The Connecticut Agricultural Experiment Station, New Haven

Grapevine Cultivation in Connecticut

BY WILLIAM R. NAIL

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INTRODUCTION

Grapes have been grown in Connecticut for centuries. Three grapevines adorn the state seal, and one of the most widely grown grapes in the country, Concord, was developed in nearby Concord, MA in 1849. European immigrants frequently tended home plantings for personal wine making. Wide-scale commercial cultivation in Connecticut is relatively new, however. Increasing interest in wine in the 1970's resulted in expansion of the existing industry in New York, and spread to other nearby areas, including New England. The passage of the Connecticut Farm Winery Act in 1978 made it possible for wineries to produce and market their product. Tourism has greatly helped increase the growth of the industry. There has also been increased interest in home wine making. New varieties of grapes for cold climates have made it easier for homeowners and small farms to grow quality table and wine grapes.

Grape growers in Connecticut face several obstacles. Severe winter temperatures can injure or even kill grapevines. Our warm, humid summers are ideal for the growth of a variety of fungal leaf (or foliar) and fruit diseases. Some grape varieties do not ripen properly in our short, mild growing seasons. Nevertheless, these limitations can usually be overcome, and there are now vineyards located throughout the state. There are over 300 acres of grapes in commercial production, and, at the time of this writing (2007), more than 22 commercial wineries, with more scheduled to open.

This guide is an introduction to grape growing in Connecticut, and will be useful for both aspiring commercial growers and those who desire just a few vines for home use. Although the information in this publication is tailored for Connecticut conditions, most of the information is applicable to surrounding states- New York, Massachusetts and Rhode Island- as well.

The guide begins with a general discussion of things to be considered prior to planting. These include variety selection of cultivars suitable for Connecticut, costs of operating a commercial vineyard, and site selection. This is followed by a section on vineyard establishment, which discusses how to design, plant, and maintain a young vineyard prior to coming into production. Managing established vineyards involves making many decisions, especially regarding pruning, training, canopy management, and harvest. These are discussed in depth, as well as factors such as fertilization, weed control, and pest management. The last section discusses some of the various pests that can affect grapevines. There is also a list of resources for growers seeking more detailed information on specific topics.

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GRAPE VARIETIES

All grape varieties can be used for wine, juice, and fresh eating. However, some varieties are more suited for one use than another. Wine grapes and most juice grapes generally have large seeds which many find unpleasant. Some table grapes do not have sufficient sugar to make high quality wine. Varieties mentioned in this bulletin are categorized based on their traditional uses.

Except in breeding programs, grapevines are propagated vegetatively. Each variety originated from a single plant. Over the course of many (in some instances, thousands) years, natural mutations arise that may be distinctive enough to warrant their own designation. The term "clone" describes genetic variations of a variety that have been deemed significantly different from each other. There are typically many named or numbered clones of well known varieties such as Chardonnay and Pinot Noir, but few or none for lesser known varieties.

WINE GRAPES

There are three types of grapes used to make wine in Connecticut: *Vitis vinifera*, hybrids, and American varieties. *Vitis vinifera*, probably native to Asia Minor, refers the traditional European grape varieties such as Chardonnay and Merlot, and produces the wine that most people are familiar with. The main limitation with their culture in most of Connecticut is lack of cold hardiness. Cold hardiness is a dynamic process, and it is impossible to state exactly how cold it needs to be to injure or kill a vine. However, most vinifera varieties can be damaged at temperatures ranging from -10° to -5°F. These varieties are likely to sustain occasional to regular winter injury in non-coastal areas of the state. They are also generally more susceptible to fungal diseases than hybrids or American varieties. All vinifera varieties must be grafted onto a rootstock, as they do not generally perform well on their own roots in Connecticut. Still, they are considered to produce the highest quality wines, so they are sometimes grown in areas with colder mesoclimates (see Site Selection).

There are literally hundreds of vinifera varieties. Experience in Connecticut and the rest of New England is limited to just a few varieties. Many growers, however, feel that there is great promise in some new varieties and clones from northern Europe; unfortunately, we do not yet have enough information on how they will perform here.

When choosing varieties, some consideration should be given to ripening time. Choosing varieties that ripen at the same time allows for fewer harvests, which may be desirable in some instances. Conversely, having grapes that ripen at different times can stagger the harvest season, allowing for more steady, less hectic harvests. For table grapes, a staggered harvest means that fresh fruit will be available for up to six or seven weeks, as opposed to a week or two. However, very late-ripening varieties might not fully mature in poor growing seasons.

Table 1. *Vitis vinifera recommendations for Connecticut.*

Recommended *Vitis vinifera* Varieties

Variety	Color	Comments
Chardonnay	W	
Muscat Ottonel	W	
Pinot Blanc	W	
Pinot Gris	W	
Riesling	W	
Cabernet Franc	R	
Lemberger	R	
Merlot	R	Marginal
Pinot noir	R	Rot prone

Non-Recommended *Vitis vinifera* Varieties

Variety	Color	Problem
Gewürztraminer	W	Cold tender- coastal areas only
Cabernet Sauvignon	R	Needs longer season

Hybrid varieties are the result of breeding programs' attempts to combine the best qualities of wine grapes (usually vinifera) with desirable qualities of other species (improved cold tolerance, better insect and disease resistance, adaptability to soil conditions, etc.). Given a suitable site, it is possible to grow most hybrid varieties in Connecticut. They tend to have higher yields and greater disease resistance than vinifera varieties. Breeding programs, especially those at Cornell University and Geisenheim, Germany, have produced much higher quality hybrid varieties in the last few years. The University of Minnesota has developed varieties that are cold hardy to -40°F. However, many people judge the flavor of hybrids inferior to that of vinifera varieties.

Table 2. Hybrid grape recommendations for Connecticut.

Recommended Hybrid Varieties

Variety	Color	Comments
Cayuga White	W	
Chardonel	W	
Frontenac Gris	W	Little tested, very hardy
La Crescent	W	Little tested, very hardy
Melody	W	Little tested
Seyval Blanc	W	
Traminette	W	
Vidal Blanc	W	
Vignoles	W	Rot prone
Villard Blanc	W	
Chambourcin	R	
Chancellor	R	Downy mildew
Frontenac	R	Very hardy
Marechal Foch	R	Falling out of favor
Marquette	R	New, very hardy
St. Croix	R	Very hardy

The principal American varieties are Catawba, Concord, and Niagara. They have fallen out of favor as wine grapes with many people, being more suited for juice, but are relatively easy to grow and produce well.

TABLE AND JUICE GRAPES

Most people equate table grapes with seedless grapes. There are many newer white, red, and black seedless varieties. Appearance is more important with table grapes than grapes intended for juice or wine, where slight bird or insect damage may be tolerable. Concord and Niagara are the two principle varieties of juice grapes grown in the United States. Niagara is the less cold hardy of the two, and some damage may occur in the coldest areas of the state.

Table 3. Recommended table grapes for Connecticut.

Recommended Table Grape Varieties

Variety	Color	Seeded? (Y/N)
Canadace	R	N
Concord Seedless	B	N
Einset Seedless	R	N
Edelweiss	W	Y
Golden Muscat	W	Y
Himrod	W	N
Jupiter	R	N
Kay Gray	W	Y
Interlaken Seedless	W	N
Lakemont	W	N
Marquis	W	N
Mars	B	N
New York Muscat	R	Y
Ontario	W	Y
Reliance	R	N
Swenson Red	R	Y
Vanessa	R	N

ROOTSTOCKS

Many grapes grow successfully on their own roots. Others, like all vinifera varieties, require grafting. In some cases, such as many of the hybrids, growers plant grafted vines to improve vine performance in varieties that will grow on their own roots. The main benefit is increased yield. For instance, grafted Vidal Blanc vines may yield twice the amount of fruit as ungrafted vines. Rootstocks have been bred for a variety of factors. The principle reasons are resistance to grape phylloxera, a root louse, and root nematodes. Other rootstocks are variously tolerant of acidity, alkalinity, poor drainage, dry soils, and other factors. The most common rootstock in Connecticut is C.3309, which is adaptable to most conditions and is widely available. Mgt 101-14 shows promise for the area, and C.1616E, while untried in the state, may also be suitable. Generally, SO4 does not perform as well in the state, although it has been widely utilized.

COSTS OF GROWING GRAPES

Commercial grape growing is very capital-intensive. The rewards can be substantial as established vineyards can be productive for many years. Costs can vary significantly depending on a variety of factors. As homeowners may not be as concerned with maximum productivity or efficiency, this section is oriented toward the commercial grower.

The costs of vineyard establishment are considerable, as vines need to be purchased and planted, and a trellising system erected by the second season. No grapes should be harvested until at least the third season after planting, and that harvest should be fairly small. Therefore, although there is substantial capital outlay, there will be no income at all until at least the third year. The investment is recouped about the seventh year after planting.

Obviously, one major variable in the cost of a commercial vineyard is the cost of land. Because this cannot be predicted, it is assumed that the land is already owned. Soil preparation will be discussed in a later section, and its costs are also not covered here. The costs can vary widely; some vineyard sites require little soil preparation, while others may require a great deal.

There are several good resources available that provide worksheets for potential and existing vineyards, as well as various scenarios that can be adapted to individual circumstances (see Resources).

LABOR

Grapevines require extensive management for optimal performance, and labor costs can represent more than forty percent of the operating cost of an established vineyard (Wolf and Poling 1995). Some vineyard operations, such as pruning, require skilled labor which may be difficult to find. Vineyards of five acres or less may be manageable for one person working evenings and weekends, with occasional help at very busy times of the year (especially during harvest). Managing larger vineyards usually requires at least one full-time worker.

MATERIALS

Grapevines are generally purchased as dormant, bare root plants. The price varies by variety; new varieties may be in high demand and inventories limited, so these tend to be more expensive. Own-rooted plants are always less expensive than grafted plants of the same variety. Currently, the average price is about $3.50-$4.00.

Other costs during the establishment phase can include stakes, grow tubes, string, pruning tools, and other items. While they will be used in small quantities at first, pest control materials will also be required. In some situations, wildlife exclusion or repellant devices may be necessary. Once vines are producing, containers and tools for harvest will be required and greater quantities of pest control products and fertilizer will be needed.

EQUIPMENT

Equipment will be necessary for mowing, spraying, cultivating, and other vineyard activities. Existing farms may already have suitable equipment, while new enterprises will have to purchase equipment. There are specialized tractors, sprayers, and other equipment designed exclusively for use in vineyards. While they do perform well, they are also usually quite expensive. Most growers use standard farm machinery with, possibly, a few vineyard-specific items. Most important is a sprayer of adequate size to apply fungicides and a tractor that will accommodate it. Air-blast sprayers are most common. Newer designs specifically made for vineyards are more efficient, confining the spray to the canopy and recycling the applied materials. Other equipment includes a mower, trailer, fertilizer spreader, auger, post hole digger, and herbicide sprayer (if herbicides are used). Larger vineyards may utilize machinery for operations that would be done manually in smaller vineyards. Such machinery may include cultivation equipment, special hoes for hilling up vines in winter, a mechanical hedger, equipment for leaf removal, a mechanical harvester, and a net applicator for bird control.

SUPPORT

Grapevines require some type of support to perform well. Homeowners can use existing structures such as fences or arbors. Commercial production, however, requires a dedicated trellising system, which, machinery excepted, is usually the single greatest cost for establishing a vineyard. The trellis must be able to support the entire weight of the grapevines with fruit in the windiest weather of the growing season. This is not an area to skimp. A well-designed trellis will make vineyard operations easier and more efficient for the life of the vineyard, while a poorly constructed one will require frequent repair and make vineyard operations more difficult.

SITE SELECTION

Grapevines are grown on many different types of sites and soils throughout the world. When evaluating a site for potential grape growing, two factors should be considered- the macroclimate and the mesoclimate. The macroclimate refers to the prevailing conditions of a general region- for instance, hilly or flat, hot or cold. In Connecticut, the most important factor influencing the macroclimate is the proximity to Long Island Sound and the Atlantic Ocean. These large bodies of water absorb heat during the summer, so areas close to the coast generally have cooler summers than those further inland. More importantly, they release some of that heat in the winter, so winter temperatures are moderated. The moderating effect only lasts for a few miles inland, however. Only in coastal areas of Connecticut can vinifera varieties be reliably grown without running the risk of occasional severe winter damage.

The mesoclimate refers to the particular site or area- specifically, your vineyard and its surroundings. The term microclimate is sometimes used incorrectly to describe the mesoclimate- the microclimate refers to very localized climates, such as the amount of shading on the lower leaves of a vine, or the humidity within a cluster of grapes. The major factors to be considered when selecting a site are discussed below.

SLOPE, ASPECT, AND TEMPERATURE VARIATIONS WITHIN THE VINEYARD

Grapevines are susceptible to both late spring and early autumn frost damage. Frost damage most commonly occurs on cold, still, cloudless nights. Under these circumstances, the colder air moves to the lower areas, flowing downhill. It is not unusual to find temperature differences of 3°F to 5°F over a 50 foot difference in elevation. Therefore, grapevines at or near the bottom of a hill may be damaged, while those higher up may be unharmed (Figure 1). It is important to remove barriers to cold air movement, such as hedgerows at the bottom of a hill, that may dam up the colder air.

Slope refers to the degree of inclination of the site. Slight slopes can be beneficial for growing grapevines, as they allow for air drainage during frost incidences. Slopes steeper than 15 percent, however, present several problems. Operating machinery can be difficult or dangerous, and the potential for soil erosion is greatly increased. Many traditional vineyards in Europe on steep slopes are terraced. The effect is beautiful, but terracing is very expensive, and such vineyards are extremely difficult to work. Relatively flat land is generally also acceptable for grapevines, so long as it is not at the bottom of a slope.

Aspect refers to the direction that the slope faces. Southern and western aspects are generally warmer than northern and eastern aspects. This can be an advantage during the growing season, but may predispose the vines to cold damage during the winter, and result in early bud break in the spring, increasing the danger of frost damage. Eastern aspects are exposed to the sun first during the day, so foliage wet from dew or rain will dry faster. Generally, the aspect of a slope is not as important as other factors when choosing a vineyard site.

It is beneficial, especially on variously sloping land, to place three or more thermometers that record maximum and minimum temperatures in various places in the potential vineyard to learn which are the warmer and which are the cooler areas. These are readily available at garden and home centers, and should be placed 3-5 feet off the ground, and shielded from the sun with a white covering. Record the maximum and minimum values from each thermometer at least weekly.

SUN

Grapevines require full exposure to sun (Smart and Robinson 1991). Anything that might shade the foliage for even part of the day should be removed. Vines in a cleared area surrounded by trees should be planted far enough away from the trees so that the vines are never shaded. Remember, as the earth rotates, the sun will appear to move in the sky throughout the growing season as well as throughout the day, so a single observation is not adequate. Also, remember that the trees will continue to grow during the life of the vineyard.

SOIL

Grapevines are tolerant of a wide range of soils. The main requirements for healthy grapevines are soils with good internal drainage. Roots require oxygen, which is limited in poorly drained soils. Grapevines never reach their potential when planted in poorly drained areas. Installation of drainage tiles can improve drainage, but the process is expensive. Soils with significant clay content are subject to compaction from routine vineyard maintenance from the weight of tractors and other equipment. The best soils are sands and sandy loams, at least 30-40 inches deep. Updated and revised detailed soil maps are available online at http://websoilsurvey.nrcs.usda.gov/app/.

Figure 1. A vineyard one week after a late spring frost. Note the brown vines at the bottom of the hill, compared to the green foliage higher up. All growing shoots were killed on those plants at the bottom.

SURROUNDING AREAS
Wooded areas near the vineyard site can harbor vineyard pests. Deer and birds can cause extensive damage to grapevines, and wild grapevines growing in woodlands provide a habitat for the grape berry moth. In more developed areas, growers contemplating a commercial vineyard should make sure that neighbors would not object to necessary vineyard activities such as spraying. Phenoxy herbicides containing 2,4-D are frequently used in urban lawns and on pasture grass. 2,4-D is extremely toxic to grapes, and the volatiles from certain formulations can drift hundreds of yards, even over a mile (Frazier et al. 1970). If possible, attempt to make sure that you are not subject to such drift.

VINEYARD ESTABLISHMENT

Getting your grapevines off to a good start will help ensure a long-lived, productive planting. While mature grapevines can frequently tolerate adverse growing conditions, young plants are much more delicate. This is also the time to establish the permanent structure of the grapevines, as the older wood will become too stiff to train.

VINEYARD DESIGN
The most important factors to consider when designing a vineyard are ensuring that the grapevines will receive maximum sunlight and that vineyard activities are easily accomplished. Homeowners can plant grapevines on existing structures, such as on a fence or an existing arbor. Growers and homeowners with more than a few plants should erect some type of dedicated trellising to support their vines. Ideally, rows should run north-south to maximize sunlight interception. However, other factors might not make north-south rows the best choice. On land with significant slopes, the contour of the land may dictate row orientation. Rows should either follow the contour or be oriented from top to bottom to facilitate vineyard operations if machinery is used. Ideally, rows should also run in the same direction as the prevailing wind so foliage and fruit dry out quickly. Many vineyard designs are a compromise between these factors.

At a minimum, rows should be as far apart as the eventual height of the grapevines (including trellis). They are generally further apart in order to accommodate tractors and other machinery. The most common between-row spacings are 9 and 10 feet. Within-row spacing will vary with vine vigor, which is influenced by variety, rootstock, water availability, and other factors. It is important that the vines fill the trellis without undue crowding. Bare space in the vineyard is wasted space- the canopies in a mature vineyard should look like a continuous wall. The most common spacings are 6 feet for vinifera varieties and 6 or 8 feet for most hybrid varieties. If possible, consult with growers in your area to see what has and has not worked for them. Unlike many other decisions in the vineyard, the choice of spacing is permanent (short of removing some plants).

Row length is generally a matter of convenience and the layout of the property. Rows can be 600 feet long, or longer, with very strong bracing. Rows of 180-350 feet are typically used in Connecticut. Longer rows are more suited to mechanized operations.

Enough space should be allowed at the end of the rows for turning tractors and other equipment. The largest (or potentially largest) piece of machinery will determine this width. Remember to include the space that will be occupied by earth anchors, if used.

SOIL TESTING AND PREPARATION
Soil preparation prior to planting should be viewed as a critical step in vineyard establishment. Proper preparation will yield significant benefits throughout the life of the vineyard. Simply put, you only have one opportunity to do it right. Lack of proper initial soil preparation may be unfixable. At best, it will be more expensive and detrimental to the grapevines to remediate poor soil conditions than if it had been done properly prior to planting.

Soil tests to determine fertility and soil reaction should be done well in advance of planting. In order to get accurate results, it is critical to employ accurate sampling procedures. Consult with your soil testing agency (the Connecticut Agricultural Experiment Station performs free soil analysis for Connecticut residents) for their sampling methodology. More information can be found at http://www.caes.state.ct.us, and click on “Soil Testing”.

The main problem with many soils in Connecticut, besides lack of drainage, is high acidity (low pH). The ideal soil pH for most grapes is about 6.0-6.8, although American varieties prefer a slightly more acid soil of about 5.5-5.8. Grapes growing in soils outside this range may have trouble obtaining nutrients from the soil even if the nutrients are present. Soil pH below the desired values can be raised by the addition of lime; soil tests will indicate how much to add. It is important to do this prior to planting. Because lime is fairly immobile in the soil, it needs to be incorporated prior to vineyard establishment. If the land has been previously used as farmland, it has probably been limed for many years, and may not require adjustment. If other nutrients need to be applied to the soil prior to planting, this will be noted on the soil test results.

A confounding factor in incorporating any material into soils in Connecticut is the abundance of rocks in the soil. This is usually more of a problem on previously uncultivated land. There is, unfortunately, no remedy for this problem short of removing the rocks.

PLANTING

Planting is done in the spring (usually mid-April through May). Plants are obtained from nurseries as dormant, bare root plants. A hole should be dug large enough to accommodate the root system. Grafted plants should be placed in the planting hole with the graft union about 1-1.5 inches above the soil level. Non-grafted vines should be planted at the level that they were previously planted- this should be apparent from their appearance. Never let the plants dry out. It is good idea to soak the roots in water for a few hours, and then keep them in the bucket until the moment of planting.

Make absolutely sure that the vines are planted straight in the row. Ideally, the basic trellis will already be in place, and the lower wire (30-36 inches high) strung to ensure straightness. The wire can, however, be installed after planting.

WATER AND FERTILIZER

While mature grapevines are among the most drought-tolerant of all fruit crops, young grapevines do not have well-established root systems. Young vines may die if they do not have sufficient water during at least the first two growing seasons. Grapevines, like all plants, do not "seek out water", but roots grow and flourish when moisture is available. Most Connecticut vineyards get adequate rainfall during the growing season to maintain the health of mature vines. Some provision should be made to ensure that water can be supplied to young vines during the first two years in case of drought. Drip irrigation is the best method, but many growers do not want to invest in the labor and expense since it would only be used occasionally after establishment (and not at all in many years). Drought stress during establishment will negatively impact the long-term health of the grapevine. Established vines (three years and older) are rarely stressed by drought in Connecticut.

Unless soil tests show that your soil is very deficient in nitrogen, no fertilizer is generally needed during the first growing season, although a small amount applied in late June or early July will do no harm. Small to moderate amounts of fertilizer can be used the second season, either when growth begins in spring or splitting the application between spring and the midsummer application. After the second growing season, the soil should be retested, and fertilization should be based on those recommendations.

Grapes are not extremely sensitive to the type of fertilizer applied, but they are sensitive to overfertilization. If compost or other organic sources of nitrogen are used, it is even more important not to apply excessive amounts, as the negative effects can last for years.

WEED CONTROL AND GROW TUBES

These are two separate concerns that can overlap from a practical perspective. Plants are in constant competition with each other for nutrients, water, and sunlight. Weed control is essential during vineyard establishment. The use of grow tubes (there are several types on the market) can enhance early vine growth by elevating the temperature and CO_2 concentration in a young grapevine's microclimate. They also promote upright growth of grapevines with no training and help protect the vines from herbicide damage. There are concerns that grow tubes, if left on too long, can predispose vines to winter cold injury and, possibly, subsequent crown gall disease. Therefore, they should probably be removed by early September to allow the vines to harden off.

Weed control can either be manual or chemical. Chemicals are usually easier and cheaper, especially in rocky soil or with grow tubes. The critical factor is that weeds are controlled. Young plants have relatively weak root systems that compete ineffectively with aggressive weeds. They can easily be overwhelmed by weeds in a very short period of time. It is not uncommon for newly planted vines to be almost invisible by late June due to weeds. The most common practice is to leave a strip of bare ground about 15-18 inches on either side of the vines, and to have some type of vegetation between the rows. This facilitates the use of machinery in the vineyard and helps prevent erosion. There are several pre-emergence herbicides that are approved for use in vineyards to help prevent weed seed germination. Post-emergence herbicides are very effective on existing weeds, but they need to be used with caution to avoid damaging the grapevines. Grow tubes greatly facilitate the use of these herbicides. It is very important to control weeds before they become established and begin reseeding.

A variety of plants can be used for the row aisles. Ideally, the choice should be dense, low growing, and slow to go to seed; fescue is a very good choice. The row aisles should be mowed periodically to prevent excessive humidity buildup and to reduce seed production.

TRAINING

Vines should be trained to a basic training system as their growth indicates. This is generally when the shoots are long enough to be trained laterally to the wire that will eventually support the fruiting wood (see Support and Trellising). Most *V. vinifera* cultivars do not require training in the first, and sometimes second, season except to establish straight trunks. Other species and hybrids may grow much more rapidly, and require some training the first season. Installation of at least a basic trellising system during the first season of growth will make initial training much easier. If grow tubes are not used, some type of training support such as bamboo stakes should be used to encourage straight trunks.

There are differences of opinion regarding whether to establish two or three shoots that will eventually become trunks as soon as possible, or to “let everything grow”. Based on available data, long-term vine health is best achieved by retaining as much growth as possible. There are logistical advantages to establishing permanent shoots as soon as possible, however; this strategy should not be ruled out if it is more compatible with vineyard management requirements.

Any fruit that might appear during the first two growing seasons should be removed as soon as possible. The fruit will compete with the other plant organs for carbohydrates, weakening the plant and ultimately delaying full productivity. A small crop, with a maximum of one cluster per shoot, can be harvested in the third season. The excess fruit should be removed prior to veraison (when grapes begin to soften and red grapes begin to change color). Veraison typically begins sometime in August in Connecticut.

The vines should be large enough by the second or third growing season to be trained to the selected trellising system, although canes may not be long enough to completely fill the trellis laterally. During the third growing season, shoots should be removed from the trunk as they emerge. This can be easily done by rubbing the shoot early in the season- waiting too late will require cutting them off. Leave one or two shoots near the base of the plant to serve as renewal shoots in case a trunk should die. Retain all shoots that are within six inches of the fruiting wire.

SUPPORT AND TRELLISING

There are many systems of trellising grapevines, and a thorough discussion is outside the scope of this bulletin. The goals of choosing a trellising system are to maximize sunlight, create and maintain a renewal zone for future growth, and to streamline vineyard operations. Grapevines are easiest to manage if you work with, rather than against, the natural growth habit of the vine. Some types of grapes, such as vinifera varieties, have an upright growth habit. Others, such as the American varieties, have a trailing (procumbent) growth habit. Given their parentage, the growth habits of hybrids are variable- some are mostly erect, some procumbent, and some in between with a lateral growth habit. Choosing the ideal system for these varieties can be difficult, and frequently requires a compromise.

The most common type of trellising involves training the fruiting wood to a low wire (30-36 inches) and training the growing shoots up. This is the standard vertical shoot positioning (VSP) system. It is suitable for all vinifera and some hybrid varieties that have an upright growth habit. The fruiting wood is located on or near the low wire. The shoots are trained upward as they grow and are supported by additional wires, called catch wires. These may be single wires that the shoots are tied or clipped to. An alternative is to use pairs of wires that the shoots can be tucked into as they grow. There should be two, or preferably three, catch wires or pairs of catch wires. Using this system, the fruit is concentrated slightly above the fruiting wire, allowing for a conveniently managed fruit zone.

Another common type of trellising system involves training the fruiting wood to a high (5-6 feet) wire, and letting the shoots grow down. This is the basic Hudson River Umbrella (HRU) system, and is widely used for juice grapes and many hybrid varieties. This system requires only two wires, as opposed to four to seven for the VSP system. The fruit zone in this system is concentrated at and slightly below the top wire. The weight of the fruit and shoots helps keep the shoots growing downward. Although some training during the growing season may be needed to retrain lateral growth, there is less training involved than with the VSP system.

There are many variations on these systems, as well as those that involve fruiting wires at about 42 inches or multiple fruiting wires. These are simply the two most common systems. Divided canopy systems in which vines are trained to multiple fruiting wires are appropriate for vigorous vines, and can increase yields. They can also be used to devigorate vines that were planted too close together or where other mistakes were made, such as the excessive application of compost or other long lasting nitrogen fertilizer. Most systems can be changed. However, it is difficult to change from a high fruiting wire system to a lower one.

Note in the illustrations that the trunks are crossed in the center. There is a natural tendency to train the left trunk to the left and the right trunk to the right; however, unless one is extremely conscientious about keeping the trunks together, a bare zone can develop in the center that can be difficult to overcome. It is not uncommon for this zone to be about one foot wide. Assuming the vines are six feet apart, this results in a 16% reduction in yield, and wastes 16% of the available space.

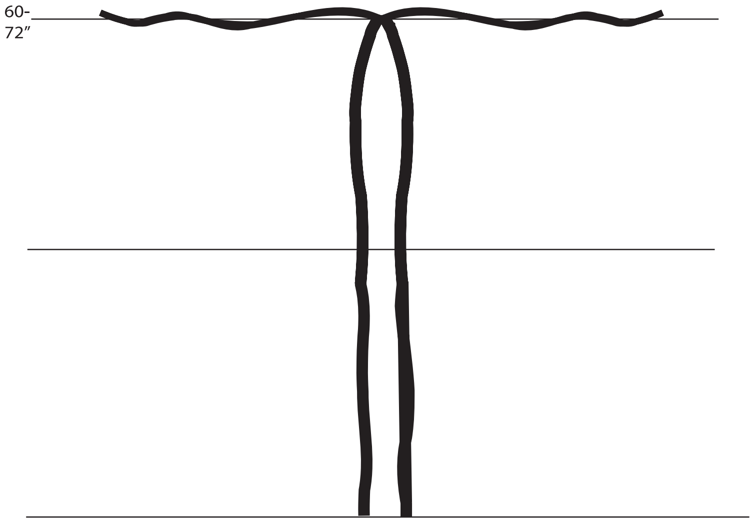

Figure 2. Basic structure of a young grapevine pruned to a Hudson River Umbrella (HRU) system. The lower wire is used for support and to help train the young vine upward.

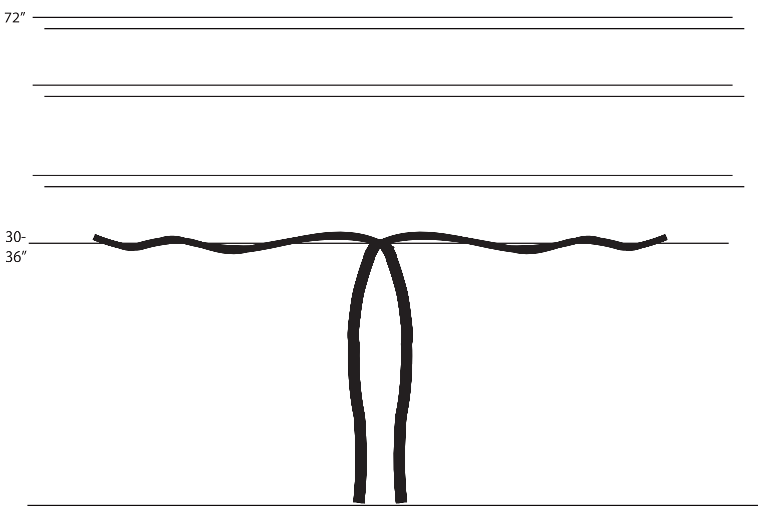

Figure 3. Basic structure of a young grapevine pruned to be trained to a Vertical Shoot Positioning (VSP) system. As the shoots grow upward during the growing season, they will be tucked into the pairs of catch wires above. Single wires can also be used, and the shoots clipped or tied.

PEST MANAGEMENT

Quality foliage is necessary for plants to grow, and is especially important for grapevines in the establishment phase. Growers should familiarize themselves with the common insect, disease, and wildlife pests that are known to occur, and control them at the very first sign of damage or infection. If fungal diseases are allowed to grow and reproduce (a process that is usually just a matter of days), they can become established in the vineyard and will be much more difficult to deal with for years to come. Since the young vines are fruitless the first two seasons, fruit rot organisms are not a concern. In the third season, if a crop is harvested, the regimen for pest control for mature vines should be followed.

WINTER PROTECTION

Own-rooted vines damaged by extremely cold weather frequently resprout from the ground, so even if the shoot system is killed, it may be possible to reestablish the plant in a year or two. Grafted vines, however, are typically killed to the soil level which is below the graft union. It is advisable to cover the graft union with soil prior to the onset of potentially damaging cold weather. The soil should be at least three inches above the graft union, and some settling should be allowed for. The soil will need to be removed each spring after danger of lethal temperatures is past and prior to the commencement of growth. Ideally, this should be done before spring pruning, so renewal shoots can be selected. This is more important for established plants. Other materials (leaves, hay, mulch, sawdust) can be used instead of soil. However, quite substantial quantities are required, and some materials may harbor rodents that can damage vines by chewing off bark to feed on the cambium.

MANAGING ESTABLISHED VINEYARDS

Once the vineyard is established, changes in vineyard activity from year to year are based on weather and alteration of cultural practices based on experience or curiosity. The season begins in winter or early spring with pruning and tying. Beginning at bud burst or shortly before, one should be constantly on the lookout for insect and disease pests which can be a problem throughout the growing season. Various vineyard activities such as leaf removal, fruit thinning, and shoot positioning are done throughout the summer beginning after fruit set. At the onset of veraison, care should be taken to protect the fruit from damage from rot, birds, or other animals. After the fruit is harvested and processed, the vines are left to acclimate for the coming winter. The cycle begins again the following spring.

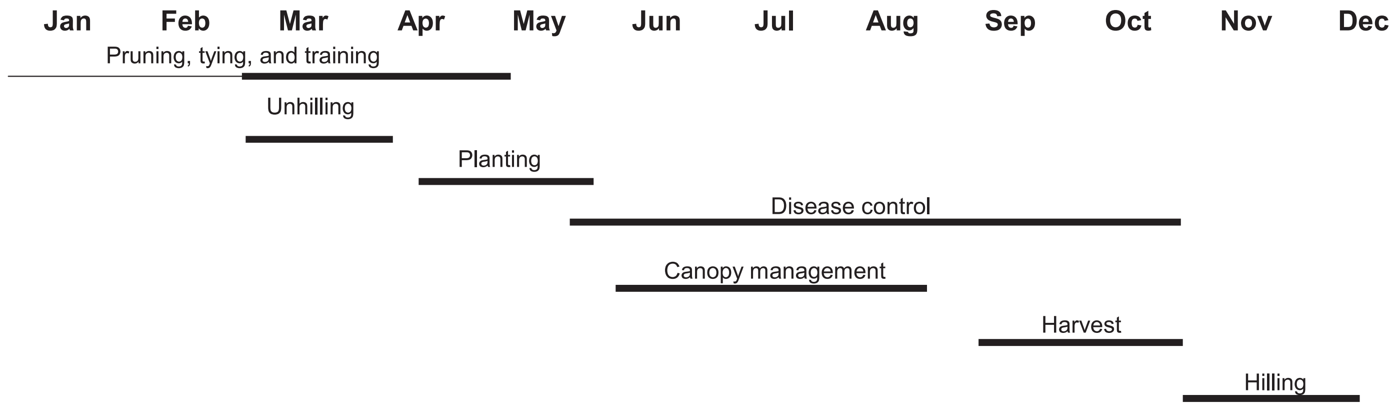

Figure 4. Overview of vineyard activities through the year.

PRUNING AND DORMANT TRAINING

Proper pruning is critical to establishing and maintaining an easily managed vineyard that consistently produces high quality fruit. Improperly pruned vines can result in a variety of negative outcomes that reduce yields, fruit quality, and long term vine health. Although grapevines are quite forgiving of mistakes that inevitably occur, improper pruning can have long-term negative effects on the vineyard. Pruning is not done just for the coming growing season, but for subsequent years as well.

The two main reasons for pruning are to control the amount of fruit that a vine will produce, and to establish and maintain a permanent vine structure. Grapes fruit on one-year-old wood, i.e., the wood that was produced during the previous growing season. Each mature node on a dormant grapevine is, in theory, capable of growing a shoot. Each new shoot will produce, on average, 12-16 leaves and two clusters of fruit. After the green shoots have turned woody at the end of the growing season, there will be a node at each leaf position to grow shoots for the following season. It is easy to see how, if left unpruned, one would eventually have grapevines with hundreds of shoots, and dense, hard to manage canopies producing excessive amounts of poor quality fruit throughout the canopy. Therefore, annual pruning is essential for most vineyards to thrive. Unpruned vines can be managed in some instances, but those circumstances rarely if ever occur in Connecticut.

The one-year-old wood is readily distinguished from older wood. One-year-old wood is a healthy brown color and is smooth. Older wood is darker and has crinkly or shedding bark. The few shoots that are produced on older wood are rarely fruitful. Clusters are generally produced opposite the third and fourth leaves from the base of the shoot. By proper pruning, the fruit will be located in the same general area of the grapevines, making vineyard activities easier and more efficient.

Regardless of the training system, grapevines are usually pruned in one of two ways: cane pruning or cordon pruning. Cane pruned vines are pruned to long canes of one-year-old wood, which are tied or clipped to the trellis wires. These canes originate from the perennial trunks just below the fruiting wire(s), and should extend halfway to the adjacent plants, so the ends of the canes touch. Cordon pruned vines have perennial arms (the cordons) that extend from plant to plant, and the one-year-old wood arises from various points along the cordon.

There are advantages and disadvantages to both systems, and many variables that enter into the decision of which system to choose. Cane pruning is easier to establish, fewer cuts are made, and the shoots are almost always regularly distributed along the trellis. Disadvantages include that, once established, it requires slightly more skilled work than cordon pruning, and canes need to be tied or clipped to the wire each year. The ties or clips also need to be removed each year prior to pruning. On less vigorous varieties, it may be difficult to find canes long enough to reach halfway to the next vine, especially with wider in-row spacings.

Cordon pruning begins as cane pruning during the establishment (usually third) year, with the canes wrapped around the wire and tied. In subsequent years, new wood is pruned back to short sections, typically two or three nodes. These are called spurs. Cordon pruning is more difficult to establish and requires more cuts than cane pruning; however, once established, pruning goes quite quickly, and does not require the same degree of skill as cane pruning. There is also some evidence that more perennial wood on a grapevine results in greater yield. In cases of severe cold damage when cordons are lost, it takes longer to reestablish the structure than with cane pruning. It is easy to change from a cane to a cordon system. Changing from a cordon to a cane system can also be done, but is more difficult.

Another factor to be considered when choosing between cane and cordon systems is the variability in fruitfulness along a cane. Regardless of whether they are on canes or cordons, the idea is to have fruitful shoots evenly distributed along the fruiting wire. Fruitfulness is largely determined by the condition of the growing shoot in the previous season; the potential for fruit production in the subsequent year is already established by late summer. There are several factors that are involved in cluster primordia development, but sunlight in the immediate area is the most important. Therefore, nodes whose leaves were shaded tend to be less fruitful than those whose leaves were in full sun. Varieties sometimes vary regarding position of bud fruitfulness. Especially in vinifera varieties, buds within about a thumb's width of the base are not fruitful, and are not counted as a node when pruning. Basal buds of many hybrid varieties can be quite fruitful. Some varieties, when cane pruned, have their most fruitful shoots near the base and near the end (≈nodes 10 and above), with weaker, less fruitful shoots in between. Knowledge and experience with an individual variety can help determine which system will result in the greatest uniformity of fruitful shoots.

Figure 5. Unpruned vine in the third year after planting.

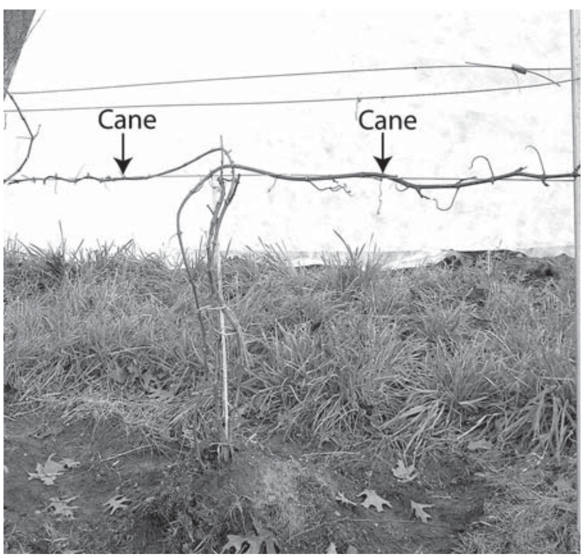

Figure 6. Cane pruned vinifera vine on a VSP system. Note that the vine is still hilled up; renewals from the base will be selected later.

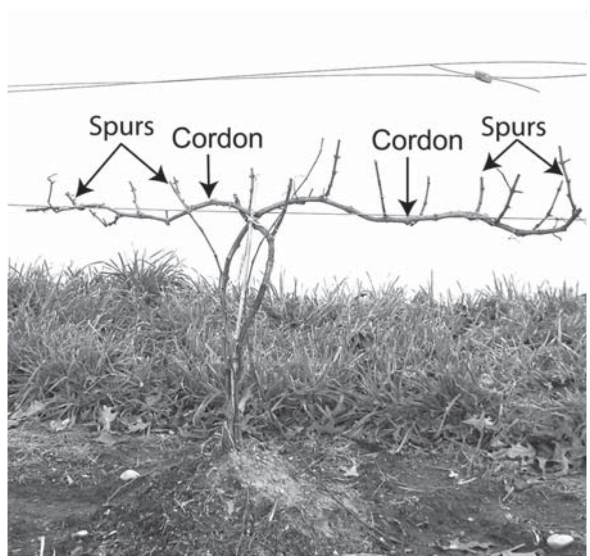

Figure 7. Spur pruned cordon vine on a VSP system.

In addition to the fruiting shoots arising from canes or cordons, short two or three bud spurs, called renewal spurs, should be left on the vines. Renewal spurs that are four to six inches below the fruiting wire will provide the canes for the following season for cane pruning systems. Leave at least one for each side of the vine. It is a good idea to leave at least one renewal spur on a cordon pruned vine also, in case of damage of death of a cordon. One renewal spur should also be left at the base of the vine just above the graft union (for grafted vines). The shoots produced will provide insurance in case of the sickness, damage, or death of one of the trunks. They can be removed later if not needed. If it is long enough, tie it to the canopy or trunk. Remove all other new growth from the bottom, cutting flush with the trunk. If using systemic contact herbicides during the growing season, be careful to avoid contact with any green tissue near the ground that may be hard to see. Any growth between the basal and apical renewal regions should be removed.

When pruning for crop control, one decision to be made is how many nodes should be left. One alternative is to leave more nodes than ultimately desired, and either prune back canes or remove individual shoots (the weaker and nonfruitful ones) after growth has begun. Another alternative is to simply prune to two to four canes or cut all spurs back to two or three nodes. This does not account for vine to vine variability in vigor, however. Since the goal is to make grapevines perform as similar to each other as possible, some growers practice a form of what it referred to as “balanced pruning” to help achieve uniformity in the vineyard.

There is a relationship between the amount of crop that a grapevine is able to carry to maturity and the vegetative performance of the vine (Ravaz 1911). This vegetativeness can be estimated by the amount of new wood the vine produced the previous season. This can be done visually, but it is best to actually measure a few vines. The procedure is simple. First, prune the grapevine back to four canes and four renewal spurs (for cane pruning) or prune all canes back to two or three bud spurs (for cordon pruning). Collect the wood from each vine and weigh it. Then, adjust bud number accordingly. Good, healthy vines of most varieties have an optimum weight of around three pounds. Much less than that, and the vine is relatively weak, while more than about four pounds indicates excessive vigor. Smaller vines should be pruned back more heavily, as they cannot carry as much crop.

To determine how many buds to leave, there are several formulas that can be used as a guideline, and experience will determine what will work best with individual varieties on your site. For vinifera varieties, a 30+10 formula might work. This means leaving 30 buds for the first pound of cane prunings, and 10 for each additional pound. So, if prunings weighed a pound or less, leave 30 nodes; if two and a half pounds, 25 nodes; if four pounds, 60 nodes, and so on. For many American varieties, a 30+30 formula is recommended. Several formulas are recommended for various hybrids, as varieties vary considerably in vigor. Formulas such as 20+10 are appropriate for low vigor varieties, while 30+10, 20+20, or 50+10 are suitable for high vigor varieties. In practice, most growers do not weigh each vine nor count each node; they prune by visual estimates. It is good practice to occasionally weigh a few vines, however, to make sure that you are still close.

Many growers will deliberately leave excessive nodes on the vine after a very cold winter, with the assumption that some of the buds were killed. This is a very good strategy, especially when combined with an assessment of bud damage. This is done by cutting a shoot from at least 10 vines per variety and location within the vineyard, and cutting through the nodes with a razor blade and checking for brown, dead buds. Record the percentage of dead buds and prune accordingly.

Canes and cordons should be tied or clipped to the fruiting wire prior to the commencement of growth in late spring to avoid breaking off tender new shoots. Growers use a variety of materials, including jute twine, twist ties, various varieties of clips, mechanical vineyard tape dispensers, and other types of fasteners. It is important that the attachments be secure enough so that during a gust of wind during the growing season, when the canopy is full of leaves and the vines are full of fruit, the canes or cordons will remain on the wire. It is also important not to tie too tightly (except beyond the last node) to avoid girdling the wood, which will expand throughout the season. A girdle will ultimately kill everything beyond the tie.

FERTILIZATION

Fertilizer, if needed, should be applied shortly after growth begins in spring or just prior to bloom. While soil tests are helpful, the most accurate assessment of plant nutrient status can be obtained using petiole analysis. Ideally, petioles should be collected just prior to veraison. However, many growers prefer to sample at bloom so nitrogen deficiencies can be addressed during the current growing season. Later sampling is more accurate for most other plant nutrients.

CANOPY MANAGEMENT

For optimum productivity and fruit quality, a variety of canopy management practices can be implemented during the growing season. Some growers use all of these techniques, others only some, and a few none at all. The main goals of canopy management are to maximize sunlight interception, promote air circulation to leaves and fruit, and ensure an adequate crop of good quality fruit. Regardless of training system, the canopy should not be much more than 1.5 leaf layers thick. Denser canopies result in shaded leaves that are a drain on the net photosynthesis of the vine.

Shoot thinning helps to establish regularly spaced, fruitful shoots on the vine. It is most easily done prior to bloom, but after the inflorescences are readily apparent. At this stage of development, the shoots break off easily. Shoots should be thinned to four to five shoots per linear foot of row. Ideally, each shoot left on the plant will have two flower clusters. Shoots that are not fruitful or are growing in an undesirable direction should be removed.

Removing leaves in the fruit zone helps improve air circulation around the fruit, reducing fruit rots, and exposes the fruit to sunlight, which improves quality (especially in red varieties). If leaf removal is practiced, it should not be done until after fruit set. Doing so earlier will likely decrease fruit set, which may not be undesirable, but will also greatly reduce the fruitfulness of the buds for the following season. Leaf removal should be completed prior to veraison. In exceptionally hot seasons, waiting too long for leaf removal can predispose the fruit to sunscald. It is not necessary, and in fact undesirable, to remove all leaves in the fruit zone; usually one or two is sufficient. Exposing the fruit to about 50% of the available sunlight is enough to realize the benefits of this practice. Leaf removal is very easily done with a VSP system. In some cases, especially in hot climates, the leaves are only removed on the eastern side of the canopy. Most Connecticut growers remove leaves from both sides.

Shoot positioning involves training the shoots to the desired direction, usually up in a VSP system and down in a HRU system. Many grape shoots tend to grow laterally, creating competition for sunlight in the canopy. Shoot positioning is most easily done before the shoots become too entangled, beginning around or shortly after bloom if training the shoots up, and slightly later if training them down.

Figure 8. Shoots trained upward on a VSP system. Note the leaves on the ground; leaves were pulled in the fruit zone.

Figure 9. Shoots trained downward in a HRU system.

In spite of proper pruning and shoot thinning, some grapevines will still set an excess of fruit. This is particularly true of some hybrid varieties, which generally require some fruit thinning every year. Vines that bear too much fruit will ripen later and will never achieve the desired sugar levels to make quality wine or juice. Cluster thinning also results in larger, more attractive clusters for table grapes. Excess fruit stresses the vines, weakening them over time and making them susceptible to winter injury.

It is difficult to give precise figures regarding how much fruit to leave on the vine. Some varieties always yield more than others, and such factors as fruit set, soil depth, rootstock, water availability, nutrient status, and seasonal variability all contribute to how much crop the vine can carry to maturity. While there are guides for estimating crop levels during the growing season, and average yields per acre are available, they are only general guides. A grower's own experience in the vineyard is needed to make accurate assessments. If fruit rarely ripens properly and cane pruning weights consistently decline, then the vines are probably overcropped, and some fruit thinning is necessary. Clusters can be removed anytime between shortly after fruit set and veraison. Basal clusters (those closest to the shoot base) form slightly earlier than other clusters on the shoot. By selectively leaving basal clusters, the fruit is usually slightly more mature at harvest.

Another type of cluster thinning is frequently done shortly after veraison, and involves removing the "green fruit", clusters that formed later in the season, usually on lateral shoots. These clusters will never ripen under Connecticut conditions and, if left on, will unduly stress the vine. Removing them will keep them from accidentally being harvested and mixed with the ripe fruit.

Grape shoots grow very rapidly in early- to midsummer. By the time shoot growth slows down or stops in late summer, shoots may spill out the top of a VSP system. These shoots can shade the older leaves in the canopy, so many growers prune or hedge the shoot tops after they have grown a foot or so higher than the trellis top. If this needs to be done repeatedly during the growing season, it is indicative that the vines are overly vigorous. Some shoots produce smaller, lateral shoots during the season that may stick out of the canopy. These can also be removed by pruning or hedging. Summer pruning is not as beneficial on downward growing shoots such as those on a HRU system. However, if the shoots begin to trail along the ground and get in the way of other vineyard activities, they can also be hedged.

WEED CONTROL

Weeds compete with grapevines for water and soil nutrients, and the same weed control program used during vineyard establishment can be utilized in established vineyards. Rainfall during the growing season in Connecticut is unpredictable. In excessively wet seasons, some weed competition will do no harm to the vines (and might even be beneficial), while competition can be detrimental during extended dry periods. It is easiest to follow a standard weed control routine, but it is not as critical to control all weeds in a mature vineyard as it is in a recently planted one.

PEST MANAGEMENT

Grapevines are subject to attack by a variety of insect, disease, and wildlife pests. Losses resulting from pest damage can range from slight foliar or fruit damage to the total loss of a crop or even eventual plant death. It is important to learn to recognize symptoms for each pest and, if necessary, take action to prevent damage to the vineyard. The section Insect and Disease Pests describes those most common to Connecticut. There are also several excellent print and online publications that describe the various pests and their damage symptoms, and growers should become familiar with potential problems. Conditions in the eastern United States are quite different than those of many of the arid areas where grapes are traditionally grown (much of Europe and California), so it is best to consult resources that are applicable to our region.

Fungal diseases are usually the most persistent pests in Connecticut vineyards, and a diligent management program is crucial to having a successful vineyard. It is important to keep in mind that most of the structures of the fungi that cause disease are microscopic, so by the time symptoms appear, the organism will already have become established in the vineyard. Early disease control will help to prevent widespread problems later in the season. Cultural practices can help control the incidence and severity of many diseases, but some sort of fungicide program is usually required.

Most disease-causing fungi have two different types of reproductive structures. During the growing season, most disease spread is caused by asexual propagules that are produced in extremely high numbers. During fall and early winter, the fungi usually form larger reproductive structures that can survive the winter; these are sometimes large enough to be seen with the naked eye. When conditions are right in spring, sexual spores are released, and the potential for a disease outbreak exists. The exact conditions for spore release and infection vary among disease organisms, but generally a combination of warm temperatures and adequate moisture for a period of time is required. Therefore, any cultural practice that minimizes moisture by fog avoidance or by improving air circulation will be useful in disease control. Also, removal of diseased material from the vineyard will reduce the chance of future outbreaks.

Fungicide applications typically begin just after the shoots have emerged in spring. The timing of applications is based on the stage of development of the grapevine and the prevailing weather patterns. More frequent applications are needed if wet, humid conditions occur. The most important times for spray applications are just before and just after bloom. If diseases have been properly controlled early in the season, there should be little disease pressure from mid-July until veraison, when fruit rot organisms can be a concern.

It is essential to achieve thorough coverage when applying spray materials. A hand-held or backpack sprayer can suffice for growers with just a few vines, but growers who own larger farms should invest in a quality sprayer large enough to treat their vineyard in one day or less. There are a variety of models on the market, including some designed exclusively for vineyards. This is an area where economy can be costly. Always be sure to use and follow label instructions and dispose of containers properly.

Bacterial and viral diseases are present in many, if not most, vineyards, and cannot be eliminated from infected plants. Crown gall is one of the most prevalent and damaging diseases in Connecticut vineyards. The causal organism is present in much plant material, but generally does not cause disease unless woody tissue is damaged. This is most often caused by wood splitting following a very cold winter, but can also occur when vines are wounded by vineyard workers or chewing animals such as rodents. Planting of cold hardy varieties and care during vineyard operations will help to reduce the disease. Viruses are also present in much plant material, and cannot be eliminated. Removal of infected vines may prevent the virus from spreading.

A variety of insects can cause damage to foliage and/or fruit at various times throughout the growing season. The vineyard should be scouted regularly for insect pests, and controlled if present in large enough quantities to cause economic damage. Some vineyards are regularly infested by insect pests, while some successful growers rarely if ever have to take control measures.

There are several products for insect and disease control that are approved for organic farming. Some of the materials with fungicidal properties are only effective on certain diseases, however, and care should be taken to ensure the proper product is used. Black rot and Phomopsis are difficult to control using organic products.

Many types of wildlife feed on leaves and fruit. Birds can completely devour a crop in several days or less. Growers should be vigilant as soon as veraison begins. A variety of scare tactics can be used, including various noisemakers and visual deterrents. None are entirely effective, and most birds eventually overcome their aversion to these control methods. Netting is expensive and time consuming to apply and remove, but is the only consistently effective method of damage control.

Deer can also be a major problem in vineyards. They eat both leaves and fruit, and can destroy a young vineyard almost overnight. It is important to control deer well before major damage occurs, or they will be very difficult to discourage. Fencing is the most effective method of exclusion. Both electric and nonelectric fencing have been used effectively, but they must be at least eight feet high to be effective. Other methods of deer control include scare devices, dogs, odor- and taste-based repellents, and, in some instances, regulated shooting.

HARVEST

The decision of when to harvest is a very individual one. Unless you are selling to a processor, deciding on when to harvest can be based on a number of factors. As fruit matures, sugar increases and acids decrease. This sugar-acid ratio is the most important perceptual aspect of grape flavor. Grapes grown in cool climates such as Connecticut never achieve the high sugar levels found in warm climates such as much of California and Australia. The relatively high acid levels present in cool climate grapes lend them a distinctive character compared to the warm climate grapes that dominate the market.

Table grapes are harvested when the desired flavors are reached. Although the same can be said for juice and wine grapes, there are some general rules based on measurable factors. The most traditional method of measuring the ripeness of grapes is by measuring sugar concentration. This is still the major factor that most buyers of wine and juice grapes use for determine acceptability. It is measured in °Brix with a refractometer. Wine grapes at 22 °Brix fermented to dryness will produce a wine of 12% alcohol, the traditional optimum for flavor and stability in table wines. Current trends are toward more mature fruit which produces higher alcohol wines. It is not unusual for cool climate grapes to have less than 22 °Brix even at maximum maturity, especially in poor years. Some hybrid wine grape varieties develop undesirable flavors at sugar levels well below 22 °Brix, so sugar is traditionally added before fermentation. Some growers believe that acid levels are more important that sugar, and base harvest decisions on acidity. Other growers feel that other flavor components, some measurable and some not, are of primary importance. Ultimately, experience is the most important factor in making maturity assessments.

Most juice grapes rarely, if ever, attain such high levels of sugar. Niagara, the most common white juice grape, is usually harvested at about 13-15 °Brix. Concord, the main purple juice grape, is usually harvested at 15-17 °Brix.

Regardless of the criteria on which harvest decisions are based, one cannot make an accurate assessment of fruit quality by sampling individual grapes. Individual berries vary, sometimes greatly, between different vines, clusters within a vine, and within individual clusters. In order to get some degree of accuracy, a representative sample must be collected from each harvest area. The easiest approach is to collect 10-20 clusters, crush them, and evaluate the juice. Another method is to collect 100 berries to crush and evaluate. The most critical factor is to collect the samples as randomly as possible from the entire section of vines. There is a natural tendency to pick berries or clusters which are most visible or look the nicest, but this is not representative of what is going on in the vineyard. Clusters should be harvested from a variety of positions both within the plot and within the vine. The same practice should be followed for individual berries. In addition, they should also be harvested at different positions within the cluster and within different orientations in relation to the outside of the canopy.

Different varieties will ripen at different times, and sometimes the same variety grown in different parts of the same property will also mature at different rates. As experience in the vineyard accumulates, the grower will become aware of the individual characteristics of different mesoclimates within the vineyard.

Other factors besides fruit maturity can be deciding factors on when to harvest. If the vineyard is large, availability of help can be important. If the grapes are almost ready and heavy or extended rain is predicted, it might be better to harvest immediately. Fruit rots can spread very fast throughout the vineyard, so optimum maturity may have to be balanced with the possibility of crop loss or an increase in undesirable flavors caused by disease. If a killing frost occurs, the grapes will not ripen further and should be harvested as soon as possible. Sometimes wineries and juice processors are operating at maximum capacity and cannot accept any more fruit for a time.

Once fruit for wine and juice is harvested, it should be processed as soon as possible and kept as cool as possible until processing. Some large vineyards in California whose grapes are mechanically harvested will harvest at night so the cool fruit will be at the winery early in the morning.

INSECT AND DISEASE PESTS

There are a great number of insects and diseases that can attack grapevines; however, it is rare for all of the possible pests to occur in an individual vineyard. Because treatments and pesticide labels frequently change, please consult our Plant Pest Handbook at hhtp://www.ct.gov/caes/PlantPestHandbook for updated information.

INSECTS

Japanese beetles (*Popillia japonica*) are the most visible pest of grape foliage. They overwinter as larvae in the soil, and typically emerge in early summer. They can extensively damage young vines in a very short period of time, especially if grow tubes are used. Mature, healthy vines can withstand a certain degree of defoliation. The beetles are relatively easy to control if they become present in sufficient numbers to cause significant damage.

The grape berry moth (*Endopiza vitana*) can cause significant fruit damage in vineyards. Adult moths do no direct damage. However, newly hatched larvae feed on blossoms and small berries, and can destroy entire clusters. Their feeding also makes ripening fruit more susceptible to fruit rot organisms such as Botrytis. The grape berry moth overwinters as pupae, and adults emerge in late May. There are usually two, sometimes three generations per year.

Areas of the vineyard which border woodland areas containing wild grape species are most susceptible to the grape berry moth. Adequate control may require controlling the pest only in those areas that border the vineyard. Pheromone traps can be used to monitor the vineyard for adults. There are also pheromone-based products that control the insect by mating disruption. However, a rather large vineyard area (about 10 acres or more) is necessary for maximum effectiveness.

Leafhoppers (principally *Empoasca fabae* and *Erythroneura* spp.) feed on grape foliage, although their damage is not as readily apparent as that caused by Japanese beetles. A few leafhoppers are unlikely to cause significant damage, but population increases can be rapid, especially in hot, dry weather. Scouting should begin in early summer, and the insects controlled if their population becomes too high. Sometimes Japanese beetles and the grape berry moth are effectively controlled at the same time. Leafhoppers overwinter in leaves and litter on the vineyard floor.

Mites (principally *Colomerus vitis*, *Panonychus ulmi*, and *Tetranychus urticae*) that feed on grape foliage are small, eight-legged arthropods that cause damage by extracting plant juices, causing a bronzing coloration of the leaves. They are usually found on the underside of leaves, and a hand lens may be necessary to see them. Four to nine generations can occur within a season. Vineyard monitoring should begin near bud break, and continue during the period of rapid shoot growth. If mites get out on the shoot tips, they can stunt shoot development. Severe outbreaks of mites are uncommon in Connecticut, but there have been severe infestations on Long Island. Good biological control can sometimes be achieved if sufficient populations of predatory mites are present in the vineyard.

The grape cane borer (*Amphicerus bicaudatus*) is a small brown beetle that bores into canes about September, potentially causing the canes to die back. It rarely causes widespread damage to an entire vineyard, but the small (1/8 inch diameter) entrance holes should be monitored for, and appropriate control used if necessary.

Climbing cutworms (*Noctuidae* spp.) are a group of related moth species whose larvae feed on grape buds in early spring, resulting in reduced shoot development or shoot destruction. They feed at night, spending the day in soil or debris. During the daytime, scouting should be done around the base of the vines, or they can be scouted for at night with a flashlight. Spraying, if warranted, is most effective if applied in early evening when feeding begins.

Bees and wasps can feed on ripe grapes, usually through entrance wounds caused by birds, other insects, and berry splitting. Like birds, they cause great damage in some seasons and little or no damage in others. Insecticides with little or no preharvest interval restrictions may be used, and care should be taken in the vineyard, especially by those allergic to wasp and bee stings.

Grape phylloxera (*Daktulosphaira vitifoliae*) are tiny, aphid-like insects that feed on grape roots and leaves. All vinifera and some hybrid varieties are very susceptible to phylloxera damage, which can cause plant weakening and death, so these varieties are always grafted onto resistant rootstock. The leaf gall form lives inside plant-produced galls on the underside of leaves, causing deformation. Some hybrid varieties are particularly susceptible to the leaf form, although galling is generally not extensive enough to warrant control. Six or more generations may emerge each year. The root form of phylloxera is sometimes considered a disease, as the symptoms are more consistent with diseases than most insect damage.

The grape root borer (*Vitacea polistiformis*), the banded grape bug (*Taedia scrupeus*), the grape plume moth (*Pterophorus periscelidactylus*), and the rose chafer (*Macrodactylus subspinosus*) are occasional pests of grapevines, but rarely cause significant damage in Connecticut vineyards.

FUNGAL DISEASES

The warm, humid summers in Connecticut predispose grapevines to a variety of fungal diseases. The five most common are downy mildew, powdery mildew, black rot, Phomopsis, and Botrytis. The first four can be a problem throughout the growing season, so control of one disease is frequently intertwined with control of others. These are diseases that almost every grape grower will likely encounter. Other diseases such as angular leaf scorch, anthracnose, bitter rot, and ripe rot are not widespread or are only occasionally encountered. Disease management strategies should focus on preventing the onset of disease from overwintering spores (called “primary inoculum”). In all cases, control is facilitated by removing as much infected plant material from the vineyard as possible. Cultivating diseased plant material into the soil can also provide some level of control if debris removal is not practical.

Downy mildew is caused by *Plasmopora viticola*, a fungus-like organism. Berries, leaves, and young shoots can be infected. Young fruit can become completely covered in whitish, cottony growth. When more mature fruits are infected, they may fail to ripen properly. White, cottony patches of the downy mildew pathogen are visible on the lower surfaces of infected leaves. Heavily infected leaves brown, shrivel, and drop. Downy mildew can also cause premature defoliation in fall, predisposing infected grapevines to winter injury. *P. viticola* overwinters as dormant oospores, mostly on fallen grapevine leaves on the vineyard floor. Primary infections are initiated from this inoculum. These spores are released in the spring during rainy periods when the temperature is above 52 °F, generally about two to three weeks before bloom. Splashing is the main mode of spore movement at this time. After primary infection has occurred, secondary spores (sporangia) are released on humid nights, so areas prone to fog are especially vulnerable. These secondary spores can be blown relatively long distances and can come from other vineyards. Management should begin as soon as temperature and moisture conditions promoting primary inoculum release exist. Under favorable conditions for growth, control may be needed throughout the growing season.

Powdery mildew, caused by the fungus *Erysiphe necator*, can develop on all green grapevine tissues. Mature tissues are generally resistant to infection, but continuous production of new leaves makes the plant susceptible throughout the season. Infected berries fail to grow; leaves become necrotic and, as with downy mildew, may abscise prematurely. Primary inoculum is produced in tiny black structures (cleistothecia) on bark, and is released during rains of about 0.1 inches or more when temperatures are above 50 °F. These spores are wind dispersed. Once infection is apparent, the characteristic grayish white powdery growth for which this disease is named appears on the young fruit and leaves. This powdery substance actually consists of thousands of spores (conidia), which are the secondary inoculum. These are also dispersed by wind, and do not require rainfall for secondary infections to occur. These secondary, repeating cycles of infection can continue throughout the season as long as temperatures are favorable and susceptible tissues are present, and are responsible for epidemic outbreaks within a vineyard. The timing of control measures for powdery mildew is similar to that for downy mildew, although materials effective on one may not be effective on the other. Unlike most other disease organisms, only the epidermal cells are penetrated by the fungus, so some spray materials, including some organic ones, can be effective in controlling this disease.

Black rot, caused by the fungus *Guignardia bidwellii*, is one of the most serious grape diseases in Connecticut. The pathogen can infect all young green grapevine tissues and can result in substantial crop loss. New growth is susceptible to infection and leaves and shoots can be stunted. Lesions on leaves are small, brown, roundish spots that eventually develop small, black spots that are the source of the secondary inoculum. Infected fruit rapidly begin to dry, shrivel, and wrinkle, and become hard, blackish mummies in midsummer. Entire clusters are frequently affected. Mummified fruit that overwinter in the vineyard serve as the source of primary inoculum. The spores require several hours of leaf wetness for infection and temperatures above 50 °F, with the shortest period required between 60 and 85 °F. This infection period also overlaps with those of the previous two diseases, so the timing of control measures can often be combined. Spores of the black rot fungus, especially the primary inoculum, do not travel as far as those of some other fungi, so some vineyards are relatively free of the disease. It is a recurring problem where it has become established.

Phomopsis cane and leaf spot is caused by the fungus *Phomopsis viticola*. Infection can develop on leaves, young shoots, petioles, and rachises. The growth of all of these tissues can be stunted, but most damage occurs when rachises are infected. The pathogen may spread to the fruit through the stem, causing berries to shrivel in a manner similar to black rot, although symptoms appear later in the season. Fruit infections first appear as small brown spots that rapidly expand. Infected rachises turn black and brittle, which can result in breakage of the cluster and loss of fruit. The fungus overwinters on canes and rachises; cane lesions are recognized by their rough, scabby appearance. Dead canes and pruning stubs are especially likely to harbor the fungus, and should be removed during pruning. The fungus overwinters as mycelium and pycnidia (spore-bearing structures) in the bark of infected canes, and almost all infections originate from two types of asexual conidia. Infection begins early in the season during periods of rainfall or very high humidity and temperatures above about 50 °F. Control from early in the season to postbloom is usually sufficient. Since most spores are distributed through free water, the disease is frequently confined to certain areas of the vineyard, making it relatively easy to control.

Ripening grapes are susceptible to a variety of fruit rots. Botrytis bunch rot, caused by the fungus *Botrytis cinerea*, is the most common rot of grapes throughout the world. Under ideal conditions, it is responsible for producing some of the world's greatest sweet wines. However, under most conditions, it seriously reduces yield and quality. Botrytis infects a wide variety of host plant material, so inoculum (conidia) is almost always present in a vineyard throughout the season. In addition to fruit, the fungus can also infect blossoms, leaves, and shoots, although these infections rarely cause significant damage. The fungus is usually present in clusters throughout most of the season, but the disease symptoms do not occur until the fruit begins to ripen. High humidity favors fungal growth, so promoting air circulation in the canopy and within clusters will help in controlling the disease. Tight-clustered varieties and clones are particularly susceptible, as humidity is trapped within, creating a warm, humid environment protected from spray coverage. Control on these susceptible varieties should begin before the clusters close, and continue from veraison through harvest. There has been some success with biological control of Botrytis, but results have been inconsistent.

Eutypa dieback, caused by the fungus *Eutypa lata*, is also known as "dead arm" or "dying arm". Disease progression is slow, but infected vines eventually weaken and die. Symptoms of eutypa are rarely seen in vines less than eight to ten years old. As Connecticut vineyards mature, there is a possibility that this disease could become more widespread. Spores are released in late winter and early spring during periods of melting snow or rainfall, and typically infect fresh wounds on two-year-old and older wood. Early in the spring, leaves are light green and cup downward; later in the season, symptoms are not apparent. Cross sections of perennial wood usually reveal a characteristic dark wedge of infected tissue. This disease can often be effectively managed by pruning infected arms in late spring.

BACTERIAL DISEASE

Crown gall of grape (*Agrobacterium vitis*) can kill individual trunks or entire vines. Losses following severe cold events may be severe enough to require replanting an entire vineyard or vineyard area. Although the bacterium is present in the majority of grapevines, symptoms usually only develop after an injury. Infections are recognized as large, fleshy galls. These galls are generally on the lower trunk near the soil line or at the graft union, although they can be produced anywhere on the trunk. The galls are masses of disorganized phloem tissue produced by the vine that disrupt nutrient flow. Vines can be girdled in as little as one season. The galls begin as white, fleshy growth in early summer, later turning brown and becoming hard and woody later in the season. During periods of high humidity, aerial roots may appear on young canes or shoots in response to the disruption of the vascular system. The extent of gall expression is determined by the cultivar and the extent of the injury. All vinifera and many hybrid varieties are susceptible to gall damage; however, the disease is not as prevalent on most hybrids due to their greater degree of cold hardiness. There is some research indicating that avirulent strains of *A. vitis* show promise as a biological control, which may help to reduce crown gall problems in the future.

VIRUS DISEASES

Virus and virus-like agents cause several diseases of grapevines. Symptoms can be minor and confined to a few vines, or major and widespread. Viruses can be spread by using infected nursery stock, by arthropod vectors, and by nematodes. The importance of virus-free nursery stock has long been recognized, and most nurseries use certified virus-free material whenever possible. Growers should try to obtain such material if it is available.

Fanleaf degeneration is caused by the grapevine fanleaf virus. Infected leaves are chlorotic and have widely open petiolar sinuses (the gap on either side of the petiole) and abnormal vein distribution, giving the leaf a fan-like appearance. Grapevine cultivars vary in their sensitivity to the virus in both the degree and type of symptoms expressed. Leaf function and fruit set are reduced in all cases. The virus is transmitted by longidorid nematodes, which feed on roots. Since the nematodes do not move rapidly in the soil, widespread outbreaks only occur when contaminated propagation material is used. Infected plants should be removed to avoid spreading the virus to neighboring vines. The nematode vectors cannot be successfully controlled in established vineyards.

Tomato ringspot virus decline and tobacco ringspot virus decline, caused by viruses of the same name, produce identical symptoms in grapevines. Symptoms, which generally appear in the second year of infection, are reduced fruit set, small and distorted leaves, shortened internodes, and stunted plants. Other symptoms may or may not be present. Yield is drastically reduced in susceptible varieties. Generally, the viruses affect only certain vinifera and hybrid varieties. The viruses have a broad range of hosts, including stone tree fruit, small fruit, and many weeds and their seeds, so they are fairly common in soils. The viruses are spread by contaminated plant material (both grape and non-grape), and by dagger nematodes. Several rootstocks are resistant to these viruses, and are used in areas with a history of the diseases. When planting a new vineyard, thoroughly preparing the land and keeping it weed free for at least one year can help reduce populations of these viruses.

Leafroll can be caused by any of at least seven different closteroviruses, each of which can cause slightly different symptoms (Gonsalves 2000). All plant parts are smaller on infected vines than on noninfected ones. Foliage usually appears normal early in the season, but gradually turns yellowish or reddish, depending on the anthocyanin pigments present. Late in the season, the leaves roll downward and the foliage is bright yellow or red. While the disease weakens the plant, frequently the most negative aspect of it is that it significantly delays ripening. Vines are rarely killed by leafroll. Since the causal agents have only recently been identified, it is not known if all forms of the virus are transmitted the same way. Mealybugs and soft scale insects have been shown to transmit leafroll in California. It is assumed that the disease is most commonly spread through propagation of infected plant material.

RESOURCES

GENERAL VITICULTURE

Jackson, Ron S. 2000. Wine Science: Principles, Practice, Perception. Academic Press. Probably the most comprehensive text on viticulture for wine grapes available today.

Smart, Richard and Mike Robinson. 1991. Sunlight into wine: A handbook for winegrape canopy management. Winetitles, Adelade, South Austrailia. This book describes the principles of canopy management, and includes details on several alternative training systems.

Wolf, Tony and Poling Barclay. 1995. The Mid-Atlantic winegrape grower's guide. North Carolina State University Press, Raleigh, NC. This is a comprehensive guide to Eastern viticulture, although oriented toward warmer climates than ours. It is available on line at http://www.ces.ncsu.edu/resources/winegrape/, and will be extensively updated in 2007.

GRAPE VARIETIES

Cornell University's list of wine and table grape varieties also includes table grapes. http://www.nysaes.cornell.edu/hort/faculty/reisch/bulletin/wine/index2.html

Information on very cold-hardy varieties from the University of Minnesota. http://fruit.coafes.umn.edu/grape/varieties.htm

COSTS OF GROWING GRAPES

Cost of establishment and production of V. vinifera grapes in the Finger Lakes- 2004. Cornell University Cooperative Extension, also can be downloaded at http://hortmgt.aem.cornell.edu/pdf/resources/eb2005-06.pdf

Winery and Vineyard Feasibility Workbooks. http://www.agmrc.org/agmrc/commodity/fruits/wine/wineryfeasibility.htm. Iowa State University Extension has produced a series of customizable spreadsheets for estimating costs and cash flow in a vineyard.

SITE SELECTION

Wolf, Tony K. and John D. Boyer. 2003. Vineyard site selection. Virginia Tech Publication Number 463-020. http://www.ext.vt.edu/pubs/viticulture/463-020/463-020.html. This publication contains detailed criteria for site selection, although it is specifically tailored to Virginia conditions,

Cornell University Cooperative Extension provides information on site selection for cool and cold climates (http://www.nysaes.cornell.edu/hort/faculty/pool/NYSite-Soils/SiteSelection.html).

VINEYARD ESTABLISHMENT

Zabadal, Thomas, and Jeffery Andresen. 1999. Vineyard establishment 1- Preplant Decisions. Michigan State University Extension Fruit Bulletin 26449701.

Zabadal, Thomas. 1999. Vineyard Establishment II Planting and Early Care of Vineyards. Michigan State University Extension Fruit Bulletin 26459701.

Zabadal, Thomas. Engineering a modern vineyard trellis. http://grapes.msu.edu/pdf/cultural/engineerTrellis.pdf

PESTS

Isaacs, Rufus, Annemiek Schilder, Tom Zabadal, and Tim Weigle. A pocket guide for grape IPM scouting the North Central and Eastern U.S. Michigan State University Extension Bulletin E-2889. A portable field guide to assist in identification of pests and the symptoms they cause on grapevines.

Pearson, R.C. and A.C. Goheen. 1988. Compendium of Grape Diseases. APS Press, St. Paul, MN. This is the standard guide to grape diseases and disorders, and includes life cycles and photographs to assist in identification and control.

Wilcox, W.F., G. English-Loeb, R.M. Dunst, and A. Landers. 2006 (updated annually). New York and Pennsylvania pest management guidelines for grapes. Cornell University and Pennsylvania University Cooperative Extension.

This is the most current and most comprehensive guideline for pest control in the northeastern United States. A web based version can be accessed from http://ipmguidelines.org/grapes/; the exact URL changes each year.

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Frazier, N.W., J.P. Fulton, J.M. Thresh, R.H. Converse, E.H. Varney, and W.B. Hewitt (eds.) 1970. Virus Diseases of Small Fruits and Grapevines. University of California Division of Agricultural Sciences, Berkeley, California. pp. 247-250.

Gonsalves, D. 2000. Progress towards understanding the genomic organization and expression of grapevine closteroviruses. Proc. 13th International Committee on Study of Virus and Virus-like Diseases of Grapevine, Adelaide, Australia. p 6–7.

Ravaz, M.L. 1911. L'effeuellage de la vigne. Annales d L'Ecole Nationale d'agriculture de Montpellier. 11:216-244.

Smart, R., and M. Robinson. 1991. Sunlight into wine: A handbook for winegrape canopy management. Winetitles, Adelade, South Austrailia.

Wolf, T. and B. Poling. 1995. The Mid-Atlantic winegrape grower's guide. North Carolina State University Cooperative Extension. A new edition of this comprehensive guide is scheduled to be published in 2006.