Chapter 6

Pruning and Training

This chapter discusses the principles of grapevine dormant pruning, reviews reasons for vine training, and describes systems appropriate for use in Virginia and North Carolina.

Profitable grape production requires that grapevines be managed so that a large area of healthy leaves is exposed to sunlight. Such vines are likely to produce large crops of high-quality fruit each year. Grapevines must be trained and pruned annually to achieve this goal. The training system chosen generally dictates how the vines are pruned. Thus, pruning practices and training systems are discussed together in this chapter.

Dormant pruning is probably the single most important task you will perform routinely in the vineyard. The term *dormant pruning* refers to the annual removal of wood during the vine's dormant period. Grapevines are pruned primarily to regulate the crop but also to maintain a vine conformation consistent with the desired training system. As we will see, pruning has both a short- and long-term effect on crop quantity and quality.

Training positions the fruit-bearing wood and other vine parts on a trellis or other support. Except for renewal of damaged vine parts or system conversion, vine training is largely complete by the third year. Training should uniformly distribute the fruit-bearing units (nodes) in the vine's row space to facilitate perennial vine management, including pruning, and to promote high fruit yield and quality.

Definitions

Knowledge of the terms used to describe a grapevine is necessary to understand pruning and training concepts. The current season's crop is borne as one to several clusters on *shoots* that develop from dormant *buds* (Figures 6.1 and 6.2). Most buds are located at *nodes*, the conspicuous joints of shoots and canes (Figures 6.1, 6.2, and 6.3). Buds are also present at the bases of shoots and canes. Also, buds can remain latent at the

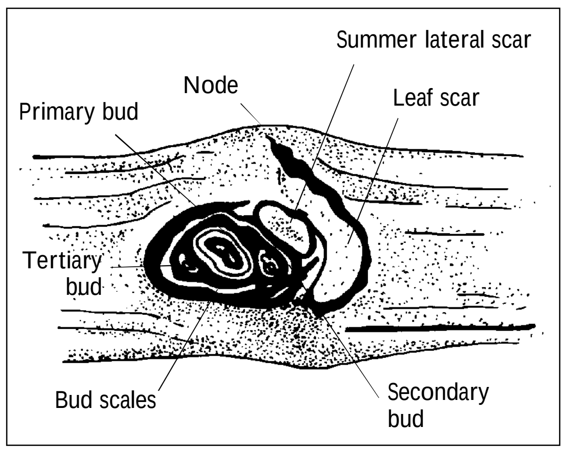
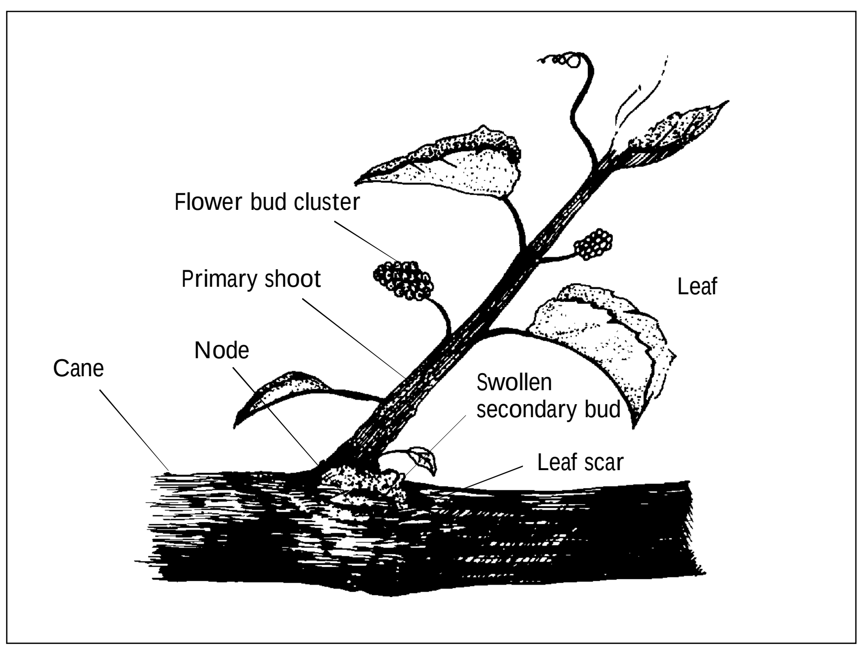


Figure 6.1 (left). Dormant bud and node of one-year-old cane. The compound bud has been cut cross-sectionally to reveal the arrangement of the bud's inner structures. Compare with Figure 6.2.

Figure 6.2 (below). Recently emerged primary shoot at node of one-year-old cane.



less conspicuous nodes of trunks and other perennial parts of the vine. Buds not borne at clearly defined nodes of canes are referred to as *base buds* (Figure 6.3), and their shoots, which are often unfruitful, are termed *base shoots*. Shoots stop growing in late summer and become brown and woody during the *acclimation*, or hardening, process. Shoots are termed *canes* after leaf-fall. Lateral shoots often develop at the nodes of primary shoots. They, too, can become woody and persist after fall frosts. Buds borne at nodes are *compound*. Compound buds consist of several growing points, or *primordia*. The primary bud is the largest primordium, the first to break bud (emerge) in the spring, and it usually bears more flower clusters than do shoots developing from secondary or tertiary buds (Figures 6.1 and 6.2).

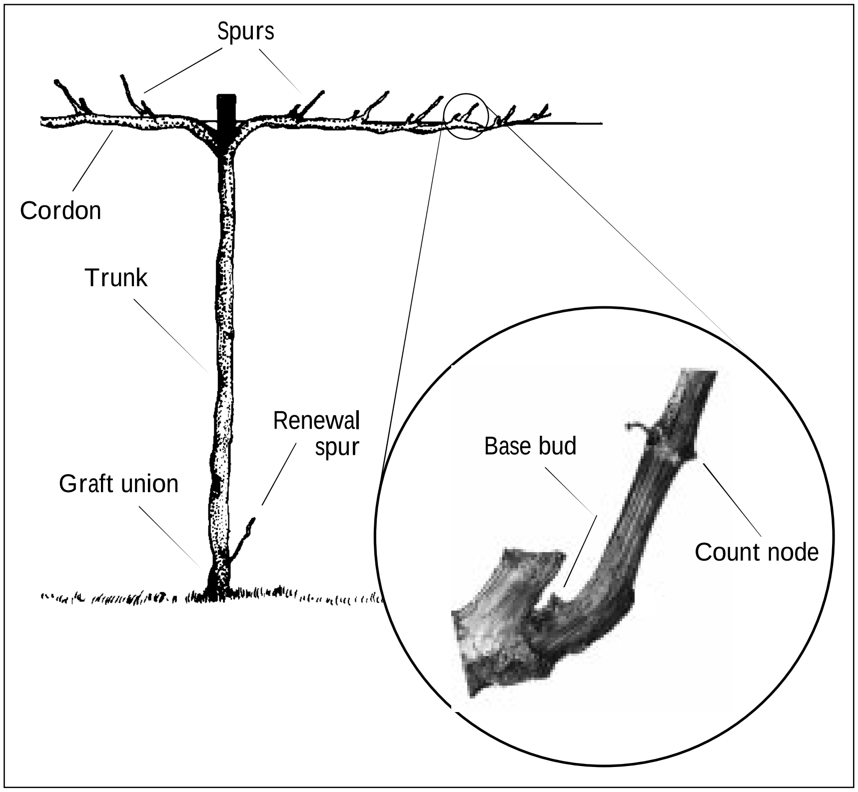


Figure 6.3 Structure of dormant, grafted grapevine. Vine has been spur-pruned; in spur close up, base bud and count node are shown.

Additional terms describe grapevine parts in the context of a particular training system's integration with a trellis or other support. The *vine trunk* is the vertical support structure that connects the root system and the fruit-bearing wood of the vine (Figure 6.3). Trunks can have horizontal extensions of two-year-old or older wood. These extensions might be short *arms*, as in the umbrella kniffin system or long *cordons*, as in the bilateral cordon system. Arms and cordons, in turn, usually bear *spurs* (canes that have been pruned to 1 to 4 nodes) or canes (8 to 15 nodes). Trunks, arms, and cordons are generally retained for years. The shoots of a vine and their leaves represent the *canopy* of the vine. The *renewal region* is that region of the canopy where buds for the next season's crop develop. The renewal region is often, but not always, the fruiting region of the canopy.

Dormant Pruning

Reasons for Pruning

A mature, unpruned grapevine can have more than 400 buds. Overcropping would occur if all of these buds were allowed to grow and bear fruit. There are both immediate and long-term effects of overcropping grapevines. Immediate effects are observed in the current year. Symptoms can include reduced sugar accumulation in fruit, reduced pigmentation in berry skins, and a small berry size that detracts from table grape appearance. Rather than maturing into woody canes, the shoots of overcropped vines typically die back completely to older wood, or they may mature only one or two basal nodes (toward the base of the shoot). Poor wood maturation occurs because the maturing fruit competes for the necessary carbohydrates.

The long-term effect of overcropping is reduction of vine vigor (rate of shoot growth) and vine size (pruning weight). Vine size reduction due to overcropping can occur without a noticeable degree of cane dieback. Although wood might appear to be mature, stored starch reserves in vines stressed by overcropping can be so low that the next year's vegetative growth and crop will be severely reduced.

Although dormant pruning is the primary means of controlling the crop, it will not provide adequate control in all situations. Additional control through thinning of flower or fruit clusters is generally required with young vines (two years old or younger), with very fruitful varieties such as some of the interspecific hybrids, and in any case where the vine vigor and vine size are insufficient to fill the available trellis space.

Number of Nodes to Retain

Eighty to 90 percent of the one-year-old wood is removed from vines at dormant pruning. Before pruning mature grapevines, the vineyardist must decide how many nodes to retain. Overcropping and excessive canopy density will occur if too many nodes are retained. On the other hand, the crop will be needlessly reduced if too few remain. Furthermore, severely pruned vines are apt to produce excessively vigorous shoots because all of the stored energy in the trunks and roots is available to relatively few growing points. Excessive shoot vigor can reduce fruit set and delay shoot maturation in the fall.

Balanced pruning was developed to help vineyardists determine the appropriate number of nodes to retain. This method is based on the concept that a vine's capacity for vegetative growth and fruit production is a function of the vine's size. The size of a vine is determined by the extent of growth of roots, shoots, and perennial wood. Because the growth of roots and other perennial wood cannot be conveniently measured, vine size is measured by weighing the one-year-old wood (canes) removed at pruning. Essentially, we balance the number of nodes retained against the weight of pruned canes: more nodes should be retained on a large vine than a on small vine because the large vine has a greater capacity for both vegetative growth and crop production. Pruning formulas for many varieties have been developed to calculate the number of nodes to be retained for a given pruning weight (Table 6.1). A pruning formula of 20 + 20, for example, would require leaving 20 nodes for the first pound of canes removed, plus an additional 20 nodes for each additional pound above the first. A 3.2-pound vine would therefore retain 64 nodes if the 20 + 20 schedule were used at pruning. Weighing is done to the nearest tenth of a pound. With all pruning formulas, these are minimum and maximum numbers of nodes that must be retained. For example, a minimum of 15 nodes should be retained on vines that are two years old or older. Given 15 or more shoots, small vines will require some degree of cluster thinning to prevent overcropping, but the shoots and leaf area are

Table 6.1. Suggested Pruning Formulas for the Balanced Pruning of Selected Grapevine Varieties

Variety	Pruning Formula*
Cabernet Sauvignon	20 + 20
Cabernet franc	20 + 20
White Riesling	20 + 20
Chardonnay	20 + 20
Seyval	5 + 10
Vidal blanc	15 + 10
Other hybrids	20 + 10
Concord	30 + 10
Delaware	20 + 10
Niagara	40 + 10

*The first number in the pruning formula indicates the number of nodes to retain for the first pound of cane prunings; the second number indicates the number of nodes to retain for each additional pound of cane prunings after the first. See text.

needed to increase vine size. The maximum number of nodes to be retained on mature vines should be on the order of 4 to 6 nodes per linear foot of row space (for example, 32 to 48 nodes for vines spaced 8 feet apart in the row). The lower number would be more appropriate for large-clustered varieties; the higher number would be acceptable for varieties with small- to medium-sized clusters.

Nodes, specifically *count nodes*, are the units counted in the pruning formulas. Count nodes have clearly defined internodes in both directions on the cane (Figure 6.3). Once the appropriate pruning formula has been determined, the vine size is visually estimated and the number of nodes that should be retained on the pruned vine is calculated on the basis of that estimate. This requires some experience, but 5- to 6-foot canes average about 0.1 pound. The vine is then pruned, leaving 10 to 15 extra nodes as a margin of estimation error. The cane prunings are weighed with a hand-held scale and their weight is entered into the pruning formula to determine accurately the number of nodes to be retained. Nodes in excess of that number are then removed. Commercially, it is neither necessary nor practical to weigh cane prunings from every vine. In practice, most pruners acquire an ability to estimate the pruning weights and node retention closely. Thereafter, only an occasional vine is weighed to check estimates.

Pruning formulas (Table 6.1) allow for additional shoots to develop from noncount node locations (base buds). Generally, the native American and vinifera varieties do not produce many base shoots unless the vines have been pruned too severely. Many of the interspecific hybrid varieties, however, produce numerous, fruitful base shoots, even with moderate pruning. Balanced pruning of hybrid varieties has limited utility. Crop control with some hybrid varieties, notably Seyval, must be achieved through a combination of fairly severe pruning and shoot or fruit cluster thinning. (See chapter 7.)

There are other, more arbitrary means of determining the number of nodes to retain at pruning. Node retention figures are sometimes based on the linear row space or the square area a vine occupies. For example, mature vines trained to conventional, nondivided canopy training systems should generally retain four to six nodes per linear foot of row. Expressing node retention on the basis of the linear measure of row or the square area of vineyard is convenient; however, it ignores individual variation in vine capacity and can lead to overcropping of small vines or undercropping of large vines. It is not as precise as balanced pruning and is therefore not a recommended procedure where variation in vine size is great.

When to Prune

Vines can be pruned any time between leaf fall and bud break the following spring. However, there is evidence that fall-pruned vines are more susceptible to winter injury than vines pruned in late winter or early spring. Delaying pruning until late winter makes it possible to evaluate bud injury and compensate by increasing the number of nodes retained. Spring pruning does not harm vines, even where sap bleeding is observed; however, swollen buds and young shoots are extremely susceptible to breakage. Therefore, the removal of unwanted wood from the trellis should be completed before bud swell. Experienced pruners require 30 to 40 hours to cane-prune an acre of vines. Somewhat less time is required for spur-pruned vines. Cane pruning and spur pruning are described in the section on grapevine training.

Double-pruning of vines is sometimes practiced in areas where spring frosts are common. At the initial pruning in late winter or early spring, canes or spurs are retained with two to three times the desired number of nodes. Buds nearest the pruning cut develop shoots as much as seven days earlier than the basal buds of the same cane or spur. To correct shoot density, a second pruning cut is made after the threat of frost before appreciable shoot growth has occurred.

What to Retain

The selection and retention of suitable fruiting canes and spurs is extremely important. Select only canes or nodes that show good wood maturation. This criterion is far more important than selecting wood strictly on the basis of its location in relation to a desired training system. Generally, dark brown canes with short internodes (4 to 6 inches long) are superior to lighter colored canes that have internodes longer than 6 inches. Canes that have internode diameters of ¼ to ½ inch are superior to canes outside that range. The diameter of a person's small finger is an appropriate guide for a desirable cane diameter. Well-matured lateral canes or spurs can be retained as fruiting wood if needed; however, medium diameter canes lacking persistent laterals are superior to large canes bearing many persistent laterals. Canes associated with good bud fruitfulness and cold hardiness are located toward the exterior of the canopy where they received more sunlight than those canes that developed within the canopy.

Complications Due to Cold Injury

In many years, assessing and compensating for cold injury is an important aspect of pruning grapevines in this region. The retention of nodes is based on the assumption that buds of retained nodes are viable. If buds have been killed by freezing or other causes, the number of retained nodes must be increased to compensate for the injury.

Bud injury is assessed before pruning by evaluating the viability of a representative sample of buds from a given variety. Dead buds are identified by a browning of their primordia, which occurs after the frozen buds are allowed to warm for a few days. To determine if a bud is dead, make several consecutively deeper cross-sectional cuts through the bud to expose the individual primordia (primary, secondary, and tertiary buds of Figure 6.1). A sharp, single-edged razor is the best tool for this purpose. The primary bud, located between the secondary and tertiary buds, is most susceptible to cold injury. Dead buds will appear brown, whereas live buds will be a light green color. If buds are sectioned too deeply, the primordia may be missed, exposing the green tissue beneath the bud. The novice should gain some experience by cutting live buds (such as those of a cold-hardy variety) to learn to recognize the individual primordia of a bud and to become familiar with the green appearance of live primordia.

Buds can be examined for viability on the vine, but it is generally more comfortable to collect 10 to 20 canes at random through a varietal block and examine the buds indoors. Collect only canes and nodes that might otherwise be retained at pruning. If there are large differences in elevation (30 to 40 feet) within a vineyard block, sample the regions separately because injury will probably be greater at the lower elevation. Examine 100 to 200 buds of each variety and record the percentage of dead primary buds.

If your bud assessment reveals 40 percent bud injury on a vinifera variety, then a 20 + 20 pruning schedule should be increased 40 percent to 28 + 28 or, for convenience, 30 + 30. Pruning adjustment is roughly proportional to primary bud injury with vinifera and native American varieties. Because many of the interspecific hybrid varieties have fairly fruitful secondary and base shoots, death of primary buds alone might not significantly reduce yields. The compensation for primary bud injury is therefore not as generous as with native American and vinifera varieties. Low temperature can also kill canes and trunks. Figure 6.4 shows in cross-section a portion of a three-year-old grapevine trunk. Trunk tissues include (from exterior to interior): a corky *periderm* or *bark*; the *phloem*, or food-conducting tissue; the *vascular cambium*; the *xylem*, or water-conducting tissue; and a central *pith*. The vascular cambium is a region of cell

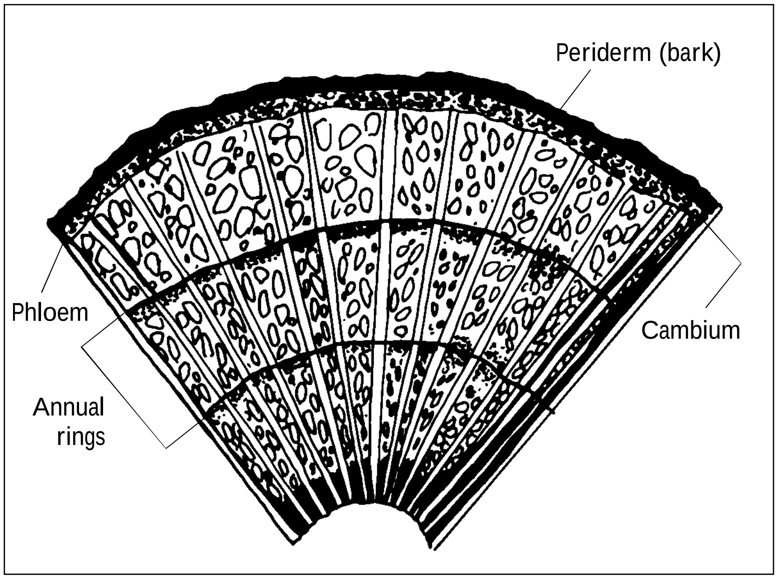


Figure 6.4 Cross-sectional view of a portion of a three-year-old grapevine trunk. (Redrawn from Esau, K. 1948. Phloem structure in the grapevine and its seasonal changes. Hilgardia 18:217-296.)

differentiation and division that produces new xylem and phloem cells annually. Canes have the same tissues as trunks but lack the annual rings of xylem. Cambium and phloem tissues are generally the most susceptible to cold injury. These tissues, like buds, will brown after being killed and subsequently rewarmed. Injury to the vascular cambium reduces or prevents the development of new xylem and phloem tissues. The old xylem tissue might sustain the initial water-conducting needs of the developing shoots in early spring. However, cold-injured vines often wilt and die in midsummer because the transpirational loss of water from leaves exceeds the ability of the impaired vascular system to transport water.

Cane and trunk cold injury is diagnosed by making shallow, longitudinal cuts into the wood and examining the phloem and cambial regions for browning. These tissues form a thin cylinder immediately beneath the bark. Browning or darkening of these tissues indicates injury. If wood injury is observed, retain extra canes at pruning. Injury will not be uniform and some canes will be unaffected. Some of these extra canes can be removed or shortened after bud break if too many shoots are present. Trunk injury is also diagnosed by making shallow, longitudinal cuts into the wood. Injury is usually most severe near the ground.

Cold-injured trunks frequently split or are affected by crown gall one to two years after the cold injury occurred. Vines will ultimately die if they must depend on a single, cold-injured trunk. Multiple trunking is therefore highly recommended to assure the long-term survival of vines. (See the section on grapevine training.) Split, heavily crown-galled, or otherwise defective trunks should be sawn off and replaced with a cane that arises near ground level but above the graft union (Figure 6.3). This strategy will ensure a continuous supply of shoots and canes to replace injured trunks.

Dormant pruning is the primary means of regulating crop. If other factors do not limit productivity, vines pruned correctly are likely to produce large crops of high-quality fruit. Pruned incorrectly, vines and crop will ultimately suffer. It is important to understand how many nodes to retain as well as which nodes are associated with good cold hardiness and fruitfulness.

Grapevine Training

Like dormant pruning, grapevine training is essential for high-quality grape production. There are numerous training systems used worldwide, and no single system is appropriate for all situations. The training system used will depend upon the variety, the frequency of cold injury, the degree of vineyard mechanization, and the availability of skilled labor. An acceptable training system will

❑ promote maximum exposure of leaf area to sunlight

❑ create a desirable environment within the canopy (microclimate), particularly in the renewal region

❑ promote uniform bud break, especially with those varieties that exhibit pronounced apical dominance (described in the section on initial training of grapevines)

- ❑ promote efficient vineyard operation with respect to equipment traffic, fruit harvesting, pesticide application, and dormant pruning
- ❑ be economical.

Initial Training

The growth potential of grapevines and the conditions under which vines are grown is never uniform. Other factors being equal, however, vines grafted to vigorous, pest-resistant rootstocks generally develop faster and usually grow larger than nongrafted vines. Variation in moisture and nutrient availability within a vineyard can cause differences in the extent of growth for a given variety. Training grapevines, therefore, requires evaluating the growth of individual vines during their establishment. Regardless of the intended training system, the initial training of grapevines has the following goals:

YEAR 1: To develop large, healthy root systems;

YEAR 2: To establish the initial components of the intended training system, including at least one semipermanent trunk;

YEAR 3: To develop or complete the training system, harvest a partial crop, and establish a second trunk.

These goals can be achieved by several methods. The following text and illustrations describe one means of establishing a low, bilateral cordon-trained vine using two semipermanent trunks. The training method described here is but one of several possible approaches.

YEAR 1: Erect the trellis posts and at least the lowest of the training wires before or during the first growing season. This wire, and a slender stake set next to individual vines, will provide a support for shoot growth. Allow two to three shoots to develop on vines during the first year (Figures 6.5a and 6.5b). Train these shoots vertically to the support stake. They may eventually be tied loosely to the training wire if their growth warrants it. Lateral shoots on these primary shoots can be pruned off to promote elongation of the primary shoots. Lateral shoot growth will be minimized if shoots are positioned upright and fastened to the support stake. Leaving several shoots on the first-year vine provides an abundant leaf area. Root growth is dependent on food produced in the leaves. Thus, the greater the leaf area, the greater the root growth that will occur in late summer. Eliminating all but one shoot can also lead to an excessive rate and duration of shoot growth, especially if the vines have large root systems when planted. Rapid and continued growth late into the fall can result in incomplete wood maturation, increasing the susceptibility to cold injury. In addition, retaining several shoots, rather than one, provides some measure of compensation for possible wind damage, deer browsing, and other factors that can retard the development of young vines.

It is essential that young vines be protected from fungal diseases by applying the appropriate fungicide. Powdery and downy mildews in particular can severely reduce the photosynthetic (food manufacturing) capabilities of leaves and retard the establishment of the training system. Deer, Japanese beetles, weeds, and other pests — as well as drought — also have greater impacts on young vines than on older vines and must be diligently controlled. Young vines do not have the food storage reserves afforded by the large root systems and trunks of older vines.

YEAR 2: Complete the trellis before bud break of the second growing season. Training in the second year starts by evaluating the extent of growth achieved during the first year (Figure 6.5c). If no canes reach the first wire, remove all but one cane. Prune this cane to three or four buds and secure it to the training stake. Treat such a vine as a one-year-old vine.

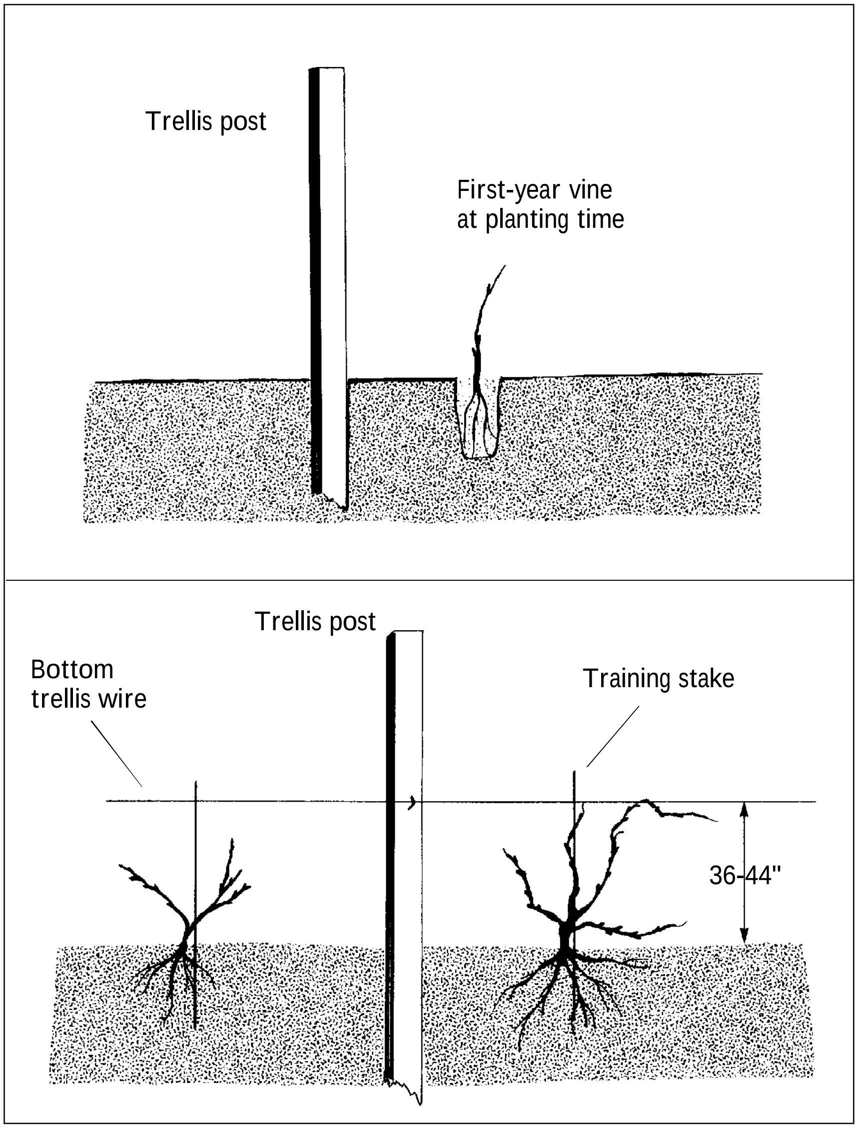


Figure 6.5a (top). Development of bilateral cordon-trained grapevines. Year 1: spring, at planting.

Figure 6.5b (bottom). Year 1: fall, at end of growing season. Vine on left has demonstrated weak growth. Vine on right grew vigorously and attained a greater size.

Vines that grew extensively in their first year will likely have one or more canes suitable for retention as a trunk. If a cane is long enough to reach the lowest trellis wire and is of adequate diameter at the wire, retain the cane as a trunk. The distal portion (the end towards the tip) of such canes can be trained horizontally along the training wire to serve as the basis for establishing the cordon (Figure 6.5c). If you elect to use a high training system, tie the cane vertically to the top wire of the trellis to form a trunk. In addition to the first trunk, retain a renewal spur of one or two buds that originates near the soil line but above the graft union (Figure 6.5c). If a second cane is large enough to serve as the second trunk, it can also be retained.

Cordon Establishment

The process of establishing cordons can begin in the first or second season, depending on the first year's shoot development. In either case, establish cordons over a two-year period. Long canes (8 to 15 nodes) often exhibit poor shoot growth at midcane nodes. Shoots that develop near the terminal, or distal, end of a cane produce growth-regulating hormones that retard the development of midcane shoots. This so-called apical dominance of distal shoots is greatest when the cane is oriented vertically up and is minimized when the cane is trained vertically down. To establish 4-foot-long cordons, use a 24-inch-long cane (or trunk extension) in year two (Figure 6.5c) and complete the cordon in year three with another 24-inch-long cane that originates near the distal end of the short cordon (Figure 6.5e). Canes used to establish cordons should be wrapped loosely around the trellis wire and securely tied at their terminal end with wire. The tying process will prevent the cordon from rotating or falling from the wire. If canes are wrapped too tightly around the cordon wire (greater than about two rotations in a 4-foot length), they may grow into the cordon wire within a few years. This does not impair vine performance, but it does prevent the cordon wire from being properly tensioned as it stretches with time.

During the second growing season, thin the shoots of vigorous vines that originate below the lowest trellis wire to one or two near the graft union (Figure 6.5d). Retain shoots that originate on the developing cordon. Retain 10 or more shoots, if possible, in year two. Treat small or weak vines as first-year vines during the second growing season (Figure 6.5d). Remove all flower clusters. Where exceptional growth was achieved in year one, it may be desirable to leave several fruit clusters per vine in the second growing season to slow vegetative growth. This token crop can be removed quickly in early summer if growth is less than expected.

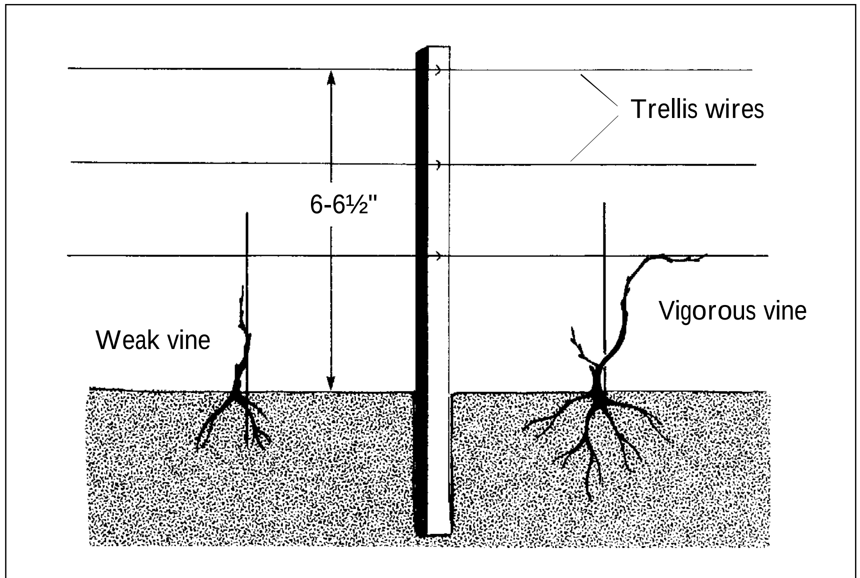


Figure 6.5c. Development of bilateral cordon-trained grapevines. Year 2: spring, after pruning. Vine on left has demonstrated weak growth. Vine on right grew vigorously and attained a greater size.

Shoots that develop in year two should be positioned and tied to the trellis wires to maximize sunlight exposure of their leaves. For cordon training, these shoots will form the spurs for shoot development during the following year (Figure 6.5e).

YEAR 3: Complete the basic elements of the training system during the third year. For low cordon-trained vines, prune the canes that arise from the upper side of the cordon to one- or two-node spurs (Figure 6.5e). For high cordon-trained vines (Figure 6.6), retain the spurs on the lower side of the cordon. Spurs should be spaced 4 to 6 inches apart. Develop a second trunk and cordon from a cane that originates near the graft union; follow the procedure outlined for the initial trunk. Retain a small crop (for example, one cluster per two shoots) on vines that had at least 1 pound of cane prunings from second-year growth. Position and tie the shoots to the upper trellis wires, as necessary, during the growing season. Treat weak vines as second-year vines and remove all crop.

Multiple Trunking, Trunk Renewal, and Graft Union Protection

Growing cold-tender grapevine varieties introduces problems not experienced in regions with mild or more constant winter temperatures. Some degree of bud injury occurs regularly with cold-tender varieties but can generally be compensated for by retaining additional buds at dormant pruning. It is much more difficult to compensate for cane and trunk injury. In some situations (such as cold-tender varieties planted in poor sites) complete vine loss has been experienced. Even in good to excellent sites, it is wise to anticipate cold injury to better compensate for its occurrence. In addition to winter injury, other forms of injury can occur to vines, such as disease and mechanical damage by vineyard equipment. The experienced grape grower recognizes that the only permanent part of living vines is the root system.

One of the best ways to compensate for trunk injury is to use multiple-trunk training systems. This recommendation applies to cold-tender vinifera or more hardy hybrids. All of the training systems illustrated here can be established using two or three trunks, as opposed to one. Cold injury or death of trunks is often not uniform. Frequently, only one trunk of a two-

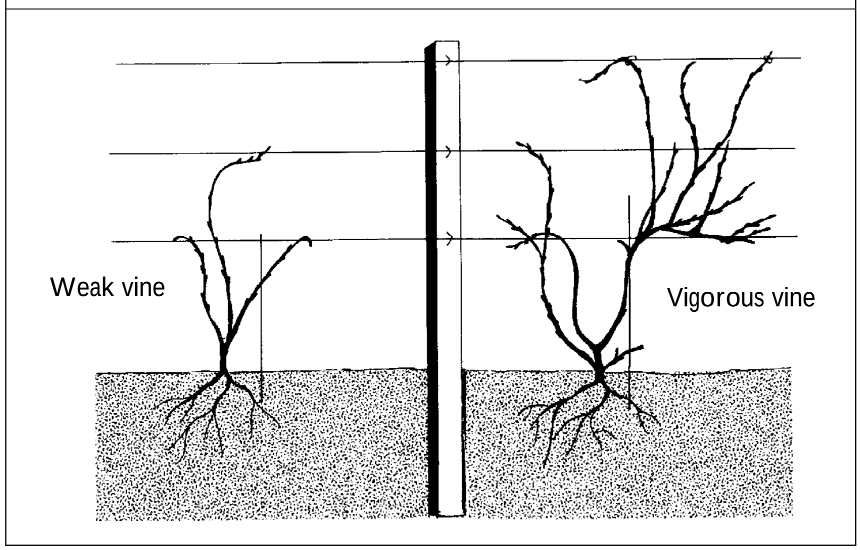


Figure 6.5d. Development of bilateral cordon-trained grapevines. Year 2: fall, at end of growing season. Vine on left has demonstrated weak growth. Vine on right grew vigorously and attained a greater size.

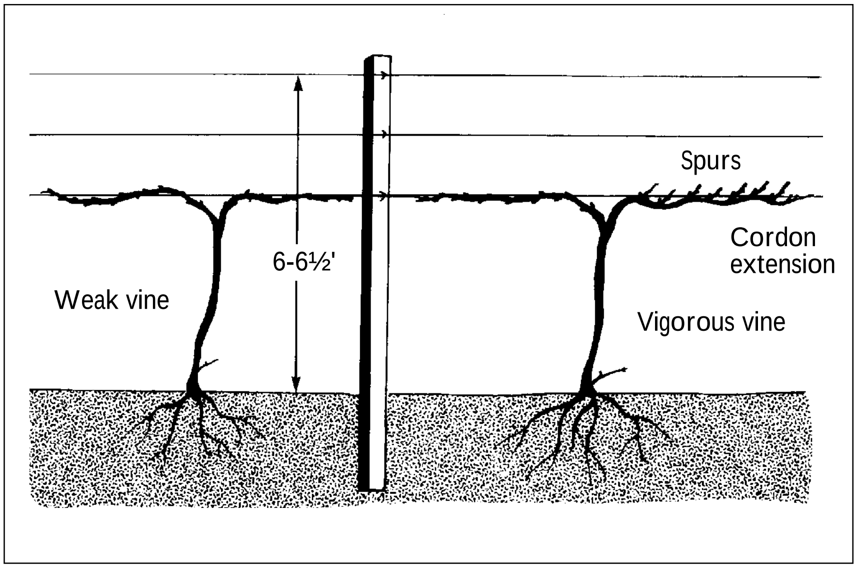


Figure 6.5e (left). Development of bilateral cordon-trained vines. Year 3: spring, after pruning. Vine on left has demonstrated weak growth. Vine on right grew vigorously and attained a greater size.

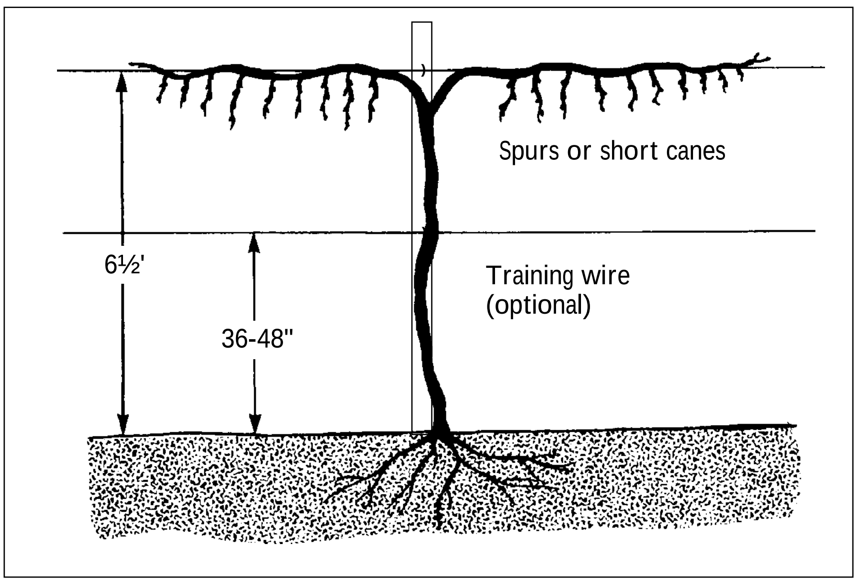


Figure 6.6 (above). High-wire cordon training system.

or three-trunk vine is killed. Similarly, the development of a wood-rotting disease such as eutypa dieback (see chapter 8) may be observed initially on only one cordon or trunk. In either case, removing one of two trunks does not eliminate grape production from the affected vine. Furthermore, it is usually easier to reestablish the lost unit from an existing trunk. A multiple-trunk training system can be developed starting in the first year as described above for a bilateral cordon system. Alternatively, a second or third trunk can be added in any year by training up a shoot originating near the graft union. Old trunks should not be replaced unless they are mechanically damaged, diseased, or cold injured. To avoid eutypa dieback infection, follow the precautions outlined in chapter 8 when removing injured trunks. The continual removal of shoots (suckers or waterspouts) from the base of the trunk will exhaust the latent buds that could be used to develop new trunks, and with such vines it is sometimes difficult to establish new trunks. Therefore, the maintenance of a one- or two-node renewal spur at the base of the vine, while adding labor, does provide a continual supply of shoots and potential new trunks. A new shoot is trained up before a planned trunk removal or at any time after an unpredicted trunk loss. Note that with grafted vines, any suckers that develop from below ground level usually arise from incompletely disbudded rootstock wood. These shoots can be recognized as rootstock variety by their distinctive leaf appearance. They are of no value in reestablishing the training system.

An additional way to compensate for winter injury of grafted vines is to protect the graft union and a portion (several inches) of the trunks with mounded soil in the fall. Hilling up of graft unions, which can be done mechanically with tractor-mounted implements, protects a portion of the trunks from low temperatures. By providing a continuum with the relatively warm soil beneath the vine, the hilled soil insulates up to several inches of the trunk, including latent buds, above the graft union. The insulating layer of soil must be carefully removed (dehilled) in early spring to prevent permanent scion rooting. In the event of very low winter temperatures, injury may occur to all exposed portions of the vine. This is a rare occurrence, but it has — and will — occur, especially in poor vineyard sites. If such damage occurs, the training system can be reestablished by dehilling the vine and bringing up shoots that had been protected as buds by the soil. This tactic is faster and cheaper then replanting the vineyard. Hilling and dehilling is an insurance practice, and its utility says much about the vineyard site. Hilling is definitely recommended if a variety's hardiness or the suitability of a site is in question. Hilling is not recommended, however, if long-term experience (seven or more years) suggests that severe winter injury is unlikely. Hilling and dehilling have resulted in considerable soil erosion in some vineyards. That problem, combined with some inevitable mechanical damage to vines, has made the practice of dubious value in good to excellent vineyard sites. On the other extreme, if a grower finds that vines are often severely injured, the site, the variety, or both are unworthy of further consideration.

Training systems for vertical trellises are catego-

Training Systems

rized as having either divided or nondivided canopies. Training methods can be further divided into head-trained or cordon-trained systems and cane-pruned or spur-pruned systems. The following training systems are acceptable for vineyards in this region. Trellis dimensions and the number of foliage catch wires used are provided as guidelines and might differ slightly from other references. It is wise to visit many existing vineyards and formulate your own dimensions from a synthesis of those observations and discussions.

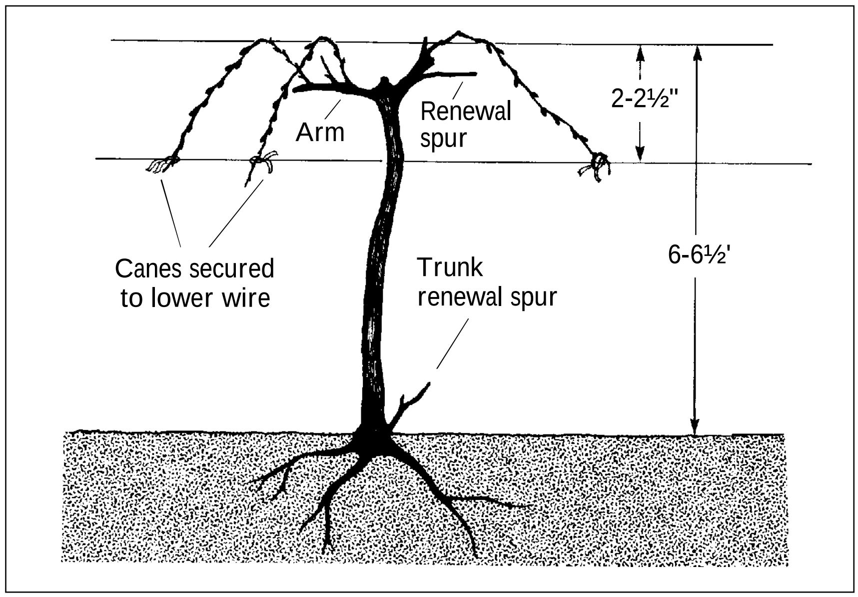


Figure 6.7. Umbrella kniffin training system.

Nondivided Canopy Systems

Nondivided canopy training systems have a single curtain of foliage and are less expensive than divided canopy systems.

Head-Trained Vines

Umbrella Kniffin

Two- or three-wire trellises are used for umbrella kniffin training (Figure 6.7). A trunk extends to a point 4 to 6 inches below the top wire. Short arms bear the fruiting cane arched over the top wire and are tied to the lower wire of the trellis. Renewal spurs are retained in the head region to provide canes for the subsequent season. Large vines (for example, those that produce 3.5 pounds of cane prunings from vines spaced 8 feet apart in the row) might retain three or four canes. Smaller vines (for example, those producing 1 pound of cane prunings) might only retain two canes to provide the appropriate node number.

ADVANTAGES

- ❑ A relatively simple, low-cost trellis is needed.
- ❑ Pruning decisions are easily learned.
- ❑ Apical dominance is reduced and more buds are positioned in a unit length of row by bending

the canes over the top wire.

❑ The high renewal region promotes good fruitfulness and good fruit quality with small- to moderate-sized vines.

DISADVANTAGES

❑ As with all cane pruning systems, the mandatory tying of canes to trellis wires adds labor costs.

❑ Little provision is made for shoot positioning, and shoot crowding can lead to shaded fruit with large, vigorous vines.

Modified Keuka High-Renewal

This training system was developed in northern grape growing regions where frequent winter injury confounds the maintenance of large amounts of perennial wood and standardized training. The system's chief asset is that it permits flexibility in pruning and training. Multiple trunks extend to a midtrellis height (Figure 6.8). The vines are pruned to short canes originating from a dispersed head region. Canes are distributed and tied to trellis wires in a manner that promotes as uniform a shoot density as possible.

ADVANTAGES

❑ This system allows a flexible approach to winter-injury compensation.

❑ Short trunks minimize the maintenance of perennial wood.

DISADVANTAGES

❑ A considerable amount of time is expended with cane tying.

❑ Uniform canopy density is extremely difficult to achieve.

❑ The flexibility in training is difficult for inexperienced pruners to grasp.

Cordon-Trained Vines

Low Bilateral Cordon

The distinction between low- and high-trellis cordon systems depends upon the point on the trellis at which the cordon is established. Low cordons are typically 36 to 42 inches above the ground. Although cordons can be established even lower, 36 to 42 inches is a comfortable working height for most persons and is still low enough to permit development of 3 to 4 feet of canopy above the cordon. High cordons are established at the top of the trellis, typically 72 inches above the ground. The establishment of a low, bilateral cordon training system was illustrated earlier. At dormant pruning, one to three node spurs are retained at a uniform spacing along the upper side of the cordon (Figure 6.9). The vertically upright spurs encourage an upright growth habit to developing shoots. Cordons can extend either unilaterally or bilaterally from the trunks; in either case, cordons should ultimately span the distance between two adjacent vines in the row, leaving no gap between cordons of adjacent vines. Multiple sets of paired catch wires can be mounted on the trellis above the cordon to facilitate shoot positioning and to promote the development of a thin, vertical canopy. (See chapter 7.) Three pairs of catch wires are illustrated in Figure 6.9. The first pair of catch wires should be no more than 10 inches above the cordon. This height reduces the likelihood that shoots will fall or be blown down before elongating through the catch wires, and thus the amount of labor required to fasten shoots to wires is greatly reduced. The recommendation to use three sets of paired catch wires, as opposed to a lesser number, is guided by (1) the underlying principles of canopy management (see chapter 7) and (2) the conviction that the installation of wire is cheaper than the alternative labor of fastening shoots to wires to maintain the thin, vertical canopy.

ADVANTAGES

❑ Spur pruning minimizes the labor associated with cane tying.

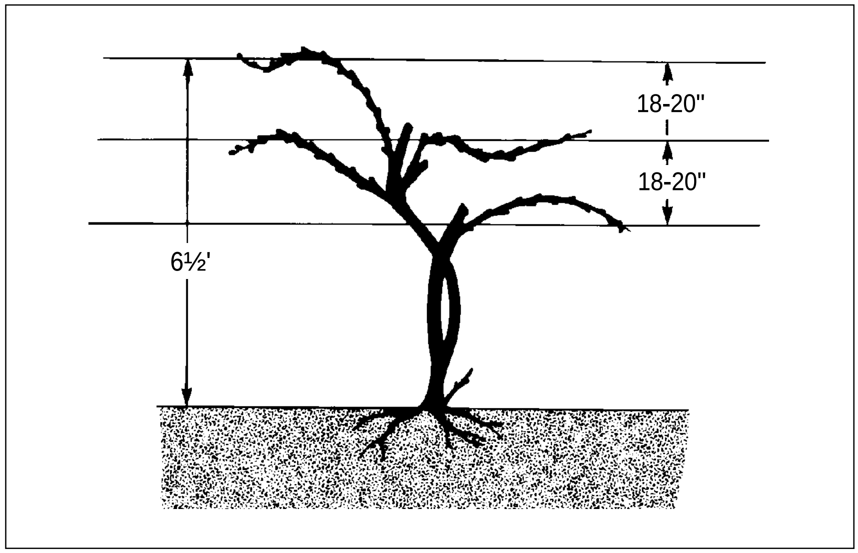
❑ Fruit and renewal regions are at a uniform height, facilitating harvest and pruning.

DISADVANTAGES

❑ Basal nodes of a cane (those retained as a spur) are often not as fruitful as midcane nodes because of the characteristics of the variety or poor sunlight exposure during bud differentiation and development.

❑ Cordons, like trunks, must be renewed in the event of winter injury.

Long-term productivity of cordons can be a problem with varieties that are subject to winter cold injury or in situations where spurs have been pruned improperly. Cold injury or poor bud development can lead to areas of the cordon that lack spurs. Poor pruning can lead to displacement of the one-year-old spurs away from the cordon on older wood. The latter problem can be minimized by retaining, where possible, buds that originate close to the cordon and by retaining base shoots that arise directly from the old wood of the cordon. Cordons with poorly spaced spurs or wide gaps in spur positions should be renovated or replaced. If the cordon is free of disease, renovation may be all that is necessary to reestablish uniform distribution of spurs along the cordon. Renovation entails removing all one-year-old wood and spur extensions from the near-barren cordon. Leave a ¼- to ½-inch crown at the base of these extensions. The removal of this older wood stimulates a proliferation of base shoots from the retained crowns. The base shoots, which will be of low fruitfulness, can be trained and used to provide fruitful spurs for the following season. Severe pruning in renovation is necessary to stimulate base shoot development. Renovation temporarily reduces vine productivity, so it should be used only as needed and on a small proportion of vines in any one year. Replacement of cordons is advised if the cordon is diseased, cold injured, or otherwise undesirable. It is extremely difficult to establish a new, parallel cordon while the original cordon is still alive and present. Therefore, cut out the old cordon at the time the new cane is laid down. The new cane can originate near the graft union, anywhere on the trunk, or anywhere proximal to the diseased or barren region of the cordon. Do not attempt to establish a cordon using a cane originating from the opposing cordon of a bilaterally cordon-trained vine.



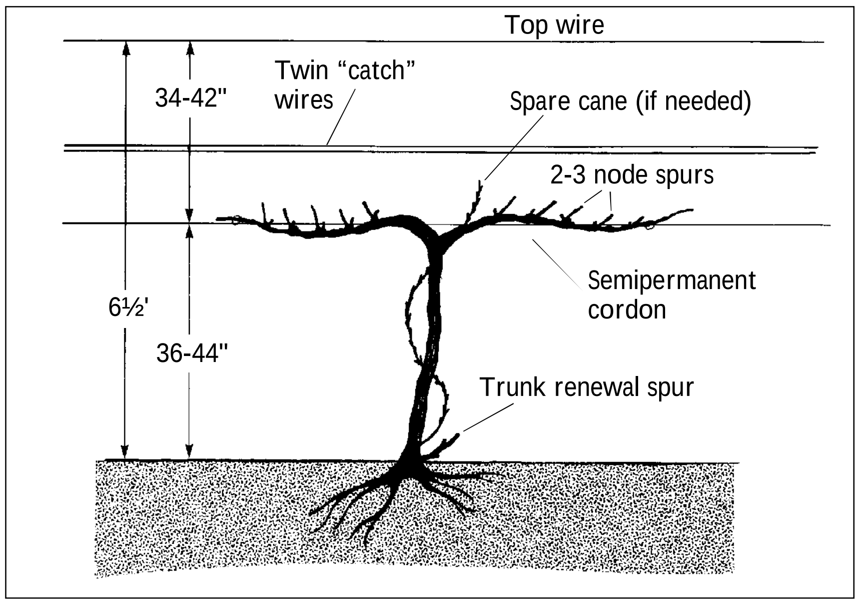


Figure 6.8 (top). Modified Keuka high-renewal training system.

Figure 6.9 (bottom). Low-wire bilateral cordon training system.

High Bilateral Cordon

Bilateral cordons are trained along the top wire of the trellis (Figure 6.10) in a manner similar to the low bilateral cordon system. Spurs or short canes are retained on the lower sides of cordons to promote downward shoot growth. Downward growth is further encouraged by positioning or "combing" shoots downward two to three times during the growing season. This positioning, which is first done near the time of bloom, is necessary to ensure sunlight penetration into the fruiting and renewal region of the canopy.

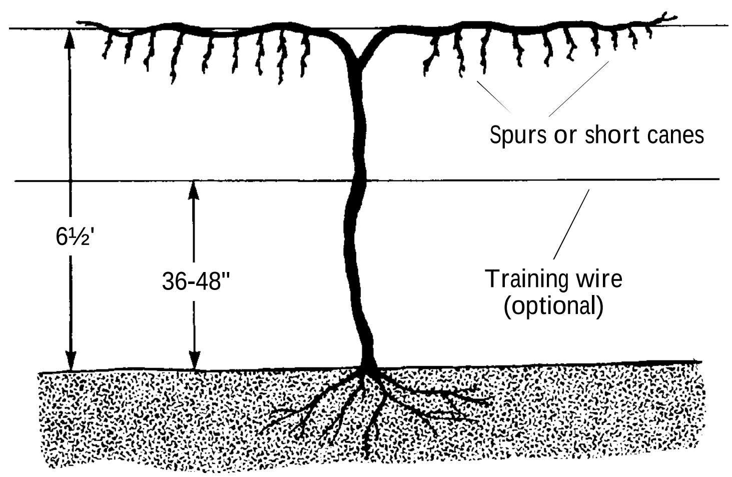


Figure 6.10. High-wire cordon training system.

ADVANTAGES

- ❑ This system uses a very low-cost trellis.
- ❑ High training is well suited to varieties that have a trailing growth habit, especially those of native American origin (for example, Concord).
- ❑ The fruiting and renewal region of the vine receives excellent illumination, provided that shoot positioning is performed.
- ❑ Pruning is rapid and cane tying is minimized.
- ❑ This system is well adapted to mechanical harvesting and pruning.

DISADVANTAGES

- ❑ A large area of perennial wood must be retained and exposed to possible winter injury.
- ❑ Varieties with upright growth habits can be difficult to manage.

Divided Canopy Systems

Divided canopy training systems consist of at least two curtains of foliage per unit length of row. Two systems, both having horizontally divided planes of foliage, are described here. Divided canopy training systems are more elaborate and more expensive to establish than nondivided training systems. Canopy division can be used to take advantage of the large surface area of leaves produced by large vines. Conversion of nondivided canopy vines to divided canopy training has resulted in significant yield increases and sometimes increased fruit and wine quality. Canopy division is not justified, however, when cane prunings average less than 0.4 pound per foot of row (for example, 3.2 pounds with vines spaced at 8 feet) in nondivided canopy training systems.

Because of the higher establishment costs, divided canopy training is not generally promoted for new vineyards: the same yield increases afforded by divided canopies can be achieved at lower cost by establishing more closely spaced, nondivided canopy rows. Similarly, the reduction in canopy density afforded by canopy division can be achieved by spacing vines farther apart in the row. The practicality of closely spaced rows hinges on the availability of narrow vineyard equipment. (See chapter 7.) Finally, it should be noted that the added costs of divided canopy training systems is wasted if the grower fails to maintain truly divided curtains of foliage.

Geneva Double Curtain

The top of the trellis is fitted with cross arms 4 feet wide (Figure 6.11). Cordon wires are supported on either end of the cross arms.

Bilateral cordons extend from trunks that alternate, by vine, between one side of the trellis and the other. Cordons are pruned to spurs on their lower sides. Shoot positioning is required to maintain canopy separation and to promote sunlight penetration into the fruiting and renewal region.

ADVANTAGES

❑ Yields and fruit quality can be increased significantly compared with nondivided canopy training systems.

❑ The Geneva double curtain system is well adapted to varieties having a trailing growth habit, such as those of native American origin.

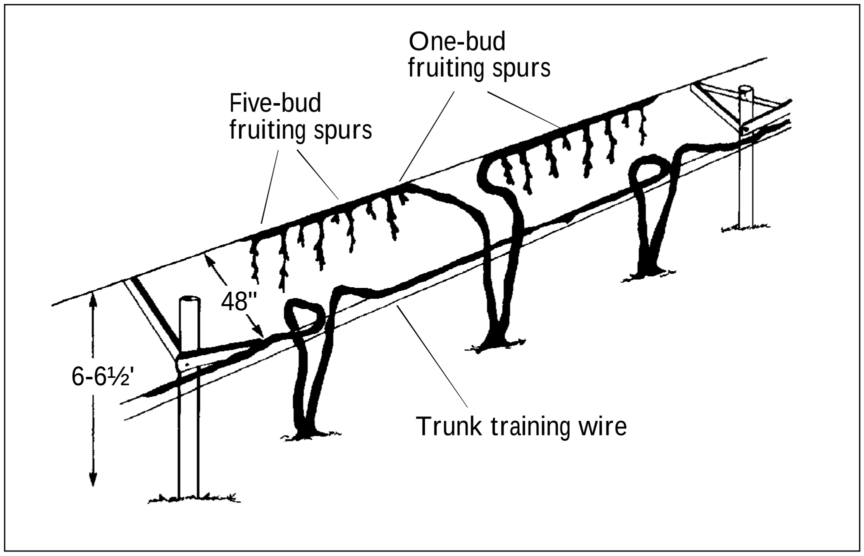
DISADVANTAGES

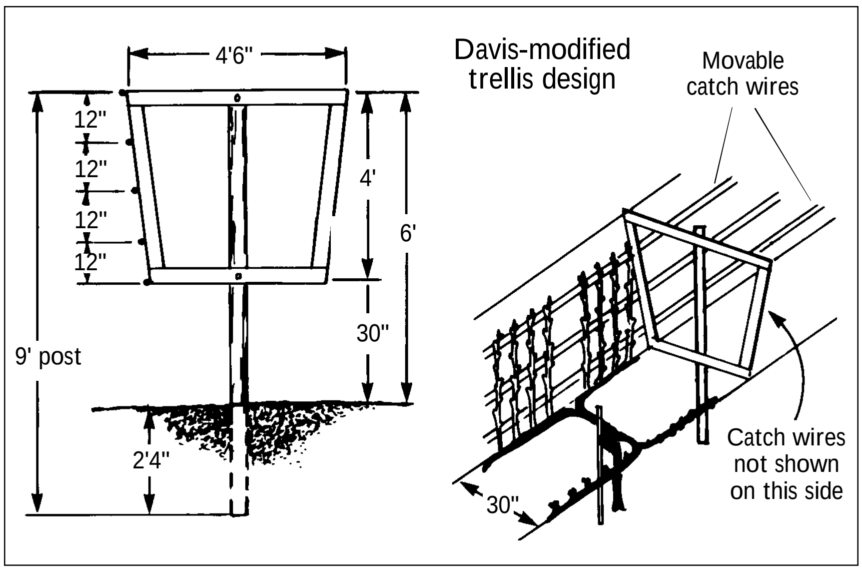
❑ A large amount of perennial wood must be maintained and exposed to winter injury.

❑ Considerable shoot positioning is required to achieve and maintain complete canopy division, especially with upright-growing varieties.

Lyre, or U-Shaped, Training

This design consists of a quadrilateral training system. Cordons are located 36 to 42 inches above ground (Figure 6.12). An elaborate trellis structure consisting of up to 16 catch wires is used to confine developing shoots to two independent and vertical curtains of foliage. The two curtains must be separated by at least 3 and preferably 4 or more feet at their bases. (A separation of 3.5 feet is illustrated in Figure 6.12.) Shoots are trained to the independent curtains with the assistance of multiple catch wires. Shoot topping is performed when shoot tops elongate much beyond the top wires. Inner catch wires can be movable to reduce the number needed. It is imperative to maintain two independent curtains of foliage by repeated shoot positioning and use of catch wires during the growing season.





ADVANTAGES

❑ This system is better suited than the Geneva double curtain system to varieties that exhibit a predominantly upright growth habit (for example, most vinifera varieties).

❑ Reestablishment of the training system after winter injury may be more rapid than with the Geneva double curtain.

❑ Greater yields can be achieved than with nondivided canopy training systems of the same row width.

Figure 6.11 (top). Geneva double curtain training system. Vines are spaced 8 feet apart in the row. (Adapted from Jordan et al., 1981.)

Figure 6.12 (bottom). U-shaped or open lyre divided canopy training system.

DISADVANTAGES

❑ The initial cost of trellis establishment is much greater ($3,000 to $4,000) than for conventional trellis systems ($1,500 to $2,000).

❑ Shoot positioning and tying is still necessary to maintain complete canopy separation.

In conclusion, several training systems are suitable for commercial grape production in Virginia and North Carolina. Advantages and disadvantages can be cited for each. Evaluate the growth potential of your vines, the availability of vineyard labor, and the hazards of winter injury before choosing a particular system. Conversion of inferior existing systems to superior systems is possible. However, converting from a high training system to a low training system is much more difficult than converting from a low to high system. Conversion of nondivided training systems to more elaborate divided-canopy training systems is also possible if rows are wide enough.

References

Adelsheim, D. 1992. Spacing, training, and trellising vinifera grapes in western Oregon. In: Oregon Winegrape Grower's Guide, 4th Edition. Ted Casteel (ed.). pp 63 - 118. Oregon Winegrowers' Association, Portland, OR.

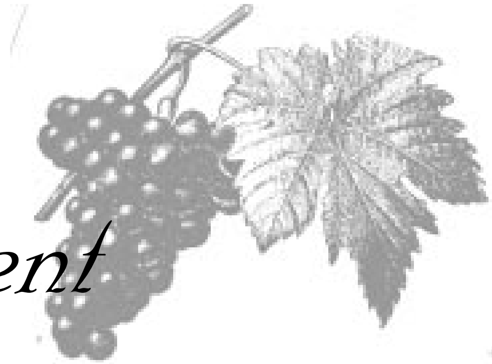
Jordan, T. D., R. M. Pool, T. J. Zabadal, and J. P. Tomkins. 1981. Cultural practices for commercial vineyards. Cornell University Extension Misc. Bulletin No. 111, Ithaca, NY.

McGrew, J. R. 1978. Basic guide to pruning. 14 pp. American Wine Society, Rochester, NY.

Shaulis, N. J., J. Einset, and A. B. Pack. 1968. Growing cold-tender grape varieties in New York. New York State Agricultural Experiment Station Bulletion No. 821.

Winkler, A. J., J. A. Cook, W. M. Kliewer, and L. A. Lider. 1974. General Viticulture. University of California Press, Berkeley, CA.

Chapter 7



Canopy Management

High-quality wines — those that command premium prices — can be produced only from high-quality grapes. Grape quality can be defined in various ways, but ripeness and freedom from rots are two of the chief qualities. Producing ripe fruit with minimum rot and maximum varietal character is not easy in Virginia and North Carolina. As described elsewhere in this publication, the combination of climate, soils, and vine vigor often leads to excessive vegetative growth. For reasons that will be discussed, luxurious vegetative growth can reduce vine fruitfulness, decrease varietal character, degrade other components of fruit quality, and hamper efforts at disease control. Canopy management practices can help alleviate these problems.

Canopy management is a broad term used to describe both proactive and remedial measures that can be taken to improve grapevine canopy characteristics. In the broadest sense, canopy management can entail decisions regarding row and vine spacing, choice of rootstock, training and pruning practices, irrigation, fertilization, and summer activities such as shoot hedging, shoot thinning, and selective leaf removal.

This chapter presents grapevine canopy management principles and describes management practices that have been used successfully to enhance fruit and wine quality in Virginia and North Carolina. Several excellent references on canopy management are cited at the end of the chapter, including the very informative text *Sunlight into Wine*.

Grapevine Canopies

The grapevine canopy is defined by the shoot system of the vine, including stems, leaves, and fruit (Figure 7.1). As described in chapter 6, vines can be trained to a single-canopy system (such as the bilateral cordon system) or to a divided-canopy system (such as the open lyre). And, just as cane pruning weights can be used as a quantitative measure of vine vigor (chapter 6), canopies can be described by various measures. We can, for example, measure them by their height, width, exposed leaf surface area, number of leaf layers, and shoot density (the number of shoots per unit length of canopy). These measures can then be compared to ideal canopy dimensions to decide whether corrective action is warranted.

Canopy Microclimate

The reasons behind many recommended canopy management practices can be better understood by recognizing that heavy, dense grapevine canopies can create a highly localized climate, distinctly different from that immediately outside the canopy. The climate within the canopy is referred to as the canopy *microclimate*. It is described in familiar terms such as temperature, humidity, wind speed, and amount of sunlight. Table 7.1 compares the microclimate of a sparse canopy or the region outside of a canopy with the microclimate inside a dense canopy.

Considerable progress has been made in understanding how grapevine canopies create

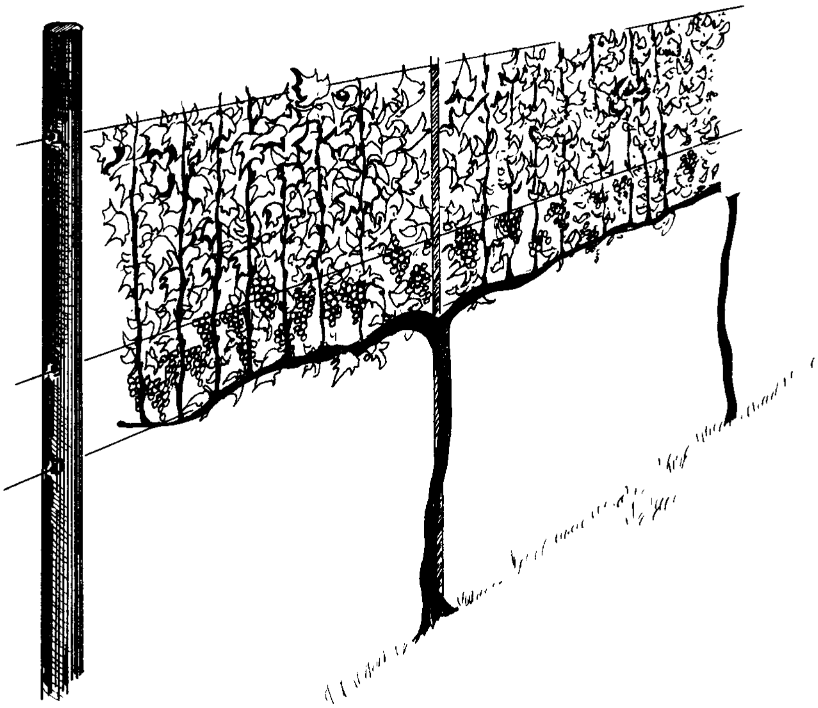


Figure 7.1. The grapevine canopy is defined by the shoot system of the vine, including stems, leaves, and fruit.

unique microclimates that, in turn, affect vine and fruit physiology.

Radiation

Grapevine leaves absorb approximately 90 percent of the sunlight that strikes them. This sunlight is responsible for photosynthesis, the process by which green plants convert sunlight and carbon dioxide into sugars and other carbohydrates. The exterior leaves of the canopy absorb large amounts of sunlight but transmit very little to the leaves deeper within the canopy. Shaded leaves are often not photosynthetically productive because they receive less sunlight than they need to produce carbohydrates. In addition, shaded leaves may contribute excess potassium to developing fruit and impede ventilation in the fruit zone. Excess potassium can, under certain conditions, contribute to elevated fruit acidity, which can be undesirable for making wine. Shade also reduces the fruitfulness of developing buds. Thus, yields from vines with dense canopies can be significantly lower than those from vines having a sparser shoot distribution.

Table 7.1 Characteristics of the Microclimates of Sparse and Dense Canopies

Characteristic	Sparse Canopy	Dense Canopy
Sunlight	Most leaves and fruit are exposed to sunlight.	Most leaves and fruit are in shade.
Temperature	Fruit and leaves can be warmed	Most leaves and fruit are interior by sunlight. At night, outside leaves
so are close to the temperature		and fruit can be
cooled.	of the ambient air day and night.	
Humidity	Leaves and fruit experience ambient humidity values.	Humidity can build up slightly in the canopy.
Wind speed	Leaves and fruit are exposed to approximately the ambient wind values.	Wind speeds are reduced in the canopy.
Evaporation	Evaporation rates are similar to ambient values.	Evaporation rates are reduced in the canopy.

Temperature

The air temperature within a grapevine canopy does not differ greatly from the temperature immediately outside the canopy. However, the shade produced by the exterior leaves can affect the radiational heating and cooling of fruit and leaves. For example, fully exposed fruit can be *heated* by solar radiation to a temperature 20° to 30°F higher than that of the surrounding air. That warming can be used to advantage in cool grape regions to reduce fruit acidity. Conversely, on clear nights, exposed fruit and leaves can cool as much as several degrees below the ambient air temperature by radiational *cooling*.

Wind Speed

Vine canopies reduce wind speed. The reduction is greater for dense canopies than for sparse ones. Wind movement — even a slight breeze — is very helpful in reducing fungal infections of fruit and leaves. Many of the fungi that attack grapevines in the eastern United States require either the presence of free water or a period of high humidity to infect the plant. Air movement helps evaporate moisture and reduce humidity in the canopy, reducing the opportunity for fungal infections to occur. Furthermore, sparse canopies permit greater pesticide penetration and coverage when vines are sprayed. The combined benefits of increased ventilation and increased pesticide penetration are fundamental reasons for using canopy management practices that promote a uniformly sparse or open canopy in Virginia and North Carolina.

Principles of Canopy Management

Richard Smart, who advanced our knowledge of the relationship between canopy characteristics and fruit and wine quality, has provided a convenient means of understanding canopy management by condensing the underlying research findings into five basic principles. Those principles are reviewed here in a slightly modified form to provide a basis for recommendations on assessing and modifying canopy characteristics.

PRINCIPLE 1: Vines should be spaced and trained to maximize the amount of leaf area exposed to sunlight. Furthermore, the canopy leaf area should develop rapidly in the spring. Principle 1 is derived from the observation that vineyard productivity increases when the percentage of available sunlight intercepted by vine leaves (rather than by the vineyard floor) increases. In essence, sunlight that falls on the vineyard floor is wasted. Studies have shown that grapevines receive the most sunlight when the vineyard rows are spaced fairly close and are oriented in a north-south direction. The canopies should be trained vertically to tall, thin curtains of foliage. Rapid leaf area development is promoted by retaining a relatively large number of short shoots on each vine, as opposed to a relatively few long shoots.

PRINCIPLE 2: Rows and canopies should not be so closely spaced that one canopy shades the renewal region of adjacent canopies. The ratio of canopy height (not trellis height) to alley width should not exceed 1 to 1. The *renewal region* of the canopy, as defined in chapter 6, is that portion in which buds for the following season's crop develop. The renewal zone is often the current season's fruit zone. Figure 7.2 illustrates principle 2 for vines trained to divided and nondivided canopies. The shade cast by one canopy on another reduces the photosynthetic function of the shaded leaves and reduces the fruitfulness of developing buds. The 1-to-1 ratio of canopy height to canopy or row width minimizes the shading of any canopy by adjacent ones. Note that principles 1 and 2 attempt to strike a balance between maximizing sunlight interception by grapevine leaves and minimizing intercanopy shade. In theory, principle 2 suggests that with a standard canopy height of 4 to 5 feet (where the height is measured from the bottom to the top of the canopy, not the trellis height),

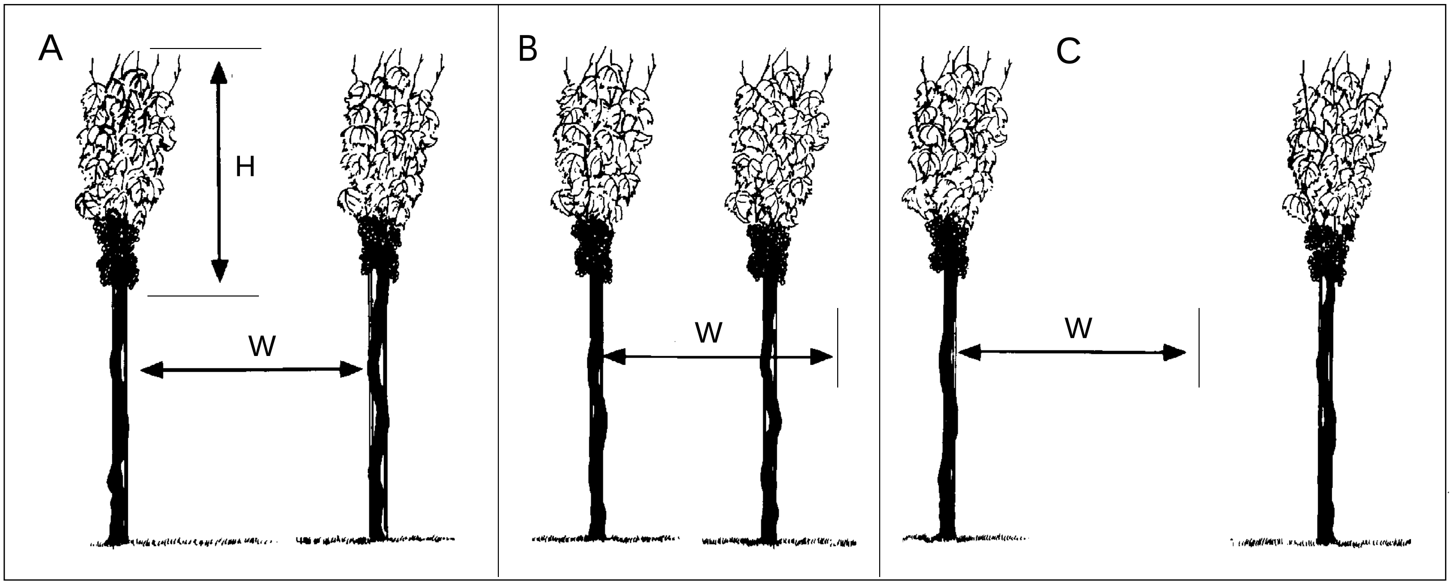


Figure 7.2. Canopy height (H) to width (W) ratio is 1:1 in A, less than 1:1 in B, and exceeds 1:1 in C. Canopies of A maximize sunlight interception by vineyard. Canopies of B shade each other. Canopies such as C result in inefficient interception of sunlight.

rows (or canopies) may be spaced as closely as 4 or 5 feet apart (Figure 7.2). In practice, equipment width often dictates that row spacing be about 8 to 10 feet. The advent of specialized, narrow vineyard equipment in the United States may permit reduction of row spacing and more efficient use of vineyard area.

PRINCIPLE 3: Canopy shade should be avoided, especially in the fruit and renewal zone. Leaves and fruit should be exposed to as uniform a microclimate as possible. Canopy shade can significantly reduce fruit and wine quality. The negative effects of shade on fruit composition include elevated levels of potassium, pH, and titratable acidity levels; reduced pigmentation; and reduced concentrations of phenols and soluble solids. Collectively, the altered fruit composition can significantly reduce wine quality. Shade can also retard the development of varietal character and impart vegetative characters to the fruit and wine. Furthermore, shade can promote fruit rot by reducing the resistance of fruit and leaves to infection and by reducing the rate of drying within the canopy. Shade also reduces bud fruitfulness. Buds that developed in shaded renewal zones tend to produce shoots with fewer and smaller clusters and reduced berry set, or those buds may fail to produce shoots at all.

PRINCIPLE 4: Shoot growth and fruit development should be balanced to avoid either too much or too little leaf area in relation to the weight of fruit. That is, vines should produce just enough foliage to ripen large crops of high quality grapes. Excessively vigorous vines produce large shoots (relatively large in diameter, with long internodes, large leaves, and a tendency to develop active lateral shoots), resulting in dense canopies. Insufficient vigor, on the other hand, typically results in stunted shoots that have insufficient leaf area to ripen the crop. Applying this concept of balance between shoot growth and crop weight requires some method of measuring the relationship between the two. One measure of balance for a given vine is the ratio of crop weight to cane pruning weight. That ratio is sometimes called crop load. (See the following section, "Assessing Canopy Characteristics.")

PRINCIPLE 5: Training systems and dormant pruning should promote uniformly positioned fruiting and renewal zones. Uniformly positioned vine parts greatly facilitate mechanization of vineyard operations and even simplify hand labor for certain practices. Shoots that arise from a uniform height on the trellis, for example, are easier to summer prune or hedge.

Uniform positioning of fruit makes it easier to remove leaves selectively from the fruit zone, and the fruit can be more rapidly picked by hand than when the fruit is borne over a larger region of the canopy. Creating a uniformly positioned renewal zone is also desirable for physiological reasons relating to uniformity of bud break and shoot growth.

Assessing Canopy Characteristics

One of the most confusing aspects of canopy management for many growers, especially novices, is determining whether the density of their vine canopies is ideal, acceptable, or excessive — in other words, knowing how to decide when corrective measures should be applied. While experienced growers may rely on observation and experience, new growers can benefit — and gain confidence — by assessing canopy characteristics with quantitative methods.

Several inexpensive, rapid techniques are commonly used by vineyardists to assess vine canopies. A collection of eight visual observations has been compiled in the form of a scorecard. (see the book *Sunlight into Wine* listed in the references.) With a minimum of practice, the scorecard can be used to assess canopies and rate characteristics such as leaf size and canopy density by comparison with an ideal canopy. Canopy scoring is a very useful technique even if not all eight elements of the scoring system are used. Direct measurements are also useful and remove some of the subjectivity inherent in the scorecard approach. Some of the more commonly used measurements are (1) cane pruning weights, (2) crop load, (3) shoot density, (4) canopy transects, and (5) periodic measures of shoot length. Each is described and related to desirable ranges in the following sections.

Cane Pruning Weights

The weight of one-year-old wood (canes) removed from a vine during dormant pruning provides a measure of the vine's capacity for fruit and shoot growth in the following year. Thus, pruning weights can be used to determine the number of buds to retain at dormant pruning, as described in chapter 6. Pruning weights also indicate whether vines have insufficient or excessive vigor for their available trellis space. Well-balanced vines should have pruning weights ranging from 0.2 to 0.4 pound per foot of canopy. Thus, for vines spaced 8 feet apart in the row and trained to a nondivided canopy system, pruning weights should range from 1.6 to 3.2 pounds. If the majority of vines produce less than 0.2 pound of pruned canes per foot of canopy, consider stimulating vine vigor. These vines probably do not have sufficient vigor to fill their available trellis space with foliage, and crop yields will be unnecessarily constrained. Vine vigor and pruning weights can be increased in several ways, including crop thinning, application of nitrogen fertilizer, and irrigation. Conversely, if most vines produce more than 0.4 pound of prunings per foot of canopy, the vine size and vigor is probably too great and the canopy has been too dense. If other observations and measures support the conclusion that vine vigor and canopy density are excessive, thought should be given to reducing canopy density in the following year. (See the section "Canopy Modification" later in this chapter.)

The practice of summer pruning reduces dormant pruning weights and should be taken into account when evaluating pruning weight data. It is incorrect, for example, to judge a vine with 0.3 pound of prunings per foot of row or canopy to be balanced if that vine required repeated summer pruning during the previous growing season.

Crop Load

Crop load, as defined earlier, is the ratio between the weight of the crop and the weight of pruned canes produced during the same season. This ratio is one measure of whether vines are balanced between vegetative growth and crop production in accordance with principle 4. Determining crop load requires weighing both the fruit at harvest and the canes removed at pruning. For practicality, these measurements are usually limited to 10 or 20 representative vines per vineyard block. Unless damaged or killed, the same vines should be used each year to develop a long-term data base on the vineyard block's performance. The same vines might be used for the other canopy measures to be described here, and for crop estimation, as described in chapter 8.

Research on different varieties under varied growing conditions has shown that crop load ratios should range from 5 to 10. Thus, for vines with cane pruning weights of 2.5 pounds, crops should range from 12.5 to 25 pounds. Vines with crop-load ratios outside the range from 5 to 10 should be evaluated for conditions that might explain the disparity. Crop-load ratios less than 5 indicate excessive vegetation in relation to crop weight (although this condition is normal for young, nonbearing vines). Crop-load ratios greater than 10 are likely associated with overcropping. Symptoms of overcropping include delayed sugar accumulation, reduced fruit coloration, and delayed or reduced wood maturation in the fall. Information gained by measuring crop load in a given year can be used to adjust crops or shoots during the following growing season in order to move toward a more balanced vine.

Shoot Density

Shoot density is a measure of the number of shoots per unit length of canopy and usually relates well to overall canopy density: the greater the shoot density, the thicker, or denser, the canopy. Shoot density can be assessed at any point in the growing season, but it is often done after bud break. The count should be in the range from 4 to 6 shoots per foot of row or canopy. For vines spaced 8 feet apart in the row and trained to a nondivided system, the total number of shoots per vine should range from 32 to 48. The lower number is more suitable for large-clustered, very fruitful varieties such as Seyval and Sangiovese. The higher limit is suitable for small-clustered varieties such as Pinot noir and Riesling. As a starting point, most varieties will produce desirable yields of ripe fruit at a density of five shoots per foot of canopy.

Canopy Transects

Canopy transects are used to quantify canopy thickness (number of leaf layers), porosity (gaps in the foliage), and the percentages of fruit and leaves exposed to sunlight. Also called *point quadrats*, canopy transects consist of multiple, transectional probes of representative vine canopies with a thin rod. Contacts that the probe tip makes with leaves, fruit, or canopy gaps are recorded as the probe is passed from one side of the canopy to the other. Transects require at least two persons (one handling the probe and one recording data) and are done at or shortly after véraison. In practice, a thin rod is inserted horizontally and at regular intervals (for example, every 6 inches) into the fruit zones of representative vines. A metal tape measure or ruled wooden frame will serve as a guide for probe insertion. Aside from locating the point of probe insertion, the person using the probe should not watch its path through the canopy. An observer tracks the point of the probe and records the nature of all probe contacts as either a leaf (L), a cluster (C), or a gap (G). Gaps are recorded only where the probe fails to contact any leaves or fruit in its passage through the canopy. Contacts with shoot stems are generally ignored. Data are recorded as shown in Table 7.2. In this case, 50 probes were made and the calculations of canopy density were as follows:

Table 7.2. Representative Canopy Transect Data Summarizing the Nature of Contact by 50 Passes of a Probe

Probe Pass	Nature of Contact*	Probe Pass	Nature of Contact	Probe Pass	Nature of Contact	Probe Pass	Nature of Contact	Probe Pass	Nature of Contact
1	LLFL	11	G	21	LL	31	F	41	L
2	LLL	12	LL	22	LLF	32	LL	42	G
3	FLL	13	FLLL	23	LFLL	33	FL	43	LF
4	LL	14	LL	24	F	34	G	44	LFL
5	G	15	LFFL	25	LL	35	LL	45	LLL
6	FL	16	LLL	26	LLL	36	LFL	46	LL
7	LF	17	LL	27	FLL	37	LLL	47	F
8	LL	18	LLL	28	LL	38	G	48	LF
9	F	19	FL	29	G	39	LFLL	49	LL
10	LL	20	LLL	30	LL	40	LLLF	50	LFL

*Nature of probe contact: L = leaf, F = fruit cluster, and G = gap. Contacts with shoot stems are ignored.

Percentage of gaps = gaps ÷ number of probes (6 ÷ 50 = 12%)

Leaf layer number = leaf contacts ÷ number of probes (85 ÷ 50 = 1.7)

Percentage of exterior leaves = exterior leaves ÷ total leaf contacts (68 ÷ 85 = 80%)

Percentage of exterior clusters = exterior clusters ÷ total cluster contacts (15 ÷ 23 = 65%)

Canopy transects, if repeated at least 10 times in each vineyard block, can provide a considerable amount of information on canopy density. Again, these data can be compared to ideal canopy parameters to determine whether remedial action is necessary, either in the current or following year. For example, the percentage of canopy gaps recorded should be about 20 percent, the leaf layer number should range from 1.0 to 2.0, and the percentage of exposed leaves and fruit should be at least 80 percent and 50 percent, respectively. (See *Sunlight into Wine*.)

Shoot length and lateral shoot development should also be assessed. Ideally, shoots should grow rapidly to 15 or 20 nodes or leaves in length and then stop growing and develop few or no lateral shoots. In reality, shoots of vigorous vines often continue to elongate after fruit harvest and may exceed 50 nodes in length. The same shoots may also develop many persistent summer laterals. Shoot vigor should be assessed periodically throughout the growing season and the shoots hedged, if necessary, to prevent shoot tops from aggravating canopy density and canopy ventilation. (See the section “Summer Pruning” in this chapter.)

Canopy Modification

An assessment of vine canopies using one or more of the methods described may show that the canopies are far from ideal. While drought, infertile soil, and vine disease can all contribute to low vigor and sparse canopies, the opposite condition — high vigor and excessive canopy density — is the more frequent situation, especially with grafted grapevines. Therefore, the canopy modifications described here are intentionally aimed at improving the microclimates of dense canopies. Some of these measures offer only short-term solutions, whereas others, such as canopy division, offer more lasting benefits.

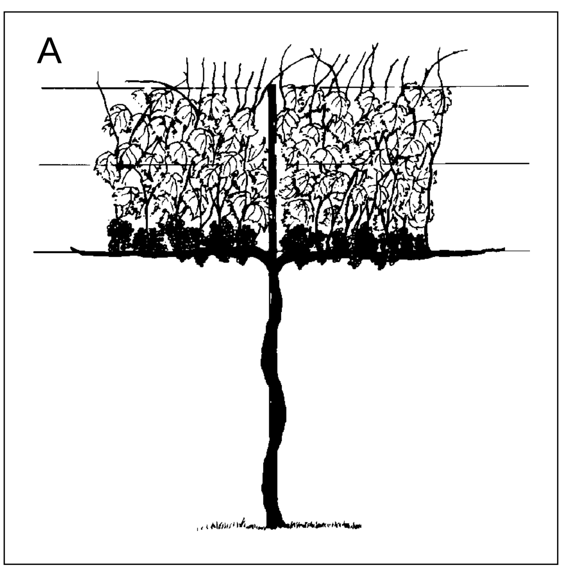
Summer Pruning

Summer pruning, or *hedging*, involves removing vegetation during the growing season. Typically, this process involves removing shoot tops, retaining only the nodes and leaves needed for adequate fruit and wood maturation. Specific recommendations for hedging depend on the training system used. Hedging is probably most beneficial when applied to low- or mid-wire-trained vines that have upright-positioned shoots. Low-wire bilateral cordon training with upright shoot positioning is such a system. It is fairly easy with this system to top shoots once the shoots have cleared the top of the trellis and before they start to droop over and shade the original canopy. Depending on cordon or cane height on the trellis, shoots that have elongated a foot or so higher than the 6-foot-high trellis will generally have 15 to 20 leaves and can be hedged at a uniform level. Shoot topping does not have as much benefit with vines whose shoots are not positioned — at least not from the standpoint of providing ventilation of the fruit zone. The reason for that reduced response is illustrated by Figure 7.3 and is one of the bases for principle 5, cited earlier. Hedging the low-trained, shoot-positioned vines removes shoot tops that are shading the fruit zone of the original canopy (A). Hedging shoots on high-trained vines, in the absence of downward shoot positioning, does not appreciably improve ventilation in the fruit zone (B). In fact, hedging such vines can sometimes reduce fruit zone ventilation by causing greater lateral shoot growth in the fruit zone. A better canopy management strategy with high-trained vines is the downward "combing" or positioning of shoots during the growing season. Whether the shoot tops are ever removed is not as important as preventing them from growing horizontally.

Hedging should be delayed as long as feasible — preferably for 30 or more days after bloom. Retain a minimum of 15 primary (not lateral) leaves per shoot. It is not necessary to count leaves on every shoot, but with most varieties the shoots will average 4½ to 5 feet in length when they bear 15 to 20 primary leaves. Heavy-duty, scissor-type hedge shears are the most commonly used hedging tools. Gasoline or battery-operated cutter-bar hedgers have also been used. In either case, the process is less tiring if one works with arms at chest height by standing on an elevated platform such as a trailer.

Altered Training Systems

Training systems that promote ventilation of fruit zones have an advantage over those that tend to hide the fruit within shaded canopy interiors. The training system should promote maintenance of a thin canopy of foliage (no more than two leaf layers thick). For large, vigorous vines in established vineyards, conversion to divided canopy training might be the most practical way to achieve the desired canopy density. Canopy division should



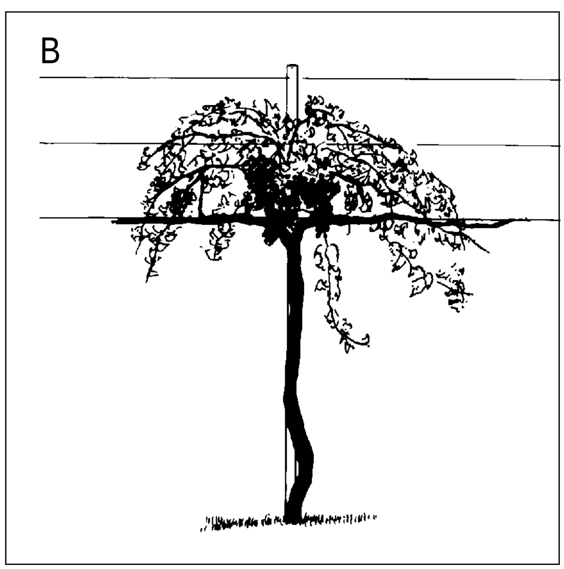


Figure 7.3. Gross effects of hedging shoot-positioned, vertically upright-trained canopies (A), compared with hedging of non-shoot-positioned canopies (B). The benefits of hedging on fruit zone ventilation (and exposure) are likely to be greater with (A) than with (B).

be considered when the majority of vines have average pruning weights in excess of 0.3 to 0.4 pound of prunings per foot of canopy in the absence of summer pruning. Several approaches to canopy division should be considered and specific guidelines sought before pursuing this course. The establishment of multiple trunks before the year of conversion makes the process much easier and avoids loss of crop in the conversion year.

Canopy division is not always practical for existing plantings. For nondivided canopies, bilateral cordon training coupled with upright shoot positioning (to be discussed later) is one of the more efficient systems in use in Virginia, both in terms of pruning labor and canopy management. With low- to mid-wire cordon training (36 to 44 inches above ground), the shoots originate at a uniform height and fruit is borne in a fairly limited region of the canopy. Both of those features greatly facilitate canopy management practices such as shoot thinning, selective leaf pulling, and shoot positioning. Cordon training (either high or low) is less desirable, however, in situations where winter cold injury makes the perennial maintenance of cordons difficult or impossible.

Shoot Positioning and Shoot Thinning

Some shoot positioning should be an integral part of vineyard management. The objective of shoot positioning is to position the vine's shoots and foliage uniformly in the vine's available trellis space and minimize mutual leaf shading. For high-trained vines, shoot positioning entails combing the shoots down to form a curtain of well-exposed foliage. For low-trained vines (for example, those trained to a low, bilateral cordon system), the shoots should be positioned upright, again to form a thin, well-exposed canopy. Paired catch wires can be added to the trellis to sandwich the shoots and prevent them from being blown free once positioned. Also, various shoot tying or taping devices are commercially available. Shoot positioning is easier if done repeatedly rather than waiting until the shoots are very long and in need of substantial redirection. If the process is started at about bloom time, most shoots can be positioned without breakage and before their tendrils have secured the shoots to wires or other supports. Depending upon the number of foliage catch wires used on the trellis, some repositioning of shoots may be necessary between bloom and véraison to maintain the desired canopy dimensions.

Shoot thinning is also a good technique for maintaining a more open canopy. An added advantage of shoot thinning is that it can control crop in varieties that tend to overproduce (for example, Seyval). Shoot thinning is done soon after bud break and preferably before shoots are more than 18 to 24 inches long. Longer shoots are more difficult to remove. A convenient rule of thumb is to retain four to six shoots per foot of canopy (as recommended previously under "Shoot Density"). The choice of shoots to be retained should be made with regard to their spacing on the cordon or trellis and their fruitfulness. Except where needed for spurs the following year, unfruitful shoots should be removed in preference to fruitful shoots unless crop reduction is desired.

Selective Leaf Removal

The selective removal of leaves from the area around fruit clusters has been practiced increasingly in the United States in recent years. Research in Virginia with Riesling and Chardonnay vines has illustrated that the practice can be an effective tool for fruit rot control. The leaves can be removed anytime between fruit set and véraison; however, early leaf removal may have to be repeated to keep fruit clusters open, and post-vérasion leaf pulling can result in the fruit being sunburned. The goal of leaf pulling is to increase ventilation and light penetration into the fruit zone. Generally, only one to three leaves per shoot are removed. It is not necessary to remove all leaves in the fruit zone. The objective is to have an average of one to two leaf layers remaining in the fruit zone after the leaves have been pulled. Leaf pulling is more efficient with training systems that have uniformly placed fruit zones (such as with bilateral cordon training), compared with systems in which one must hunt for the fruit clusters. With the latter systems, as with hedging, more basic canopy management techniques such as training system conversion and shoot positioning may be more useful than leaf pulling. Leaf pulling is most often done by hand, but several vineyards use tractor-mounted machines to increase the speed of operation.

References

Smart, R. E., J. K. Dick, I. M. Gravett, and B. M. Fisher. 1990. Canopy management to improve grape yield and wine quality: Principles and practices. South African Journal of Enological Viticulture 11:3-17.

Smart, R. E., and M. Robinson. 1991. Sunlight into Wine: A Handbook for Wine Grape Canopy Management. Winetitles, Adelaide, Australia.