage.
- Calibrate the sprayer, use recommended water volumes and spray pressure (see the label), and maintain good agitation in the spray tank. For information on sprayer calibration, see Ohio State University Extension Fact Sheet AEX-520, Boom Sprayer Calibration. This can be downloaded from the Internet at **http://ohioline.osu.edu/aex-fact/0520.html** and can also be obtained from most county Extension offices in Ohio.
- Maintain a 3- to 4-foot weed-free swath under the trellis. Use grow tubes on young vines. Grow tubes enable you to safely direct contact and systemic herbicides to weeds under the trellis.
- Recall that no one herbicide controls all weeds. If the same product or products are used repeatedly, *weed escapes* will occur and eventually become dominant. To prevent *weed shifts*, rotate herbicides from year to year. For instance, if you use Princep one year, switch to Karmex the following year, and then back (though both materials inhibit photosynthesis in sensitive plants, their mechanism of action differs and resistance is not likely to develop). Better yet,

switch from Princep, to Karmex, to Solicam, and then back.

- Avoid spraying grape foliage or green bark, as severe damage may occur with some herbicides (especially systemics). Windy conditions can cause spray drift to be deposited on sensitive plant parts.
- For specific information on herbicide rates and timing of applications, growers should consult the regional bulletins and spray guides on small fruit for their state. For more information on these publications, contact your local Extension office. Ohio growers should consult the Ohio publications, published by Ohio State University Extension. For more information on these publications, contact your county Extension office or Ohio State University Extension, Media Distribution, 2021 Coffey Road, Columbus, OH 43210-1044. Herbicide recommendations in these bulletins are updated yearly.
- No herbicide should be applied in vineyards unless it is labeled for that specific use. Use of other than federally labeled or approved herbicides is illegal and may result in injury to the vines and liability to the growers. Improper use of even labeled herbicides can result in severe crop damage or lack of weed control.

Controlling Specific Perennial Weeds with Systemic Herbicides

In the recommendations presented in this section, application rates are provided for two of the most common formulations of glyphosate. The use of these brand names does not imply an endorsement of these over other glyphosate products, nor a criticism of those products that are not named.

Quackgrass

For long-term control, use Roundup Ultra at 1 to 2 quarts per acre or Touchdown at 3.33 pints per acre. Use the 1-quart-per-acre rate of Roundup Ultra in 5 to 10 gallons of water per acre on land that has been in row crops. The 2-quart-per-acre rate will provide longer lasting control when spraying sod. Spray when the grass is about 8-inches high and wait at least three full days (72 hours) but not more than seven days before plowing.

Fall frosts before spraying will not affect control provided at least 60% of the foliage is still green when you spray. If planning a spring application, do not fall plow; simply wait until quackgrass reaches the right growth stage (four to five new leaves) and spray.

Johnsongrass

Apply Roundup Ultra at 1 quart per acre plus ammonium sulfate (17 pounds per 100 gallons of spray) in a spray volume of 5 to 10 gallons per acre, when Johnsongrass is in the boot to heading stage. In the fall, application can be made anytime prior to frost.

If using Touchdown, apply 2-1/3 pints per acre plus ammonium sulfate (17 pounds per 100 gallons of spray) and apply in 5 to 10 gallons per acre at the same stage of growth as for Roundup Ultra.

Yellow Nutsedge

Yellow nutsedge is difficult to control. Nutsedge persists by producing nutlets which grow at the end of rhizomes. Nutlets break dormancy in spring, and emergence follows in late spring and early summer. Control with herbicides is rarely or never complete, because insufficient herbicide translocates into the nutlets.

Attack nutsedge one or two years before planting using an integrated approach. Apply preplant glyphosate on small nutsedge plants (control with Roundup Ultra is best when nutsedge is 6- to 12-inches high; earlier applications will provide some suppression—

Monsanto Research) and/or tillage before planting.

If you do not already have nutsedge in a field, prevent its introduction. Wash all soil from recently purchased used equipment before allowing it on your farm. If you have some infested fields and others that are not, or if your equipment is used on fields of other farmers, be sure to wash all soil off the equipment before using it on land that is nutsedge-free. Make sure all transplant materials were produced under nutsedge-free conditions.

Canada Thistle

Canada thistle can be treated in the flower-bud to flowering stage in early summer or in late summer and fall during the rosette to flower-bud stage. In fallow fields, stop tillage in late July and allow thistles to regrow for at least five weeks.

Apply Roundup Ultra or Touchdown before a killing frost and when Canada thistle regrowth reaches the flower-bud stage or is at least 10- to 12-inches high. Apply Roundup Ultra at 2 to 3 quarts per acre in 5 to 10 gallons of water or Touchdown at 2 quarts per acre. Spot sprays of a 2% solution (0.5 pints in 6 gallons of water) of either herbicide will also be effective.

Field Bindweed

Field bindweed must be treated when it is actively growing and at or beyond bloom. Fall treatment is best, but apply herbicides before a killing frost. Apply Roundup Ultra at 3 to 4 quarts per acre or Touchdown at 5.33 pints per acre. Spot spray with a 2% solution of either product.

Hard water with more than 500 parts per million of calcium or magnesium will usually reduce glyphosate activity. If hard water must be used, keep the volume low (5 gallons per acre) or increase the rate of herbicide. Use clean water. Silt, clay, and organic debris in water will also reduce glyphosate activity. Always add ammonium sulfate (17 lb/100 gal water) to glyphosate for maximum effectiveness on perennial weeds.

Table 16. Herbicides for Perennial Weed Control the Year Before Planting and for Spot Treatment.

Prevalent Weeds	Timing of Treatment[a]	Herbicide/A[b]
Canada Thistle	Late spring/early summer; early/late fall	Roundup[c] 1 qt. or 2% spot treatment
Field Bindweed	When plants are at or past full bloom/before killing frost	Roundup 2 qt + 2,4-D 1 pt or Banvel 8 oz + Roundup 1 qt
Horsenettle	Late bud to flowering stage	Roundup 4 qt or 2,4-D 2 qt
Dogbane	Late bud to flowering stage	Roundup 1 qt + 2,4-D 1 pt or Roundup 1 qt + Banvel 2 pt
Poison Ivy	7/1 to 9/15	Banvel 1 qt + Roundup 2 qt or Crossbow 2 qt
Quackgrass	Spring – 8” tall to heading or Fall 8” tall regrowth	Roundup 2 qt
Wild Brambles	Bud to bloom stage	Banvel 1 qt + Roundup 1 qt or Crossbow 6 qt (1-1.5% solution)
Swamp Smartweed	7/1 to 9/15	Banvel 8 oz + Roundup 1 qt

[a] Apply at least three weeks before an anticipated frost (exceptions: C. thistle and quackgrass).

[b] Adding a surfactant to these herbicides will improve their effectiveness; Roundup already contains a surfactant. Rates are given in amounts of commercial product per acre.

[c] Apply Roundup with Banvel or 2,4-D where several weeds are present. Roundup alone is best applied on tall weeds, at 5 to 10 gpa with surfactant and ammonium sulfate. Follow label recommendations. Do not apply Banvel, 2,4-D, or Crossbow near grapes. Avoid drift. Apply spot treatments using low pressure or a wick applicator.

Injury from Herbicides

Herbicide injury symptoms on occasional plants in the vineyard are not uncommon. However, yield and quality are rarely an issue unless injury is widespread and persistent. Sporadic injury in the vineyard can most often be traced to directed sprays of systemic herbicides contacting foliage or green bark, using too high a rate of residual herbicides on light soils, incorrectly calibrated sprayers, sensitive cultivars, and weak plants growing under unfavorable conditions. The grower has control over many of these factors.

Any factor that injures the crop—other pests, winter injury, exposure of crowns and root systems as a result of erosion, improper mineral nutrition, wet spots in the field, etc.—will make the crop more susceptible to injury. Light, sandy soils require less herbicide than heavier soils for comparable levels of weed control. Grapevines growing on soils low in organic matter are more prone to herbicide injury from soil-applied herbicides than vines growing on soils high in organic matter. Accordingly, lower rates of herbicide should be used on fields low in organic matter (less than 2%).

Of much greater significance to vineyards in the Corn Belt are risks associated with herbicide spray drift from nearby small grain, corn, and soybean fields. Spray drift that occurs while nearby fields are sprayed can severely damage grapevines. Grapes are extremely sensitive to 2,4-D and closely related growth-regulator herbicides used for weed control on pastures, wheat, oats, barley, and rye. Grapes may also be severely damaged by drift of glyphosate (Roundup and generics), currently the most commonly used herbicide on soybean. Grapes are sensitive to drift of many additional field crop herbicides including Atrazine, Sencor, and ALS-inhibitor herbicides such as Accent and Firstrate. Injury symptoms caused by some of these herbicides may easily be confused with disease and insect damage.

Symptoms of 2,4-D injury (Figure 103) to grapevines are easily distinguished. The youngest terminal growth is most severely affected. Vines and leaf petioles are severely twisted. Leaf blades may be stunted and misshapen with closely packed, thick veins. Terminal growth may cease for a time following the initial effects; if injury is severe, growth will be retarded for several weeks. Vines with these symptoms rarely produce new normal growth for the remainder of the season. If the injury is not too severe, normal growth will resume the following year. Severely injured vines may die or not recover for two years or more. Vines injured by 2,4-D also may have delayed fruit ripening. If vines are severely injured, fruits may never mature, regardless of the length of season. These delayed-maturity effects may persist for one to three years before normal ripening returns. Cultivars vary in their tolerance of 2,4-D.

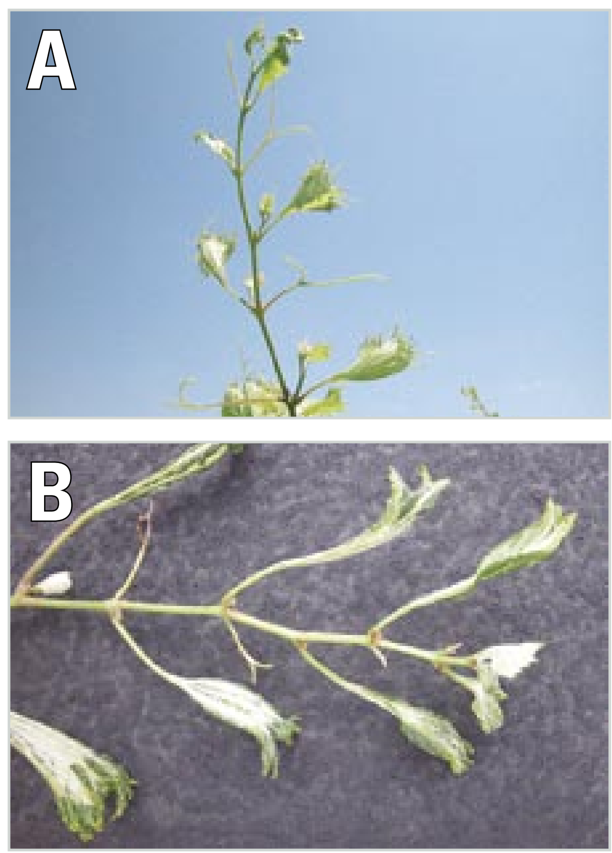

FIGURE 103. Symptoms of 2,4-D drift on Concord grape (A and B).

Concord is one of the most susceptible, while some vinifera cultivars are fairly tolerant to 2,4-D.

Glyphosate injury (Figure 104) is similar to injury from growth-regulator herbicides. Glyphosate injury shows up first on the newest growth, usually about two weeks after contact. New leaves are chlorotic, stunted, and misshapen. In particular, affected leaves may be elongated, and somewhat strap-shaped with a puckered surface. Terminal growth may die and slough off. In severe instances, vines may be killed or growth severely stunted. Recovery from severe injury may be slow, and symptoms can be expected to slowly decline over two or more years.

Atrazine and Sencor are photosynthesis inhibitors similar to Princep and Karmex, herbicides that are used on grapes. Symptoms are similar to that caused by Princep and Karmex—leaf chlorosis that may be a halo around the margin, interveinal, or veinal (Figures 105 and 106). In severe examples, leaves turn brown and drop off. Symptoms caused by drift are unlikely to persist beyond the year the incident occurred.

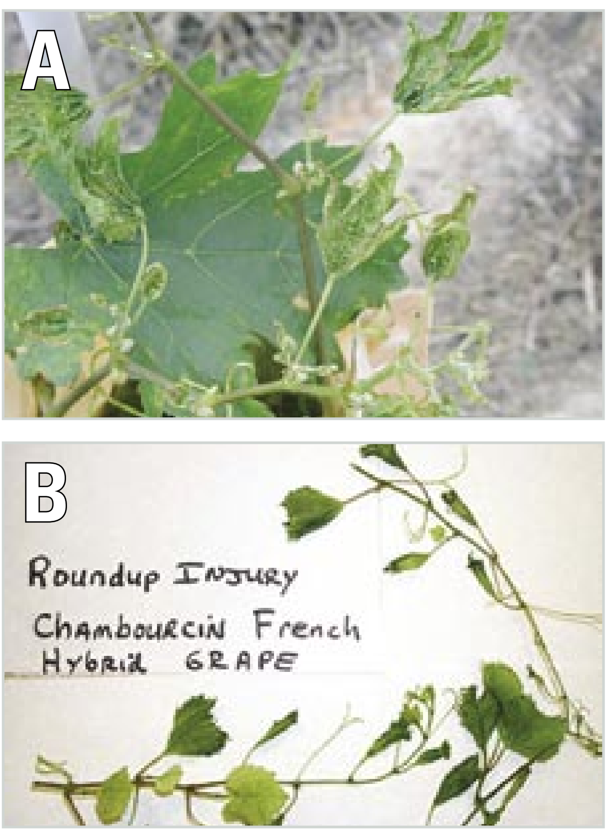

FIGURE 104. Symptoms of glyphosate injury (A and B).

FIGURE 105. Symptoms of Karmex injury.

FIGURE 106. Symptoms of Princep injury.

Systemic postemergence herbicides, such as Accent (Figure 107) and Firstrate (Figure 108), used on corn and soybeans, respectively, can also damage vines.

Grape growers should discuss the problem of drift and the risks of herbicide injury to the vineyard with surrounding growers of field crops. Stress the importance of not using high-volatile herbicides and avoiding windy conditions. Because of their volatility, many 2,4-D compounds can injure vines at great distances from the point of their application.

FIGURE 107. Symptoms of Accent injury.

FIGURE 108. Symptoms of Firstrate injury.

Effects of volatile formulations of 2,4-D (ester formulations are generally more volatile than amine formulations) and related compounds have been observed in vineyards at least five miles from the point of application. If a 2,4-D herbicide must be applied near grapes, use the least volatile forms. If possible, do not use 2,4-D products in the immediate vicinity of grapes. Additional information on herbicide injury is available in a recent publication *Herbicide Drift and Injury to Grapes,* Southern Illinois University, Bulletin C1382.

Soil Management

Two soil-management systems are now in general use in Midwestern vineyards. Many growers cultivate between the rows during the growing season and plant a cover crop over winter. A more recent system is to maintain a permanent sod cover between the rows. In both cases, weed growth under the trellis is controlled by chemicals or tillage.

Cultivation Plus Cover Crop

Vineyards planted on shallow soils or the lighter soils in the lake plains areas usually respond best over a period of years to the cultivation plus cover-crop system. Those planted on the fine-textured soils and those on the more sloping sites subject to soil erosion may respond more favorably to the system of permanent sod cover between the rows. However, with care, almost any vineyard can be maintained under either system.

The kind of winter crop cover selected is relatively unimportant. Rye and ryegrass are most common, and both are satisfactory. Seed is planted in August or early September. Satisfactory seeding rates are two bushels per acre for rye seeded in early August, or 20 pounds per acre of ryegrass seeded in July. A light fertilizer application, such as 3–12–12, at the rate of 200 to 250 pounds per acre can be made at seeding time. When seeding, avoid scattering seed in the vine rows.

Disk the overwintering cover crop down in early spring before it competes with the grapevines. For rye, competition with vines begins when rye reaches a height of 1 to 2 feet, and for ryegrass, when seed heads just begin to appear. However, growers should never disk when the soil is wet enough to deteriorate the structure. Disk only enough to knock down the cover. Excessive disking not only wastes labor, but also can damage the soil structure and create compaction zones.

Cultivate between vine rows during the summer only when necessary to control weeds. Cultivate as shallow as possible, but deep enough to destroy weeds or grass beneath the trellis. Deep cultivation or plowing between rows will do more damage than weed growth because of loss of soil organic matter and soil structure.

After the planting year, avoid excessive cultivation in the vine row that can injure shallow roots and increase soil compaction. Chemical weed control is recommended under the trellis.

Competition from a cover crop during spring and early summer can reduce yields. The extent of yield reduction depends on the degree of competition between the cover crop and the vines for soil moisture and nutrients. Because nutrients can be applied with fertilizers, the primary competition is for water.

Permanent-Sod Management

A permanent-sod cover between vineyard rows is desirable in the Midwest (Figure 109). This practice is recommended in vineyards where soil erosion is likely to be moderate to severe under summer cultivation.

Bluegrass is recommended for this purpose. It is suited to Midwestern environmental conditions and competes less severely with grapes than deeply rooted cover crops. A new grass mixture marketed under the trade name Companion Grass also is gaining acceptance in vineyards and orchards because of its slow-growing characteristics. Companion Grass is a mixture of Elka perennial ryegrass and Ensylva creeping red fescue. Avoid deep-rooted crops such as tall fescue, timothy, and other vigorously growing grasses.

FIGURE 109. A permanent sod cover between rows is recommended in erosion-prone vineyards.

Seeding of bluegrass is more successful in the fall than in early spring. The ideal time is early September. If the vineyard has been under summer cultivation, bluegrass or Companion Grass may be seeded following the last cultivation at the rate of 20 to 30 pounds per acre. If the vineyard has not been under cultivation, these grass seeds may be broadcast following a light disking that does not destroy existing sod. Avoid broadcasting seed under the trellis.

Mow the grass cover as needed, directing the clippings to the row middle, away from grape rows, and leave the clippings on the vineyard floor. Vineyard fertilization usually can support a good sod cover. However, if poor sod results, take a soil test, and follow the recommended fertilizer practice.

Growers may experience reduced crop yields with a permanent cover-crop system on lighter, sandy, or gravelly soils. This probably results from the reduced available moisture in these soil types. Keeping the sod short will reduce competition.

Mulching

Mulching has been used in soil management for grapes, although it is not generally accepted. Mulching has several advantages over cultivation plus cover crops. Mulching:

1. Suppresses weed growth, which reduces competition for soil moisture and nutrients.
2. Conserves soil moisture, increases rainfall penetration, and reduces erosion.
3. Requires less nitrogen each year for equivalent yields.
4. Often maintains or increases vine vigor and productivity without other added nutrient elements, because these are supplied by the decaying mulch.

In vineyards where vine vigor is low, mulching and other sound soil-management practices can economically and effectively boost vigor. In this situation, growers can achieve the most favorable results of mulching.

However, mulch may have some disadvantages in certain situations. Vigorous vines may require a longer season to mature fruits with optimum soluble solids (°Brix) content than vines of less vigor. The problem arises when growers try to reduce the vigor or amount of growth on over-vigorous vines under continuous mulch. Often, two to three years are required to reduce annual vine growth to a more desirable level, even when balanced pruning is followed.

Heavy mulching of poorly drained soils should be avoided because it could actually increase excess soil moisture in the root zone. Mulching also may increase fire and rodent hazards.

Most organic materials such as straw, hay, corn cobs, sawdust, composted grape pomace, or fine wood chips will serve satisfactorily in the vineyard. The mulch may be applied to the entire vineyard floor or confined to a 4- or 5-foot band beneath the trellis. If erosion control is the primary goal, adding mulch to row middles generally is effective. The depth of the mulch can vary from 2 to 10 inches. The necessary mulch depth depends on the quantity available, density of the material used, and the cost. Generally, 6 to 8 inches of loose straw or 2 to 3 inches of sawdust are adequate. Bales of rolled hay also have been effective in vineyards, but can be a source of weeds, especially perennials like Canada thistle.

Once the initial mulch has been established, annual additions are necessary to maintain the desired depth. In general, a ton of straw is required for an inch of mulch over one acre. Other materials may require varying amounts to form an inch of mulch, depending on their density and bulk.

Liming and Soil Reaction

Grapes can be grown successfully over a wide range of soil pH conditions. They perform best where soil pH is between 5.5 and 6.5. Vineyard fertilization often has fewer problems and may be less expensive where the soil pH is maintained in that range. Periodic soil testing is necessary to determine the soil pH and liming requirements. Lime should be applied only when soil analysis indicates a need.

Research has shown that potassium deficiency can be intensified by dolomitic limestone, which is high in magnesium. Excessive applications of calcium limestone also can result in manganese deficiency. The deficiency occurs because soil manganese becomes more insoluble and less available to roots when the pH is raised to near 7.0 or above.

Applying dolomitic limestone can help correct magnesium-deficient vineyards. Dolomitic limestone also can be used to reduce soil potassium levels if magnesium is above recommended levels. For more information, refer to Ohio State University Extension Bulletin 458, *Fertilizing Fruit Crops*.

Fertilization

Fertilization

Grapes, like other crops, require adequate supplies of all essential plant nutrients for optimum growth and yield. Most soils contain adequate or near-adequate quantities of all nutrients. Nitrogen, phosphorous, potassium, magnesium, and boron are the nutrients most likely to limit grape production in the Midwest. Vineyard fertilizer practices are designed to boost the supply of available soil nutrients to the levels required for optimum growth and fruit production.

For successful soil fertilization, growers must accurately determine the nutrient status of the vineyard. Vineyard sites or sections of the same site may vary in the levels of nutrients available to vines. Growers can choose from several methods to determine their vineyard's nutrient status. Weak growth, poor leaf color and fruit set, and early defoliation indicate low levels of one or more nutrients. Delayed vine and fruit maturity and excessive vigor suggest an over (or late) application of nitrogen.

Soil tests are helpful for determining the level of nutrients in the soil. Plant petiole analysis, however, is a very important companion analysis that allows a grower the ability to follow the actual amount of nutrients taken up into the vine. Both forms of analysis should be used to maintain a good working knowledge of a vineyard's fertility.

Soil Analysis

Soil testing is a relatively simple procedure that can be done during the fall or spring. Soil analysis will determine the availability of the primary (N, P, K), secondary (S, Mg, Ca), and micro (Fe, Mn, B, Cl, Zn, Cu, Mo) nutrients. Soil pH in the range of 5.5 to 6.5 is adequate for grape production. American varieties with, for example, *Vitis labrusca* in the pedigree will be more adaptable to lower pH (high acidity) soil than varieties with a greater amount of *V. vinifera*. There is very little potential of nutrient elements being tied up or being released at high levels that can cause toxicity to the vines.

Cation exchange capacity (CEC) is an important indicator of the soil's particles to readily exchange cations (*e.g.*, H^+, Ca^{++}, K^+) with the plant roots. Generally, as the clay content increases, the more soil particles will be available to hold nutrients. Vineyard soils with 2% to 3% organic matter are considered normal. CEC measures the ability of a soil to retain exchangeable cations (H^+, CA^{++}, Mg^{++}, and K^+). The percent of organic matter and clay influence the CEC of a soil and ultimately determine the amount of each element available to the plant. There can be different ranges of CEC, depending on the classification of the soil as sand (1 to 5), silt (5 to 20), clay (20 to 30), and organic (30+). The amount of organic matter in a soil can influence soil fertility and tilth.

Nitrogen is generally lacking in Midwestern soils and is customarily applied each growing season at the rate of 50 to 80 lbs. of actual nitrogen per acre. Phosphorus deficiencies are not wide spread in Midwestern soils, with 40 to 50 lbs. per acre considered adequate. Potassium is an element that should be maintained around 300 lbs. per acre. Grape-vines use considerable amounts of K for development of foliage, wood, and fruit production. Magnesium, boron (B), and zinc (Z) are considered adequate in the ranges of 200 to 250 lbs., 1.5 to 2% and 8 to 10% per acre, respectively (Table 17).

Liming is beneficial where acidic soils are common. By increasing the soil pH through liming, Ca^{++} and Mg^{++} levels can be increased, toxic levels of micro-nutrients can be reduced, and microbial activity can be increased, causing a release of N, P, K, and B. Additionally, soil structure and tilth have been shown to improve through the use of lime.

The Lime Test Index (LTI) indicates the tons per acre of Ag-ground lime needed to adjust a mineral soil to a specific pH. For example, a vineyard soil that has an LTI = 68 would require 1.2 tons per acre of Ag-lime to raise the soil pH to 6.5. An LTI is derived by multiplying the SMP (Shoemaker, McLean, and Pratt) buffer pH x 10. Coarsely ground material takes longer to react with the soil chemistry, and thus the pH will not change as quickly as when finer ground lime is used.

Soil samples are generally taken either during the fall or early spring, depending on when you would like to apply fertilizer. Some growers feel that by having their soil analyzed in the fall they are able to purchase needed fertilizer at a reduced rate. Others feel that applications of nitrogen and other elements should be made in the spring prior to shoot growth. (See Table 17 for desirable ranges of soil characteristics for grapes.)

Nitrogen applications should be completed around fruit set, but no later than veraison, to allow for uptake and utilization by the vines during the growing season. Mid- to late summer applications of nitrogen will encourage the vines to continue vegetative growth into the fall season when plants should begin to harden off prior to dormancy.

You can collect samples by using either a soil probe, spade, or shovel. Be sure to take samples in your vineyard along a Z- or X-shaped pattern in the field or block of vines to assure representative samples. Avoid sampling soil only in the middle or along the edges of the vineyard. In order to have a representative sample, be sure to use a clean plastic bucket and take a generous amount of soil from each subsample. To adequately evaluate your vineyard soil, be sure to sample at two different depths starting at just below the surface to 8 inches, then from 8 to 16 inches. This will allow you to make any necessary adjustments in soil fertility or pH or both.

When submitting a soil sample for analysis, you should fill out a Soil Test form. This form

Table 17. Desirable Range of pH, Organic Matter, and Elements from Soil Test for Grapes.

	Grapes
pH	5.5 to 6.5
Organic Matter	2 to 3%
Phosphorus	40 to 50
Potassium	250 to 300
Magnesium	200 to 250
Boron	1.5 to 2.0
Zinc	8 to 10

[a] Phosphorus given at actual pounds of available phosphorus, manganese, boron, and zinc and as exchangeable potassium, calcium, and magnesium, per acre.

[b] Desirable range will vary with soil type (sand, silt, or clay), organic matter already present in the soil, and pH. Soil levels may need to be changed to correct deficiencies or excesses as they are accessed.

will instruct the individual processing your soil sample as to the type of test(s) you want to have conducted. Information given on the form will provide the location of the soil sample, recent history of fertilizer and lime applications, depth of where the sample was taken, crop status, intended crop, crop age (if planted), and whether irrigation is applied.

Plant Analysis

In plant analysis of grapes, leaf petioles are the parts sampled. Chemical analysis of the petioles indicates the level of nutrients in the entire vine. Samples are normally collected between July 1 and August 30 which corresponds to veraison. Contact your county Extension office for a listing of potential laboratories where you can send your samples for analysis. Be sure to provide complete information on the container as to the date, location, and variety sampled.

To be most efficient, petiole analysis should be conducted over a period of years as part of the management program. A single analysis is useful in diagnosing a nutrient problem or in determining the nutrient status of the vine at the time sampled. However, one analysis cannot indicate what the nutrient status may be a year later.

Petiole analysis continued for three to five years in a given vineyard will help establish trends and changes in nutrient element levels. The direction and nature of the trends are then interpreted and used in planning annual fertilizer and cultural programs. This information can greatly help growers maintain vineyards at their peak of production year after year. The recommendations for nutrients in grape petioles are shown in Table 18.

Primary Nutrients

Primary nutrients are essential for sustaining vegetative growth, yield production, plant vigor, and winter hardiness of vines. Nutrient levels can be assessed by soil and/or plant tissue analysis.

Historically, grapes grown in the Midwest were petiole sampled during mid-July to the end of August. Research from California and New York indicated that sampling for N during

Table 18. Specific Element Recommendations for Grapes from Petioles.

Element[a]	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	0.3-0.7	0.7-0.9	0.9-1.3	1.4-2.0	2.1+
P (%)	0.12	0.13-0.15	0.16-0.29	0.30-0.50	0.51+
K (%)	0.5-1.0	1.1-1.4	1.5-2.5	2.6-4.5	4.6+
Ca (%)	0.5-0.8	0.8-1.1	1.2-1.8	1.9-3.0	3.1+
Mg (%)	0.14	0.15-0.25	0.26-0.45	0.46-0.80	0.81+
Mn (ppm)	10-24	25-30	31-150	150-700	700+
Fe (ppm)	10-20	21-30	31-50	51-200	200+
Cu (ppm)	0-2	3-4	5-15	15-30	31+
B (ppm)	14-19	20-25	25-50	51-100	100+
Zn (ppm)	0-15	16-29	30-50	51-80	80+

[a] Values may differ among species for optimal growth. Values from leaves will vary significantly. For petioles taken between July 15 to August 15.
Source: *Fertilizing Fruit Crops*, Ohio State University Extension, Bulletin 458.

June would provide a more accurate example of the N that is available for plant growth and development during the growing season. This may, in the future, become a more acceptable practice for Midwest grape growers.

Nitrogen

The nutrient element that is often low or deficient in a vineyard is nitrogen. Grape leaves will exhibit a light-green to yellowish-green color as nitrogen in the vine drops to low or deficient levels. Leaf discoloration will appear in the older leaves as the nitrogen is translocated from older to new emerging leaves. Vines will have poor vegetative growth and reduced fruit set where nitrogen is deficient.

Nitrogen is generally applied in split applications at budbreak or post-budbreak and during bloom. Application rates vary with vine vigor and other factors. In general, most vineyards should receive between 40 and 80 pounds actual nitrogen per acre each year. If ammonium nitrate (33-1/2% nitrogen) is used, 120 to 240 pounds of the material will be broadcast per acre over the vineyard row area. Less-vigorous vines should receive higher rates. In small vineyards, nitrogen fertilizer can be applied annually at the rate of 1/2 to 1/3 pound of a 33-1/3% nitrogen carrier, or its equivalent, around each vine. Do not concentrate the fertilizer at the base or allow fertilizer to touch the vine.

Most nitrogen forms can be used equally well in vineyards. The choice depends largely on the cost per pound of nitrogen applied, with one possible exception. On soils with a high pH, where grape leaves show symptoms of manganese or iron deficiency, sulfate of ammonia is preferred. This form of nitrogen tends to increase soil acidity, which makes more manganese available to the vine roots. Do not use sulfate of ammonia on low-pH soils.

High application rates can stimulate excessive growth, which may result in the appearance of deficiency symptoms of other nutrients. For example, if supplies of potassium, magnesium, or other nutrients are low in a given vineyard soil, excessive nitrogen application rates could result in the appearance of deficiency symptoms of one or more of these elements.

Phosphorus

Midwestern vineyards tend not to have serious phosphorus (P) deficiency problems. Generally, adequate amounts of P can be found when soils are tested. In the event that a soil analysis indicates a lack of P, then superphosphate or blended fertilizer with P included can be applied at a rate based on soil and/or leaf tissue analysis.

Potassium

Grapevines will often show signs of potassium (K) deficiency when heavily cropped and little or no additional K has been added. A dull, dark green color will appear on the leaves. In mid- to late summer, leaves may have a bronze color, especially on the west-facing side of the trellis. Some leaves may have dark spots or blotches. This symptom often has been characterized as *black leaf* of grapes (Figure 110).

FIGURE 110. Potassium deficiency symptoms characterized by yellowing of leaf margins.

Marginal chlorosis, browning, and dying may occur as the deficiency becomes more severe. Other possible symptoms include brown dead spots or areas throughout the leaf. In severe cases, more than half of the leaves on a vine may show these symptoms. Severe potassium deficiency greatly reduces vine vigor, berry size, and crop yield.

Symptoms of potassium deficiency generally develop in mid-shoot leaves followed by older basal leaves. Potassium carriers include potassium sulfate (sulfate of potash), containing about 50% K_2O; potassium chloride (muriate of potash), containing about 60% K_2O; and potassium nitrate, with 44% K_2O.

Foliar sprays of potassium sulfate or potassium nitrate can be effective to temporarily reduce a severe K deficiency. Potassium compounds tend to be fixed in the soil surface, although less than phosphate. This fixation, which makes potassium unavailable to plant roots, generally is greater in a clay soil with pH near 7.0 than in a sandy soil with a pH near 5.0. Therefore, potash application rates may need to be greater and more frequent on clay than on sandy loam soils, especially if the pH is above 6.5.

Response to potash fertilizers is greatest when applications are made in 2-foot bands beneath the trellis. Broadcasting potash over the entire vineyard is less efficient and less economical.

Either soil or foliar applications of sulfate or nitrate of potash should be made where potassium is low. Soil application rates should be based on a soil test, foliar analysis, or both. In general, 100 to 400 pounds per acre have been adequate.

If foliar sprays are indicated, use a solution containing 6 to 10 pounds of either carrier per 100 gallons. Apply at a rate of 200 to 300 gallons per acre of mature vineyard. Foliage applications are of primary value, but they provide only a temporary solution to a potassium problem. Soil applications have a more lasting effect. Make one or more applications as soon as the need is determined. Avoid excessive rates of potash, which can lead to magnesium deficiencies in the vineyard and high pH must and wine.

Magnesium

Magnesium (Mg) is most likely to be deficient in vineyards with low pH (acidic) soil or in situations where excessive amounts of potassium have been applied. The lower the soil pH, the more Mg is tied up in the soil particles and not available for plant use. Increased levels of potassium will cause the displacement of Mg^{++} cations on the soil surface, which causes a reduction in available Mg ions.

Symptoms of Mg deficiency develop on the older leaves first. Chlorosis (yellowing) appears between the veins of the leaves while the veins remain green (Figure 111). As a vine becomes more severely affected, the interveinal chlorosis intensifies in older leaves and spreads to younger leaves toward the terminals of canes. The younger terminal leaves may not exhibit symptoms until the entire vine is extremely deficient.

Where the soil pH is below 5.5, apply dolomitic lime (high in magnesium) at the rate of two to four tons per acre. This will increase soil pH and correct a magnesium deficiency. Complete correction could occur within a few months or may not be achieved until one or two years after the application.

If the soil pH is above 6.5 and no liming is needed, correction is best achieved through foliage applications of magnesium sulfate (Epsom salts). Even if dolomitic limestone has been applied and Mg deficiency symptoms are severe, foliage application provides a quick but temporary solution.

For foliar sprays, mix magnesium sulfate at the rate of 16 pounds per 100 gallons of water. Two applications usually are adequate.

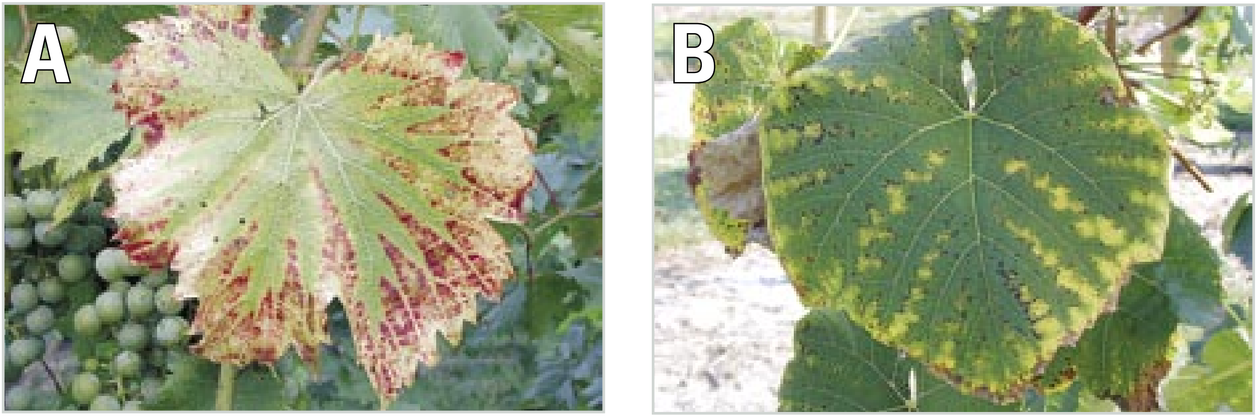

FIGURE 111. Magnesium deficiency symptoms in a red (A) and a white (B) cultivar.

Apply the first shortly after bloom and the second two weeks later. Each spray application requires about 200 to 300 gallons of the mixture per acre to adequately cover the vines.

If longer-lasting effects are desired, magnesium sulfate can be applied to the soil. This is recommended on high pH soils where magnesium deficiency has resulted from excessive potash applications. In these cases, magnesium sulfate may be applied alone or mixed with other fertilizer materials at the rate of 100 to 500 pounds per acre broadcast over the entire vineyard floor. In small vineyards, apply magnesium sulfate at 1/4 to 3/4 pound per vine. Magnesium sulfate or dolomitic limestone can be applied any time of year.

Secondary Nutrients

Secondary nutrients, although not required in large amounts, are essential for good plant growth and vigor. Over-application can occur when adjusting levels of calcium (Ca), manganese (Mn), iron (Fe), boron (B) or copper (Cu). If too high a concentration of secondary nutrients is applied either by foliar or soil application, then there is a risk of increasing each of the elements to toxic levels.

Secondary nutrients Mn, Ca, and Fe are normally not found to be deficient. Soil and/or leaf tissue may indicate that these elements are deficient. A foliar application of a deficient nutrient(s) can be sprayed on for immediate effect. This type of fertilization is a temporary means of correcting a deficiency and should not to be used in a long-term fertility program.

Calcium

Calcium is generally not found to be deficient in soils that are well limed. Unless the pH is allowed to drop below 5.8, there is little chance for Ca to be tied up in the soil. Additionally, lime that is high in Ca can add adequate amounts to the soil. Calcium can be applied as finely ground limestone or hydrated lime, or in fertilizer mixtures.

Boron

Boron deficiencies have been observed in grape plantings in the form of poor fruit set. Clusters will tend to be small, and (shot) berries will not fully develop on the rachis. Terminal buds may not break in the spring, and ends of shoots sometimes are distorted. A plant tissue analysis can determine if there is a deficiency in B, and appropriate amounts can be applied in a foliar spray. Boron availability should not be a problem if soil pH does not become alkaline. Borax or borate, B carriers, can be sprayed on in the spring when needed.

Manganese

Manganese deficiency symptoms first appear as interveinal chlorosis, or yellowing, of the younger terminal leaves. A Mn deficiency may occur when the soil pH is 7.0 or higher and can be corrected by applying fertilizer-grade manganese sulfate at one to two pounds per vine, or 250 to 500 pounds per acre, depending on vine size and severity of the deficiency. Manganese chelate (EDTA), or its equivalent, can be used in place of manganese sulfate. Always read the product label before applying these materials.

A foliar application of Mn can be sprayed on for immediate effect. This application is considered to be a temporary means of correcting a deficiency and not for long-term adjustment of the nutrient level. Mix manganese sulfate at the rate of 4 pounds plus 2 pounds of hydrate lime per 100 gallons of water. Manganese chelate is mixed at the rate of 1 pound per 100 gallons of water. Spray at the rate of 200 to 300 gallons per acre. Two applications usually will provide season-long control of manganese symptoms. Apply the first just after bloom or when symptoms first appear and the second two weeks later.

Iron

If deficiency symptoms develop or a petiole analysis indicates a need, apply iron in the form of iron chelates.

Copper

Copper is required in minor amounts and, if needed, can be applied at no more than 4 to 6 lbs. of copper sulfate per acre in a foliar spray in early spring before budbreak.

Zinc

Zinc is required in minor amounts and, if needed, can be applied in a foliar spray at 5.5 lbs. of zinc chelate per acre in early spring before budbreak.

Harvesting and Marketing

Harvest Timing

The proper harvesting time for grapes depends on the cultivars, nature of the growing season, and the particular use of the fruit. Although proper harvest methods cannot make up for poor weather or cultural management, harvest can diminish a quality crop to a level of mediocrity, if not handled with care. The rate at which grape fruits mature, as well as the time of their ripening, is governed by several factors, some of which can be altered by the grower.

Factors Affecting Harvest Timing

1. **Selection of cultivars.**

   Select cultivars that inherently mature their fruits within the growing season common in the Midwest, with bloom in early June and harvest before a killing frost in mid-October.

2. **Growing-season temperatures.**

   An average growing-season temperature of 65°F to 70°F is necessary for proper functioning of the natural processes that mature fruits and vines. A minimum amount of heat units is necessary to mature a cultivar such as Concord. A heat unit is defined as the daily accumulation of temperature above a certain threshold value (generally 50°F) for a specific stage of plant development.

3. **Crop load.**

   Vines carrying a normal, or less than normal, crop mature fruits earlier than those carrying heavy crop loads.

4. **Light exposure.**

   Vines trained to expose the highest percentage of leaves to light mature fruits and wood earlier than vines with less light exposure.

5. **Healthy foliage.**

   Grapes with leaves free from insects, disease, herbicide injuries, and nutrient deficiencies mature faster.

6. **Vine vigor.**

   Over-vigorous vine growth delays maturity of fruit and wood; vines with low vigor generally mature wood and fruit earlier than normal vines, if the crop load is not excessive. Moderately vigorous vines normally mature their fruits earlier than highly vigorous vines. Therefore, over-vigorous vines with densely shaded areas may not mature their fruit or wood before autumn frosts kill leaves and tender shoot terminals.

7. **Intended use.**

   Grapes intended for fresh eating, processing into juice, jam, jelly, or wine, may have different desired harvest parameters.

As the harvest season approaches, growers should try to pick the fruit at optimum maturity and quality for the specific use. Grapes do not improve in flavor, color, and sugar content after separation from the vine, so harvest should be delayed until desired levels are reached. On the other hand, if the grapes are left too long on the vine, the berries may shatter; damage from birds, insects, and rots may become significant; and yields will be reduced.

The first indication of physiological changes in the maturing fruit is the development of pigments in colored cultivars and softening of berry skins. The beginning of the ripening process is called veraison. Following veraison, berry sugars will rapidly increase, acid will decrease, and the berry will reach its final size. Approximately three to four weeks after veraison, or three weeks before harvest, regular berry sampling should begin to monitor fruit composition. It is critical that the sampling procedure be consistent each time to fully evaluate ripening.

Most cultivars change color long before they are mature enough to harvest. Human taste buds respond primarily to the sugar/acid ratio. Grapes are approaching an acceptable maturity for fresh eating at a sugar/acid ratio of 15:1 (15% soluble solids and an acid content of 1%). As the sugar content increases and the acid content decreases, this ratio may rise to as high as 25:1 or 30:1. For table use, grapes should be picked when both color and flavor have reached their peak.

The average length of time between bloom and optimum harvest date for a cultivar can be helpful in determining the time of harvest but may vary considerably from year to year and from region to region. The section on grape cultivars contains information on approximate date of maturity to use as a guide.

Grapes for commercial processing into juice or wine generally are harvested at the state of maturity desired by the processor. The primary index of maturity for this purpose for juice grapes is the soluble solids (°Brix) content. (Brix is determined with a refractometer. See Figure 112.) In addition to soluble solids, total acid content and pH also are important indicators of maturity, especially for wine grapes.

When grapes are grown for processing, the entire vineyard is harvested at one time to facilitate processing. Therefore, it is extremely important to determine the fruit composition in the vineyard prior to harvest. Berry samples should be taken from exposed fruit and shaded fruit in different parts of the canopy, on opposite sides of the row, and in a manner that as close as possible represents the balance

FIGURE 112. A refractometer is used to determine the soluble solids (°Brix) content.

of fruit in the vineyard. Berries at the tip of the cluster ripen last, so it is important that the sample include berries from all parts of the cluster. Avoid sampling from vines at the ends of rows or from odd vines. Although under-developed secondary clusters are best removed at veraison, if they are to be harvested (as with mechanical harvesting), they must be included in the sample. For the sample to accurately represent maturity, a minimum of 100 berries should be collected from multiple clusters on at least 20 vines.

Total acidity (often called titratable acidity) and pH are important harvest parameters because they affect both flavor balance and wine stability. Titratable acidity measures the quantity of grape acids (mostly tartaric and malic), while pH is a measure of the strength of the acidity. Normally, titratable acid decreases during ripening, and the decrease is greater under warm than cool conditions. Titratable acid level is measured by titrating against a standard base using a pH meter or color change indicator. Juice and wine with lower pH tend to have better color, microbial and chemical stability. If pH is too high, wine may taste flat and lack crisp, fruity flavors. A meter with a pH sensitive electrode is used to measure juice pH. Growers may work with a winery to perform tests of titratable acidity and pH, but the procedure is not difficult if the grower has access to the proper equipment and supplies.

A good reference on wine and juice analysis, including pH and TA measurement, is available from Southwest Missouri State University. See *Micro Vinification: A practical guide to small-scale wine production*, Dharmadhikari, M. R. and K. L. Wilker. 2001.

Guidelines for fruit harvest parameters vary according to the intended wine style. Generally, for dry white wines, fruit is harvested when the pH is 3.1 to 3.2 and the titratable acidity is about 0.75%. For dry red wines, fruit is harvested when the pH is 3.4 to 3.5 and the titratable acidity is about 0.65%. In both cases, winemakers generally prefer fruit at about 0.15% higher acid levels for wines they intend to finish sweeter, with 2 to 3% residual sugar.

In most cases, soluble solids should be 20% or above when the pH and titratable acidity are in the appropriate range. However, some cultivars, particularly labrusca types, tend to be lower in soluble solids when other parameters are optimal. Additionally, some winemakers prefer more or less ripe fruit of specific cultivars.

There are notable exceptions to these general guidelines, but they should help growers understand the importance of fruit composition to wine quality. Flavor, seed maturity, skin color, and other factors may also be important with certain cultivars and for discriminating winemakers. Working with the processor to determine the optimal level of ripeness is the best approach to success.

Fresh-market grapes and those for table use must be hand-picked and handled carefully. To achieve optimum quality and extend the length of the season, growers may sometimes harvest a vine more than once, selecting fully ripened clusters determined by color and taste. Some cultivars tend to crack at maturity, particularly if there has been excessive rain. In such cases, fruit rots can develop and spread rapidly. If fruit rots start to develop, harvest immediately to avoid losing the entire crop.

While grapes for wine making are often hand harvested, the majority of grapes for juice are harvested mechanically (Figure 113). Most of the harvesters rely on high-frequency vibration to shake both individual grapes and intact clusters from the vines. Several commercial models are available for both single- and double-curtain trellises. Some winemakers prefer machine harvesting because it facilitates rapid harvest and processing, especially on larger acreages and where labor may be limited.

FIGURE 113. Mechanical harvesters are used with juice grapes and some wine grapes, especially where acreages are large and labor may be limited.

Marketing

All grape growers should develop a marketing plan. Time and money spent cultivating a vineyard is wasted unless a suitable marketing plan is developed. There is not enough time to develop a market after grapes are ripe.

Successful marketing requires more than producing good fruit, although a quality product is necessary. The key is to develop a marketing plan that forces the grower to examine all the facets of grape growing as a business. It also forces growers to set realistic goals and devise methods to achieve them.

The first decision in formulating a marketing plan is identifying the target market. Growers cannot realistically try to sell grapes to everyone. They must aim for a segment of the total market. The wine producers or marketing association in each state can provide prospective growers with lists of wineries and other potential markets. A first step is to identify wineries and get input from them on what cultivar they need and whether a mutual relationship of supply and demand can be developed (Figure 114).

Growers must be realistic about the potential yield from their vineyard, the cultivars adapted to their site, and the price those cultivars can bring. One of the best ways of ensuring a good business relationship is to operate under a mutually agreed-upon contract. Although it is best to consult legal advice to develop a contract, some characteristics that may be included are listed here.

1. Cultivar and clone, quantity to be delivered, price, Brix, TA, pH.
2. Who transports and in what containers? Time requirements?
3. Who is responsible for off-loading? Getting certified weights?
4. Method and time of payment.
5. What happens if grapes are below minimum quality?
6. Level of rot and material other than grapes allowed.

Depending on the location of the vineyards, other types of markets such as pick-your-own, fresh-pressed juice, or produce distributors may be possibilities.

FIGURE 114. Retail sales room.

Publications for Additional Information

Additional information on the sources indicated here can be found in the next section.

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Source 1

Communication Services Distribution
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Cornell University
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Source 8

The Southwest Michigan Research and Extension Center web site:
www.msue.msu.edu/swmrec

Source 9

Practical Winery and Vineyard Magazine
15 Grand Paseo
San Rafael, CA 94903
This magazine sells numerous grape publications.

Source 10

University of Illinois
Publication Plus
Information Technology and Communication Services
1-800-345-6087
webstore.aces.uiuc.edu/Shopsite/c1382.html

Source 11

Southwest Missouri State University
Department of Fruit Science
9470 Red Springs Road
Mountain Grove, MO 65711-2999
Phone: 417-926-4105
Fax: 417-926-6646
http://mtngrv.smsu.edu/

Glossary

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

Arthropod
Any invertebrate animal (including insects, mites, spiders, and crustaceans) that has a jointed body and limbs.

Ascospore
The sexual spore of an ascomycete fungus.

Balanced Pruning
Pruning the vine based on its growth and number of nodes the previous growing season. A method of determining the potential fruiting capacity of a vine at pruning time.

Base Shoot
A shoot arising from a bud at the base of a cane.

Bleeding
Flow of plant sap from wounds.

Brix
A scale used to indicate soluble solids content: °Brix = grams of sucrose per 100 grams of liquid at 68°F.

Bud
The compound bud or eye in the axil of a leaf, at the node.

Callus
Parenchyma tissue that grows over a wound or graft and protects it from drying or injury.

Calyptra
The petals of a grape flower.

Cane
A mature woody, brown shoot that develops after leaf fall.

Canker
A necrotic, localized disease area with a sharp line of demarcation between healthy and diseased tissue. Usually on trunks or canes.

Canopy
The entire foliage of a grapevine as it is positioned on the trellis.

Chlorosis
Yellowing of normally green parts of the plant, especially shoots and leaves.

Cleistothecium
The sexual fruiting body of a powdery mildew fungus.

Conidia
Asexual spores formed by several types of fungi.

Cordon
An extension of the grapevine trunk, usually horizontally oriented and trained along the trellis wire.

Crop Load
The ratio of crop size/vine size.

Crop Size
The fruit weight per vine (in pounds) measured at harvest.

Curtain
A portion of the canopy composed of the current season's shoot growth that is normally oriented downward.

Dormancy
That stage when the plant is not actively growing.

Escapes
Weeds in a treated area that have been missed or that have survived the treatment.

Floret
The individual flower of a cluster.

Fragipans
Impermeable soil layers or texture changes that prevent free downward movement of water.

Fruiting Wood
One-year-old wood (cane) that produces the current season's crop.

Fungicide
A chemical or physical agent that kills fungi or inhibits its growth.

Gall
An abnormal growth of plant tissue caused by stimuli external to the plant itself, generally caused by insects or parasitic bacteria. Example: Phylloxera gall.

Germ Tube
The initial hyphae strand from a germinating fungus spore.

Head
The top of the vine where canes are selected to produce the current season's crop.

Hedging
Trimming ends of shoots in a vertically shoot-positioned traning system, such as VSP.

Herbicides:
Selective Herbicide — One that affects some plants but not others.
Non-Selective Herbicide — One that will kill any plant it contacts.
Contact Herbicide — One that affects only the tissue sprayed.
Systemic Herbicide — One that moves within the plant; also known as a translocated herbicide.

Infection
The process in which a pathogen enters, invades, or penetrates a host plant and establishes a parasitic relationship with it.

Infection Period
The time required for a plant pathogen to penetrate host plant tissue and establish a parasitic relationship. Length of the infection period depends on environmental factors such as wetness duration and temperature, and host susceptibility.

Internode
That portion of the cane or shoot between nodes.

Lateral
Side branches of a shoot or cane.

Lesion
A wound or delimited disease area.

Life Cycle
The period of time between fertilization of an insect egg and the death of the individual that proceeds from that egg. In most insects, includes the stages of egg, larva (grub), pupa, and adult.

Mummy
A dried and shriveled grape berry resulting from attack by a fungus.

Necrosis
The localized death of plant tissue, generally brown or black in color.

Node
: The thickened portion of a shoot or cane where the leaf and its compound bud are attached.

Oospore
: A thick-walled, sexually derived resting spore of oomycete (downy mildew) fungi.

Pedicel
: The stem of an individual flower or berry.

Peduncle
: That portion of the rachis extending from the shoot to the first branch of the cluster.

Petiole
: The stem end of a leaf.

Pheromone
: A chemical substance (i.e., sex attractant) produced by an animal that serves as a stimulus to other individuals of the same species for a behavioral response.

Pruning
: Physical removal of portions of the vine for the purpose of maintaining size and productivity.

Pycnidia
: An asexual, globose, or flask-shaped fruiting body of a fungus that produces conidia. See *Conidia.*

Rachis
: The main stem or axis of a cluster. The framework of the cluster to which the pedicels are attached.

Renewal Spur
: A cane pruned to one or two nodes, generally on an arm or cordon. Its primary purpose is to position a cane for fruiting the following season.

Rest
: That period of nonvisible growth controlled by internal factors. Visible growth will not occur even under favorable environmental conditions.

Sclerotia
: Hard, dark, and rounded mass of fungal tissue that permits survival in adverse environments.

Shatter
: That physiological stage following bloom when impotent flowers and small green berries begin to drop from the cluster.

Shoot
: The green, leafy growth developing from a cane, spur, cordon, or trunk. The developing growth is the source of leaves, stems, tendrils, flowers, and fruit.

Skirting
: Trimming ends of shoots in a downward shoot-positioned training system, such as High Cordon.

Slip-Skinned
: The grape flesh separates readily from the skin.

Sporangiophore
: A sporangium-bearing body of the downy mildew fungus.

Sporangium
: A fungal structure producing asexual spores, usually zoospores.

Spore
: A reproductive body of a fungus.

Spur
: A cane pruned to one or two nodes. A fruiting spur is chosen to produce shoots with fruit. See *Renewal Spur.*

Stomate
An opening or pore usually in the lower surface of a leaf that functions in gas exchange.

Sucker
A shoot arising from a bud below ground.

Summer Lateral
A weak shoot produced in the axil of the leaf adjacent to the bud.

Tendril
A curled structure arising from some nodes of the shoot and capable of attaching itself to other portions of the vine or trellis.

Trunk
The main, upright structure of the vine from which arms, cordons, shoots, and canes arise. Vines may have more than one trunk.

Veraison
That physiological stage in the development of a grape berry when it begins to ripen as indicated by color change and fruit softening.

Vine Size
Weight of cane prunings on a vine. Measured by weighing cane pruning per vine (in pounds) during the dormant season.

Water Sprout
An unwanted shoot arising from buds on the trunk.

Weed Shift
The build up of tolerant weed species.

Zoospore
A fungal spore with flagella, capable of locomotion in water.


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