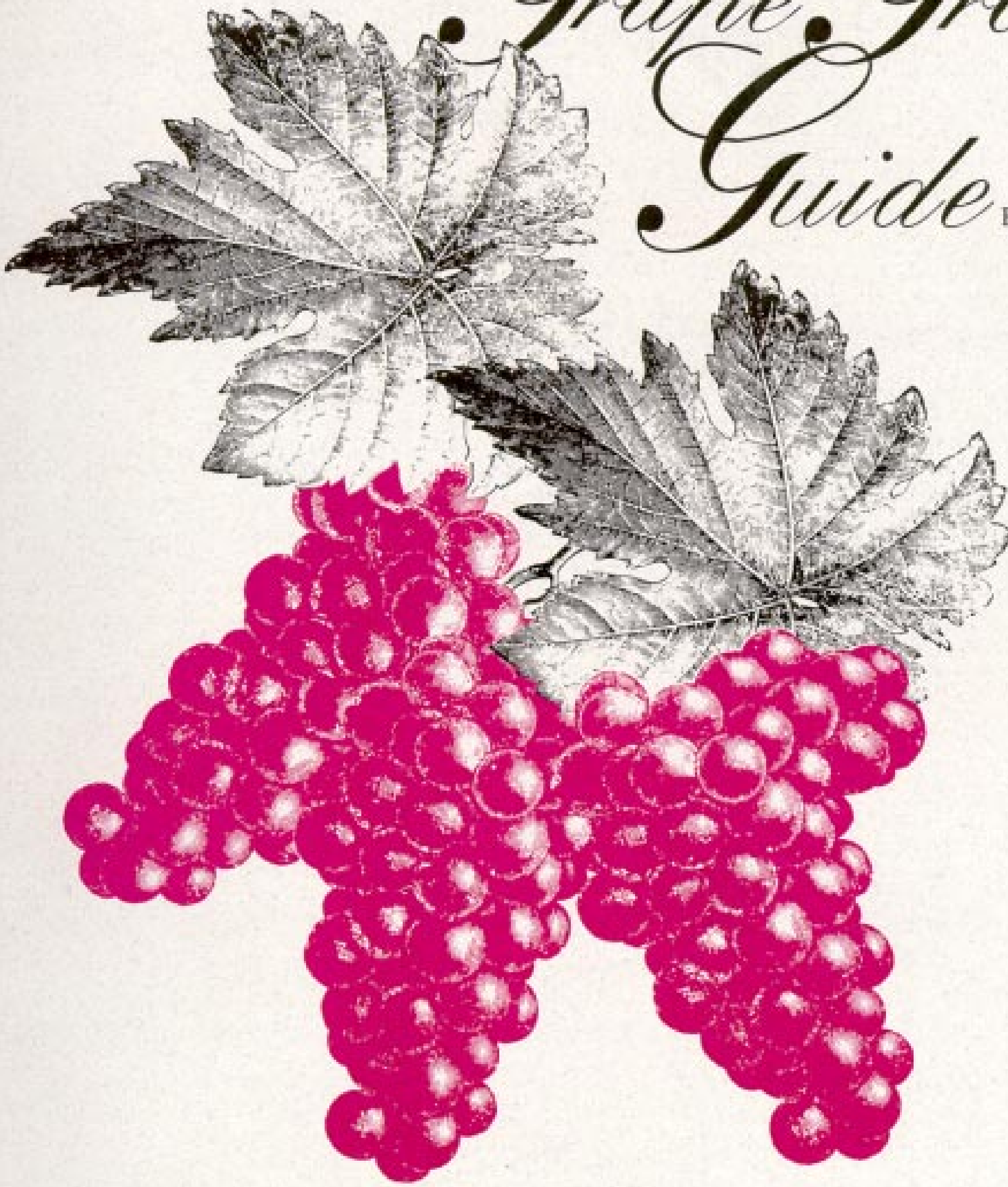
Colorado Grape Growers' Guide

Bulletin 550A



Colorado State University Cooperative Extension

THE COLORADO GRAPE GROWERS' GUIDE

1998 Edition

by

Richard A. Hamman[1], Jr., Steven D. Savage, and Harold J. Larsen

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(970) 491-6198

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[1]Research Viticulturalist, Plant Pathologist (formerly with Colorado State University), and Research Plant Pathologist and Cooperative Extension Fruit Disease Specialist, respectively. **Colorado State University, Colorado Agricultural Experiment Station - Orchard Mesa Research Center, 3168 B.5 Road, Grand Junction, CO 81503.**

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Introduction

Wine grapes have been grown in several counties of Colorado since the end of the last century. A renewed interest in wine grape cultivation was initiated during the mid-70's and the most dramatic growth of the Colorado Wine Industry is occurring this decade. Since 1990, vineyard acreage has increased from 242 to over 400 acres. State production levels have also increased from 107 tons to 755 tons and mature vineyards in 1997 averaged 3.4 tons/acre. The current and future market for Colorado wine grapes appears healthy with 21 licensed wineries that have the capacity to produce approximately 215,000 gallons of wine or the equivalent of 1,300 tons. Ninety percent of the Colorado acreage is in Mesa and Delta counties. The issues of cold climate limitations on wine grape culture are of extreme importance to Colorado growers. It has been demonstrated that with careful site selection, varietal selection and use of proper viticultural management techniques, vineyards can tolerate winter conditions to a degree that allows their survival in selected locations in Colorado. Winter hardiness is the only limiting factor for grape culture in the state, since many severe disease and insect pest problems do not yet play an important role.

The unique aspects of grape growing in Colorado are the indirect effects of high elevation. Most suitable sites lie between 4,500 and 6,000 feet above sea level – substantially higher than most growing regions of the world. The high elevation is accompanied by an extremely dry climate. Because of these factors the region experiences intense sunlight and large daily temperature fluctuations. These features foster high pigment production and high acid, retention in most grape varieties just as they do for the traditional peach and apple crops of the area. Thus, grapes that survive Colorado winters can mature and produce fruit with highly desirable wine making characteristics.

As grape growing is both uncommon and in a sense new in Colorado, many gaps remain in our knowledge of optimal growing practices. The viticulture program at Colorado State University Orchard Mesa Research Center is currently addressing the unique problems facing Colorado growers. The CSU viticulture program provides growers and vintners with technical assistance and conducts applied research and field demonstrations in wine grape production. Colorado State University Orchard Mesa Research Center is located at 3168 B½ Road, Grand Junction, Colorado 81503, 970-434-3264.

This publication is intended to present what has been learned about the particular needs of grapes in a high desert region. The experience of many growers is included as well as that from the test vineyard at the Colorado State University Orchard Mesa Research Center.

Many people contributed to the preparation of this new edition and their help has been truly appreciated. Special recognition is due to the pioneering grape growers of Colorado and the visiting scientists who have shared their experience and knowledge with us over the last decade.

ANATOMY OF THE GRAPEVINE

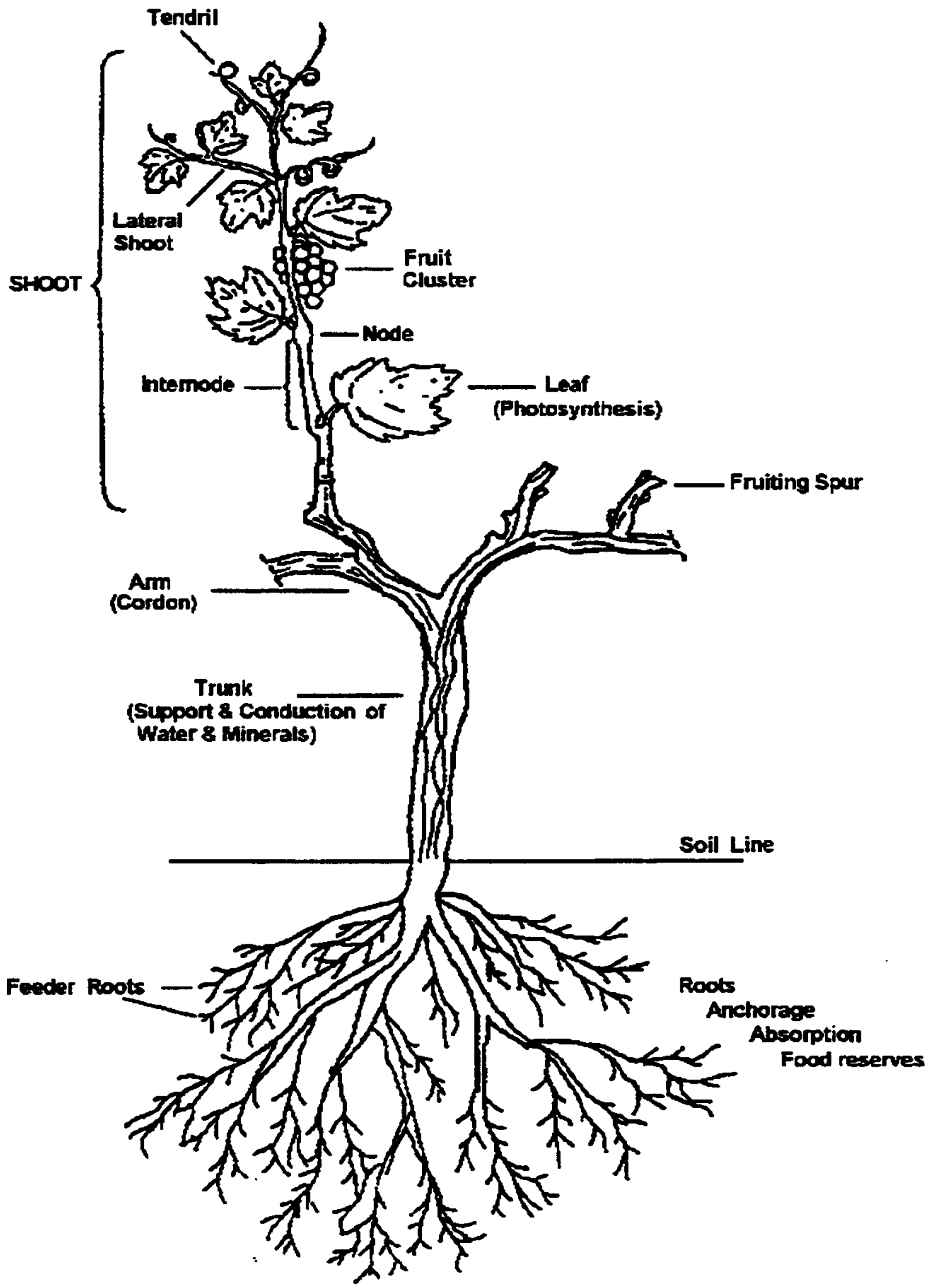

Figure 1. Anatomy of the grapevine.

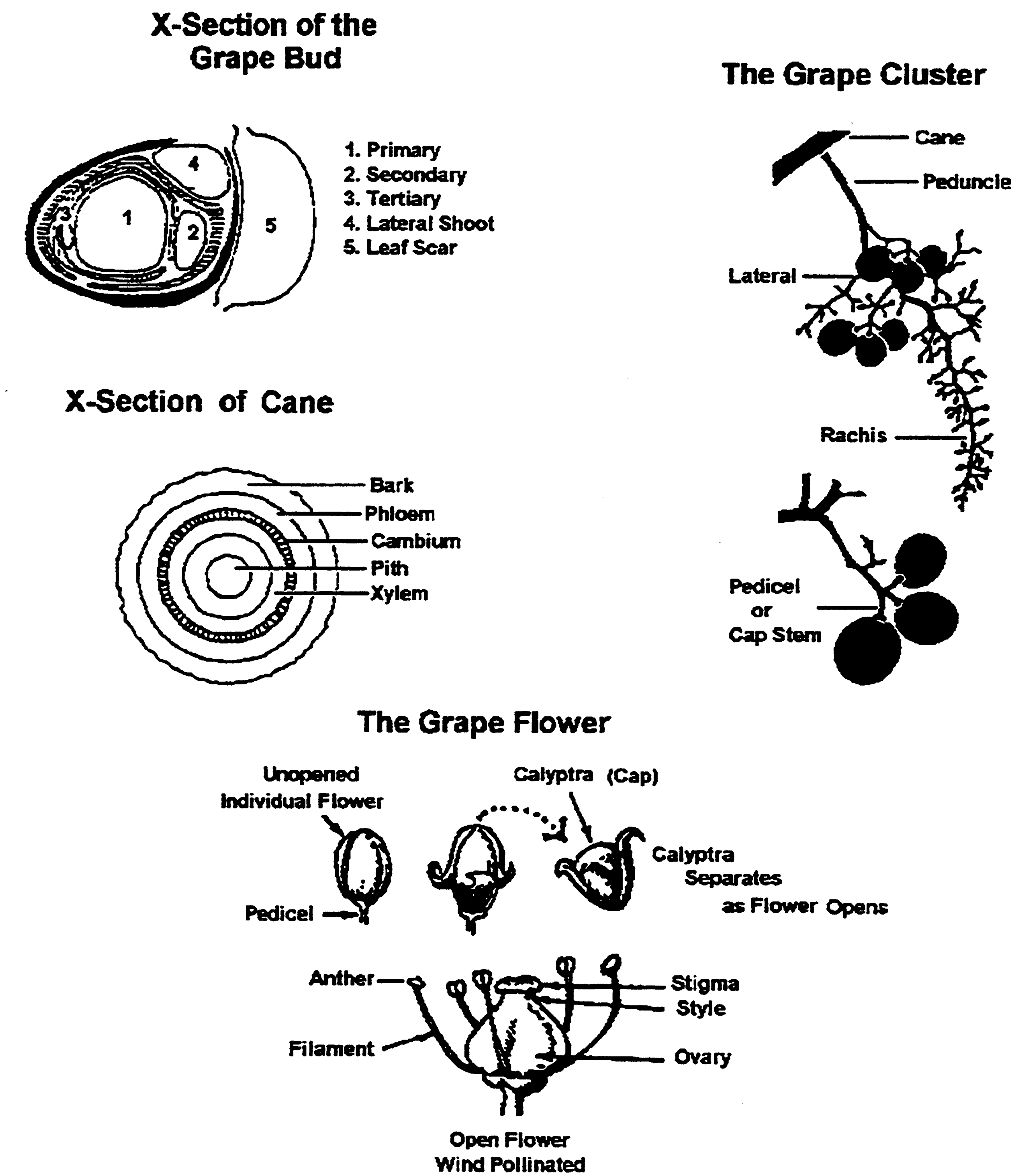

Figure 2. Grapevine structures.

Establishing a Vineyard

Site Selection

There are limits to the absolute cold temperatures that grapevines can survive, and the suitability of a location greatly depends on the frequency of large temperature changes. In general, arid continental weather is subject to dramatic changes and thus grape survival is feasible only in restricted areas that are somehow buffered from these changes. Large bodies of water, lacking in Colorado, moderate temperature changes. In the high desert region, the mildest, most buffered climates occur in certain major river valleys such as the Grand Valley of the Colorado, the North Fork Valley of the Gunnison and the Arkansas River Valley near Canon City. The protection afforded by these geologic features is beyond the scope of this publication, but the historic success of other fruit crops often is the best indicator of a location's suitability for grape production.

Within these major areas, localized microclimates play an important role in the feasibility of planting grapes on a specific site. The most important feature is cold air drainage (See Figure 1). Under calm conditions, the earth radiates energy to the sky and receives heat from the air closet to it. Cold air is heavier than warm and sinks to the ground; the gradient formed (cold air below to warm air above) is called an inversion. Cold air also acts like a liquid and flows to the lowest point. Slopes of two to three percent are sufficient to allow much of the cold air to move away, drawing down warmer air from higher layers. This process is extremely important in determining how cold a specific site will become on a calm, clear night. Temperature differences of as much as 10°F can occur in sites that are in close proximity, but have different cold air drainage characteristics. Often the coldest winter temperatures and the most damaging spring frosts occur during calm nights following the general cooling by a storm or cold front. Sites that escape spring frosts also will often be warmer during midwinter episodes. Such differences can be critical for vine damage. Because grapes start growth fairly late in Colorado (usually early May), there is only a short period during which frost damage may occur. Frost is actually a threat over a longer period in California and other major grape growing regions. As a rule of thumb, avoid planting wine grapes where there are 150 frost-free days or less.

Common Mistakes That Can Cause Poor Vineyard Development

Site:	planting in the wrong site (poor drainage)
Vine purchase:	poor quality
Timing of planting:	planting too late in the season
Irrigation system:	inadequate or not installed, poor use

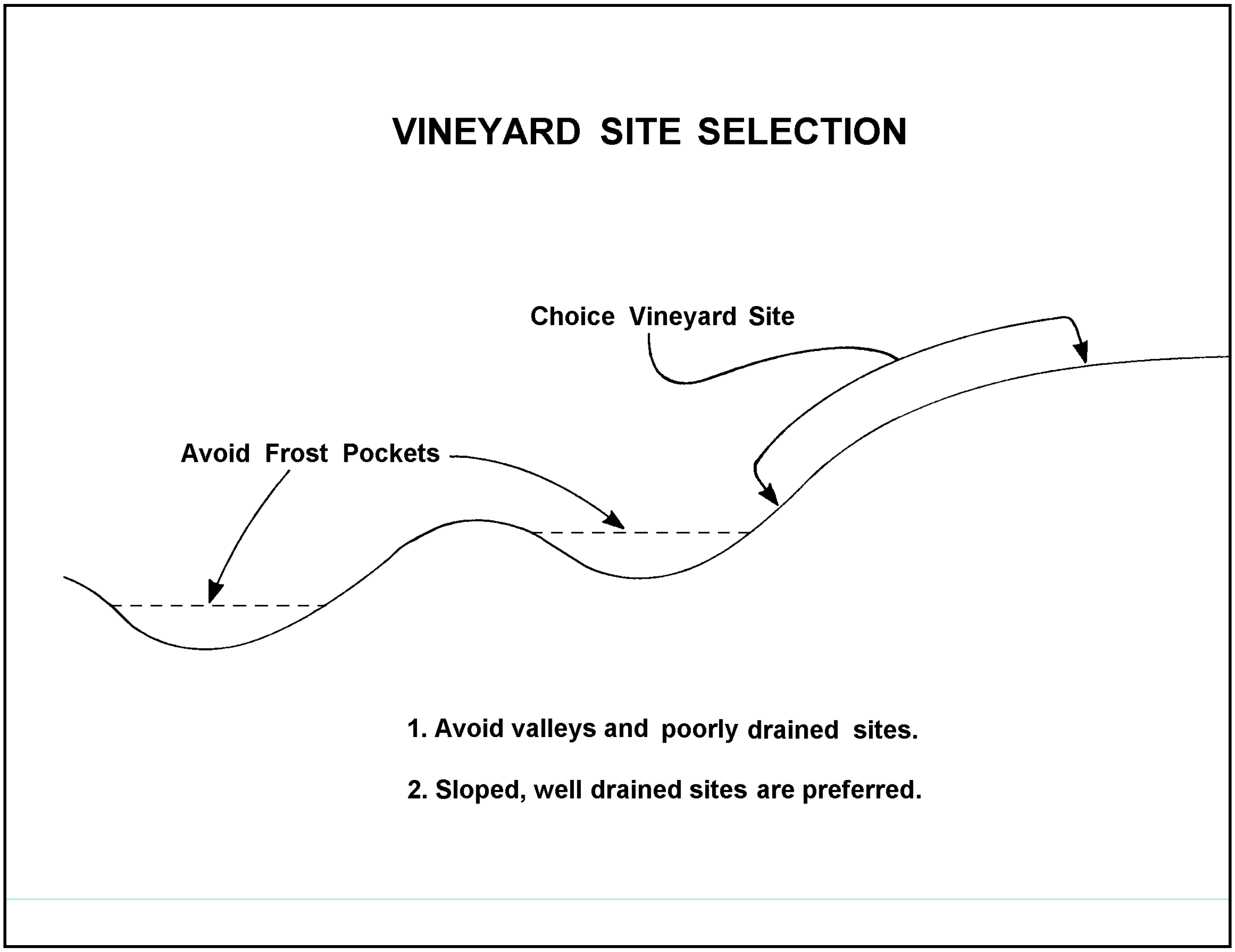

Figure 3. Vineyard site selection factors.

The exposure of a slope relative to the sun is a more complicated factor. During the day, a south or west facing slope will be some-what warmer throughout the year; however, this feature is not necessary to ripen grapes in Colorado even though it is important in other locations such as northern Germany. In fact, warming of soil on a south slope during the winter in Colorado can reduce winter survival.

Soils can play an important role in grape survival and potential wine quality. Ideal soils are deep, well-drained and not overly fertile. Such soils are difficult to find in many parts of Colorado with a climate sufficient for grape growth. For this reason, the limits due to undesirable soil types need to be discussed.

Deep soils - at least 3 to 5 feet - are needed to discourage shallow rooting. Many cultivated soils are sufficiently deep, but have formed clay hardpans. This can prevent grapes from rooting deeply, which is their natural growth characteristic. Checking for hardpans and taking steps to eliminate them (i.e., deep ripping) are critical steps in vineyard establishment; hardpans or other obstructions to deep water percolation need to be avoided or changed. The grape grower must be able to control the water status of the soil to manage vine hardiness. Extremely gravelly soils can prove difficult to water adequately in the semi-arid climate of Colorado; however, extremely heavy clay soils that cannot be drained should be avoided.

Grapevines have lower requirements for mineral nutrient levels than many other crops. Therefore, few soils require substantial fertilization to support grapes. High nitrogen avail-ability can inhibit the transition of grapes from vegetative to fruiting to dormant states and thus should be used with caution.

High salt is a more common soil problem than over/underfertility in western Colorado. The parent materials for many soils in the area are very high in calcium sulfates (gypsum) and carbonates. Grapes are not tolerant of high salts, and thus unleached soils or spots that accumulate salts through seepage and evaporation will not support vine growth. Analyze soil samples for a planting site. These tests include a check of soil conductivity which is an indication of salt content. Conductivities of less than 4 mmhos/cm are considered safe. Those above 6 mmhos/cm are considered to be very damaging to grapes. Check the salt content at various depths at the planting site; a low salt content near the surface does not guarantee a low salt content at a depth of 2 to 3 feet. In soils with previous cropping history, one generally encounters salt problems in discreet areas fed by seepage from irrigation canal systems. Areas with high water tables also are unsuitable for grapes due to high salts and excessive moisture.

Areas with sufficiently low salt levels are common, and it is possible to maintain low salt levels with low volume irrigation systems. However, true drip systems can accumulate salts if insufficient volume is applied.

A vineyard must have good quality water available throughout the growing season; water from drain ditches should not be used because of possible high salt content or unknown pesticide residue. Water is required during April to May for planting. Irrigation systems must be operational before planting occurs. Finally, midwinter desiccation can kill many vines in Colorado and must be prevented with a late fall irrigation to recharge the soil reservoir intentionally dried out after harvest. This is best applied after a frost to prevent any possibility of the vine's returning to a vegetative state.

Other factors to consider in site selection are wind, hail, deer and birds. Extremely windy sites could be troublesome due to mechanical vine damage and desiccation. Certain locations may tend to have a higher probability of hail damage. Check with neighbors for historical weather patterns. Bird feeding is a common problem in small vineyards with trees or other refuges for birds nearby. Deer and elk can cause major damage to both mature and immature vines. Fencing is the most effective means of control.

In summary, critical aspects to avoid in vineyard site selection are frost pockets, shallow or poorly drained soils, high salt accumulations, poorly irrigated and overfertilized locations. Desirable factors include unobstructed slopes, and relatively deep and well drained salt free soils without serious nutrient imbalances.

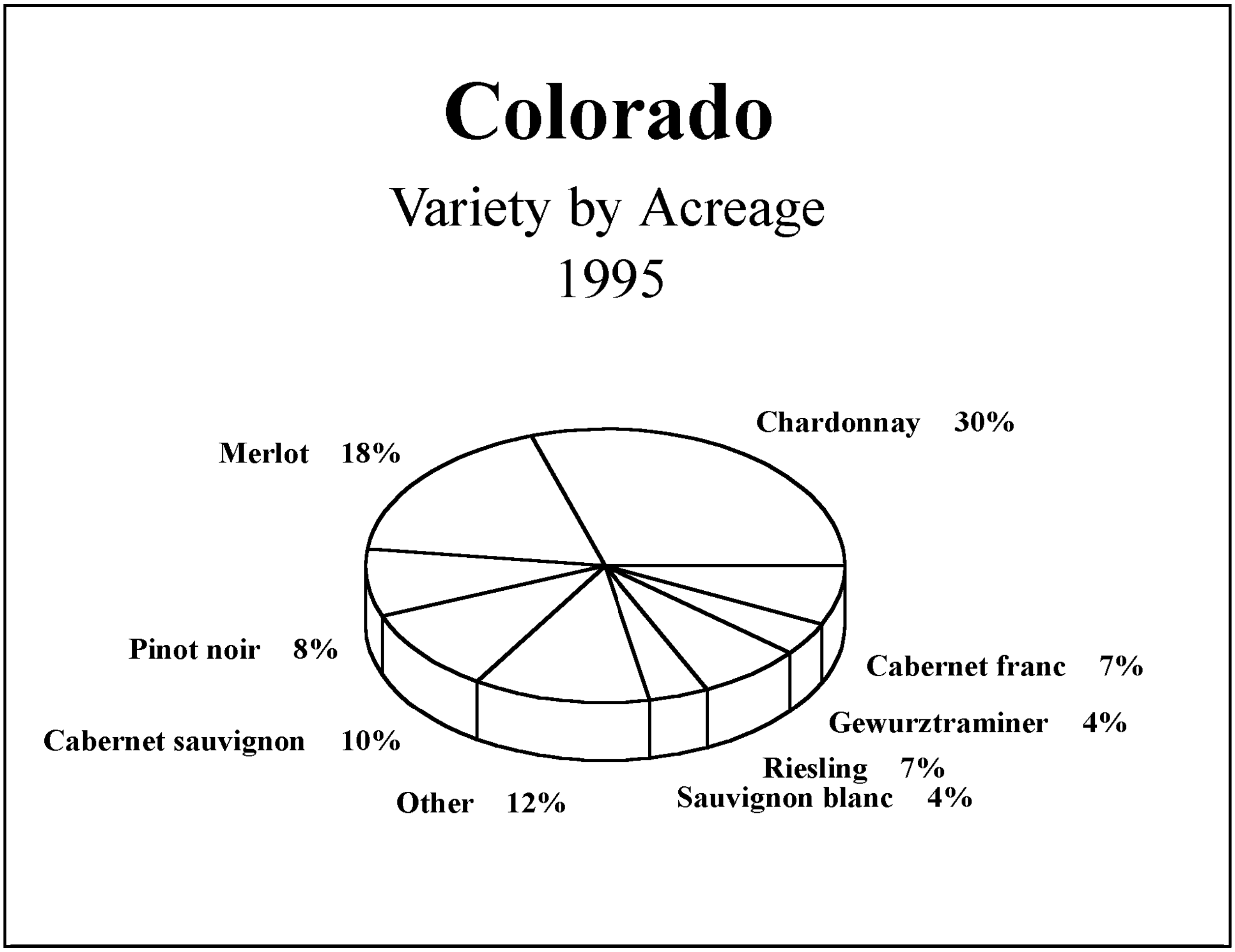

Figure 4. Wine grape varieties by acreage in Colorado. Source: 1997 CSU grower survey.

Plant Selection

Once a suitable site is chosen, many critical decisions and steps must be taken before the grapes arrive. Perhaps the most critical decision is which grape varieties to utilize. (Note: It is often necessary to place orders nine months to a year ahead of planting). Relatively few of the thousands of grape varieties known are of any present or potential commercial value. The grape grower must consider the relative winter hardiness, marketability, and potential quality of the variety when grown in Colorado. Visit 4 or 5 wineries and determine what varieties are currently in demand and what the future market looks like (See Figure 4). Additionally, many varieties have not been tested in Colorado. Even so, there are many varieties where not enough is known to either strongly recommend or tentatively discourage their planting. Wine grape varieties are presented in Section V and table grape varieties are discussed in Section VI.

Planning a Commercial Vineyard in Colorado

Considerable planning and investigative work is needed before planting a vineyard on a new site. This preliminary work can minimize or prevent future problems and often can determine ultimate success or failure. Some questions that must be addressed are as follows.

Economic Considerations: Will this project be economically viable? Gather all information possible and look carefully at start-up costs and annual expenses; then evaluate your projected returns. Market potential must be explored before planting grapes. Ask several local wineries what varieties they are currently buying and what they anticipate buying in 3 years. Ask them the current price per ton paid for these varieties. Supply and demand often directly affect winegrape prices.

Climate: Is it suitable or not? Winegrapes have been successfully grown in over 60 countries with a variety of climates. Between 160-200 frost free days are needed to mature fruit of many varieties grown in Colorado. Mid-winter low temperatures of -10^{o}F and lower can injure or kill buds and canes. Weather data gathered on the vineyard site are invaluable, however, be cautious when interpreting weather data obtained from a station located some distance from the actual vineyard site. Temperature differences of 10^{o}F or more between the station and vineyard may occur.

Site: What is a good site? Site selection cannot be over emphasized. Planting the vineyard in the wrong site can be very discouraging and costly. Continual retraining and low production are frustrating and labor intensive. The ideal vineyard site will be sloped (hill sides are best) and have very well drained soil with no hard pans. Avoid low lying valleys or areas where water and cold air naturally settle.

Water: Is irrigation water available when you need it? Most fruit growing areas in western Colorado are irrigated by open ditches from either rivers or reservoirs. Check availability of the irrigation water throughout the growing season. Grapevines typically use between 20-25 inches of moisture per season depending on conditions (soil, climate, etc.). Have the water analyzed if you suspect high salt content or if you are pumping from a well.

It is critical that an irrigation system that can supply adequate water for young vines is functional <u>before</u> planting begins. The most important aspect of the irrigation system is that it be reliable. Much of the acreage being newly planted is using micro-irrigation rather than surface irrigation. Both systems will grow grapes however, the micro-irrigation system has advantages such as; maintaining soil moisture at an optimum level, increased irrigation efficiency, improved chemical application, reduced weed growth, automation, and adaptability to difficult soil and terrain conditions.

Previous crop history? Observe other crops that are growing on or adjacent to the proposed vineyard site. These crops can give valuable clues to problem areas. Poor growth and low production may indicate problem areas and the need for further investigation. Subsurface water created by over-watering neighbors can be a problem. Careful observation of irrigation practices of land uphill and adjacent to your proposed vineyard site can help identify the need for a drainage system or an alternate site.

Any wildlife problems? Some vineyard sites are excellent homes for rabbits, prairie dogs, deer and elk. These animals can cause considerable damage to new or established vineyards if preventative measures are not taken.

If you suspect these animals are near by but see no evidence or signs, check with neighbors who may have historical knowledge of wildlife patterns in the area.

Fencing may be required before planting your vineyard.

Nursery Stock and Standards

The majority of grapevines are sold as dormant rooted cuttings. The dormant rooted cuttings are either grafted or self rooted. These rooted cuttings are graded by nursery industry standards.

Becoming familiar with these standards can make the difference between success and failure. Figure 5 demonstrates the relative size differences between a 2 year number 1 dormant rooted cutting and a 1 year number cutting and will transplant with better success and become number 1 dormant rooted cutting and a 1 year number 2 cutting. The 2 year number 1 is a more vigorous cutting and will transplant with better success and become productive quicker than the number 2 cutting. The rooted cutting should be produced in a *Phylloxera* free nursery and certified as virus free. Although certified virus-free vines are initially more expensive, they avoid the higher costs of lower production and poor plant health that virus-infected vines experience later. These cuttings should be ordered as far in advance as possible - usually one year prior to planting.

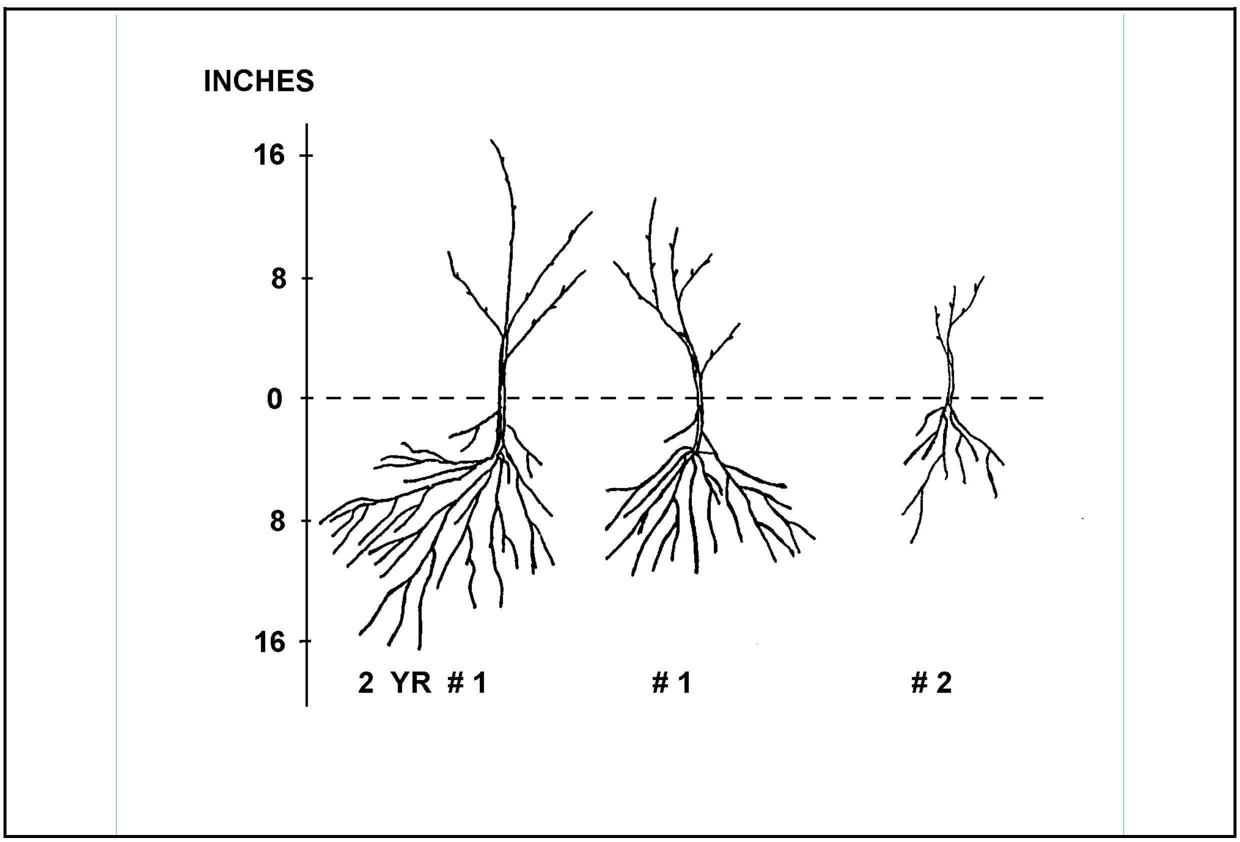

Figure 5. Typical nursery grading differences. The 2 YR #1 cutting is most desirable followed by the 1 YR #1 and then #2 cutting.

Rootstocks and Phylloxera

The primary reason for planting rootstock-grafted vines is the presence of phylloxera, a tiny aphid-like root louse that spends most of its life cycle in the soil feeding on grape vine roots. Susceptible vines eventually die.

The most effective technique in managing phylloxera has been the use of tolerant or resistant rootstocks. Grafting 2 different varieties or species to form a plant with desired characteristics is a technique that has been used for centuries in fruit tree production and viticulture. This cultural practice was first used to change variety, increase vigor or increase limestone tolerance with grapevines.

It wasn't until after the great European phylloxera epidemic during the decade of 1860, that the use of rootstocks increased dramatically. In France, the phylloxera epidemic had spread at a rate of 12.5 miles a year and by the end of the 19th century, grape phylloxera had killed more than two-thirds of the vineyards on the continent. At that time, all of the vineyards on the European continent were planted to self-rooted *Vitis vinifera*. The interest to control this pest was extremely important. Grafting the susceptible wine varieties to the resistant American species worked well and became an adopted practice that led to a chaotic period (1880-1930). Nurseries offered an assortment of rootstocks which caused new problems that were not previously known. Rootstocks were extensively studied in Europe and the New World for more than a century. Research after 1950 revealed that several aspects of scion behavior such as tolerance to soil borne pests and diseases, vigor, productivity, adaptations to growing conditions, resistance to chlorosis, etc. were dependent on features of the rootstock. (See tables 1-4).

In the 1850's, phylloxera was brought to California from the eastern US. In 1988, phylloxera was discovered in commercial vineyards in Washington state and in 1990 it was discovered in vineyards in Oregon. Both Washington and Oregon are relatively new grape growing regions. Colorado is also a new grape growing region with only 380 acres planted, however, the size of the industry or the climate does not make Colorado immune from phylloxera. Phylloxera has not been detected on the western slope of Colorado and has only been observed in Baca County (1993-Kondratieff) on a native american grape species. Currently, the Colorado wine industry is 98% self-rooted. In 1995 approximately 6 acres of rootstock grafted vines were planted in Colorado. Rootstocks should be considered in new plantings as an insurance against possible infestation.

A new strain of phylloxera called biotype B has recently become a major problem for California growers using AXR #1 rootstocks. The AXR #1 rootstock is susceptible to biotype B phylloxera. California growers are spending millions of dollars replanting AXR #1 rootstock vineyards to resistant rootstock-grafted vines. Due to the problem California has encountered with AXR #1 being susceptible to phylloxera biotype B, Colorado growers should avoid planting on rootstocks that have *Vitis vinifera* parentage (see table 1). In 1992, four phylloxera resistant rootstocks (3309C, 420 A, 101-14 and 5C) were planted for study at the Orchard Mesa Research Center. These rootstocks were selected for their phylloxera resistance and low-to-moderate vigor. The results of this study are not complete and their recommendations would be premature. Consequently, rootstock recommendations for Colorado is limited to experience from other cool climate grape growing regions (e.g. New York, Washington, Oregon). Based on experience from these areas vigorous rootstocks that tend to produce undesirable rank growth (eg. 5BB, 5C, 504, 99 Richter, Kober 125 AA) should be avoided. Rank excessive growth is winter tender growth and rootstocks with this characteristic should only be used in very low vigor sites (sandy, rocky well drained soils with low fertility). Rootstocks with low to moderate vigor (eg. 3309, 101-14, 420-A) are more desirable for most Colorado sites. Rootstocks require protection during the cold winter months. Routine hilling of soil 6-10 inches above the graft union in the fall will protect enough scion tissue to regenerate in the event of very cold trunk killing temperatures.

Table 1. Common rootstocks listed by parentage (Morton and Jackson, 1988)

Parentage	Rootstock
Riparia	*Riparia gloire* de Montpellier (Portalis)
Riparia, Berlandieri	SO4, 5 A, 5 BB, 5 C, 8 B, 34 E.M., 125 AA, 225 Ru, 420 A, 157-11 C, 161-49 C, RSB 1, Cosmo 2 & Craciunel 2 & 71
Riparia, Labrusca	Vialla
Riparia, Rupestris	3306 C, 3309 C, 101-14 Mgt, Schwarzmann
Riparia, Vinifera	143 A, 143 B
Rupestris	Rupestris du Lot (St. George)
Rupestris, Berlandieri	57 R, 99 R, Prosperi Super 99 R, 110 R, 140 RU, 775 P, 779 P, 1103 P, 1447 P
Rupestris, Vinifera	AXR 1 (ARG 1), 93-5 C ("XX"), 1202 C
Berlandieri, Vinifera	41 B, 333 E.M., Fercal
Complex (2 species)	44-53 M, 1613 C, 1616 C, 1045 P, 196-17 Ca, 216-3 CA, 4010 Ca, Dog Ridge, Golia, Grezot 1, Harmony, Salt Creek (Ramsey), Tampa

Table 2. Phylloxera resistance rating; based on potted vines and Italian phylloxera. 10 is absolute resistance, 5 is tolerable resistance and 0 is completely susceptible. (from Pastena, B. 1976 Trattato di Viticoltura Italiana)

Rating	Rootstock
10	*rotundifolia*
9	*riparia, berlandieri,* and *cordifolia*
8	*rupestris,* 779P, 420A, 41B(?)
7	St George, 1103P, 140Ru, 11OR, 775P, 41B (in Palermo), 1447P
6	3306C, 3309C, 225Ru, SO4, 5BB, 161-49, 157-11, 1045P, 44-53
5	Solonis, Jacquez
4	AXR#1, several hybrid direct producers
2-3	several *vinifera* cultivars: Tannat, Nocera, Olivetta, Carignane, Sangiovese, Barbera, Trebbiano dorato, Sauvignon, Grecanico
1	hybrid direct producers (many S.V. numbers, some Seibel)
0	*Vinifera* and more hybrid direct producers.

Table 3. Resistance to nematodes (*Meloidogyne* spp.) (from Pouget and Delas, 1989)

Rootstock Variety	Resistance
3309C	low
Gravesac	low
110R	low
161-49	low
41B	low
Riparia Gloire	moderate
420A	moderate
Fercal	moderate
101-14	high
140Ru	high
1103P	high
SO4	high

Table 4. Resistance to lime-induced chlorosis; value of the Chlorosing Power Index (IPC) above which symptoms appear.(from Pouget and Delas, 1989)

Rootstock Variety	IPC	
Riparia Gloire	5	Low
101-14	10	
3309C	10	
Gravesac	20	
110R	30	
1103P	30	
SO4	30	
420A	40	
161-49C	50	
41B	60	
140Ru	90	
Fercal	120	High

Site Preparation

Preparing the site for a vineyard is very important and should be planned out in advance. One of the first steps in preparation is to remove all trees, stumps, rocks, wire, and even old unusable irrigation pipe. Reluctance to remove that wonderful shade tree is often regretted later when the vines planted near the shade of the tree don't grow like the vines planted in the open, unshaded field. Special soil preparation decisions like deep ripping or weed control are best attended to before vines are planted, especially if the use of big machinery is required. Perennial weeds such as bindweed (*Convulvus* sp.) or even alfalfa are very persistant and are best removed if treated with herbicides (i.e. glyphosate) the season before planting, typically at the end of August. If a subsurface hardpan (created by equipment use or a natural impervious layer) is suspected, the vineyard should be deep ripped below that depth before planting when the soil is dry, typically the first of September. Powerful heavy machinery (D-8 cat or larger) is required for effective ripping of 45 inches or more. The ripped field will benefit from freeze/thaw action if left uncultivated during the winter months. As soon as the winter moisture subsides, disk, plow, disk, and float (level) your vineyard site for final preparation. At this time, surveying the vineyard for row orientation and vine spacing will facilitate the planting process. Planting holes are most often augered, although in clay soils this can produce a "flower pot" effect. Holes can be made in the fall before planting and will weather sufficiently to prevent this. Holes augered in the spring should have their sides cut away (caved in) at planting in order to break any glazing of the hole wall. Vines can also be planted in a V-ditch with the aid of a tractor mounted V-ditcher. A very reliable but often disliked method of planting is simple hand digging. Individual vine stakes should be placed before or during planting since delays in their placement during the training year can be costly in terms of proper vine formation.

Vineyard Development Checklist
(One year in advance)

- Determine Market outlook and winery demand, and select appropriate varieties.
- Determine physical and chemical suitability of soil (back hoe, soil test).
- Check irrigation water availability and quality.
- Check for diseases and nutritional imbalances of existing crops.
- Control perennial weeds: bindweed.
- Clear site and level the land if needed.
- Rip the soil when it is dry (August-September).
- Disc, plow, smooth soil in preparation for planting.
- Survey the vineyard site.
- Make scale drawing of the proposed new vineyard.
- Order #1 certified virus free dormant rooted cuttings from nursery.
- Install irrigation system.
- Install elk/deer fence (if necessary).
- Lay out and plant vineyard in the spring after frost hazard is past and soil has warmed.

Trellising/Training:

There are several dozen different trellis systems in use today. We do not attempt to discuss them all in this grape guide. Each trellis system is unique and has a function specific to each situation. The handbook for canopy management "Sunlight into Wine" by Smart and Robinson is an excellent reference for those who need more information on various trellis/training systems. The scope of this section is to provide some major factors to consider when selecting your trellis and to provide some basic information on constructing a commonly used vertical shoot positioned trellis system.

Trellising and training go hand in hand. Training is the strategic development of grapevine structure and the trellis supports that vine structure. The basic goal of trellising and training is to maximize production, facilitate cultural operations (i.e. spraying, tillage, pruning, harvesting), improve canopy microclimate and to support the mechanical load of the vine.

The initial choice of a trellis system is critical because vineyards are long term and usually trellised only once. Vineyard retrofitting or converting a vineyard to an improved trellising system is possible during the dormant season but can be very costly.

In the last 20 years trellising of grapevines has seen considerable advances. The advances have been initiated by the desire to improve fruit quality, produce higher yields and increase vineyard mechanization (trimming, leaf removal, harvesting and winter pruning). These new improved trellis systems have had the most significant impact on vineyard canopy management. Some common features of improved trellis systems are; increased canopy surface area, decreased canopy density, increased capability for mechanization, improved yield and quality, better spray penetration, less disease (Botrytis and Powdery Mildew) and increased winter hardiness (more "sun" canes and less "shade" canes).

The following factors are the most important considerations when selecting your trellis system. Vineyard potential, variety vigor, and canopy spacing are the most important and to a lesser degree economic factors. Vineyard potential would include environmental factors (i.e. temperature, topography, soil, rainfall and wind) and cultural management decisions (shoot thinning, fertilization, irrigation etc.). Variety vigor can often determine the choice of trellis system. For example, choosing a single wire trellis as compared to an improved multiwired trellis system with moveable foliage wires may be sufficient for varieties with low vigor. Vines with excess vigor (long shoots, lateral growth, and shading) may need a more extensive trellis system such as a Geneva Double curtain, U-trellis or Lyre system. The high vigor trellis systems usually divide the canopy to support a higher number of buds and thus increasing canopy surface area.

Canopy spacing is a combination of row spacing and vine spacing. In Colorado, the distance between rows varies from 6 to 12 feet. Equipment availability, tractor widths and compaction has most growers planting 9 to 10 feet between rows. Specialized narrow vineyard equipment is not readily available in Colorado and thus 30-50 HP standard farm tractors are common. Closer row spacings (6 to 7 feet) increases soil compaction with standard tractors. As a general rule of thumb, row-spacings should not be planted closer than the height of the trellis (shading can occur).

Vine spacing, the distance between vines within the vine row is a combination of vine genetic vigor, soil capability and climatic factors. Vineyards in Colorado commonly have vine spacings between 4 and 8 feet. Vineyard sites that are fertile and productive need larger distances between vines. Soils in many vineyards of western Colorado substantially vary within the vineyard and may require vine spacing adjustments within a 200 foot vine row. Soil analysis and visual inspections before planting can assist in these decisions. Genetic vigor variation among varieties also plays an important role with vine spacing. Site specific vigor i.e. how well a particular variety grows in that specific site/situation would be ideal, but unfortunately only general information exists at this time. Genetically vigorous varieties typically require more distance between vines than less vigorous varieties. Vineyards in cooler sites generally have less growth (vigor) than warmer sites and therefore narrower spacings are more suitable. Growers in Colorado who have ignored soil or genetic vigor differences have had trouble training their vines to maximum production levels because of overcrowding, too dense of canopy, poor spray penetration and training/pruning confusion.

The Vertical Shoot Positioned Trellis (VSP)

The VSP trellis is a good canopy management system for low to moderately vigorous vines. The VSP works well in Colorado and the one described here is currently used at the OMRC. The VSP trellis contains either fixed or moveable pairs of foliage wires that enable the grower to form a narrow vertical canopy (see figure 6). The VSP trellis system can be used with either cane-pruned vines or spur-pruned vines on unilateral or bilateral cordons. Shoots are kept between the foliage wires by lifting the moveable foliage wires and attaching them at successive heights on either side of the line posts and hand tucking. This procedure is usually required 2 to 3 times during the period of active shoot growth. The shoots are retained in a narrow (5 to 7 inch wide) vertical curtain. Up to 3 pairs of foliage wires can be used but 1 or 2 pairs is more common. The fruiting wire is normally at 40 inches with the first pair of foliage catch wires 10-12 inches above and the second pair 10-12 inches above that. The single catch wire positioned at the top of the trellis also serves as a support for bird netting. The entire canopy height of approximately 40 inches contains plenty of leaf area for fruit maturation. The VSP trellis described in figure 6 uses 4 inch by 8 foot CCA treated pine line posts driven 2 feet and spaced every 30-40 feet. End bracing posts are also CCA treated pine that measure 4-5 inches by 10 feet and are driven 4 feet.

Posts: Lodgepole pine and native juniper posts are frequently used in Colorado vineyards. Pine posts are the most common and are typically pressure treated with a mixture of copper, chromium and arsenic salts (CCA). Once bound in the wood, CCA treatment becomes insoluble and non-toxic to vines. Juniper posts contain natural preservatives and are not treated. An advantage of pine posts is the ability to be able to drive them into the soil with a hydraulic power driver. Driving the posts with the narrow end down compresses the soil and increases post stability. Driving the posts is also more economical than boring a hole and hand tamping. The importance of a stake per vine cannot be over stressed. When vineyard construction begins do not neglect a stake per vine. Individual vine stakes vary in size, material (metal, wood, plastic, bamboo) and strength. Select a stake that will last for a good 15-20 years. These stakes will aid the retraining efforts and help stabilize and protect the vine if mechanical weed control is used.

Wire: Trellis wire usually ranges between 10 and 13 gauge. Twelve and a half gauge high tensile wire is common and normally wound on 100 pound spools that contain 4,000 linear feet. A "spinning jenny", a device used to unwind the wire painlessly in the field is a must for any trellis construction. The wire is fastened to line posts with 1.5-2 inch barbed staples, and in the case of moveable foliage wires, one legged J-nails are used. Trellis wire is tightened with a standard wire stretcher and attached to the end posts with patented wire fasteners. These fasteners are small 1/2 inch leaded sleeves that hold two wires together when crimped. Temperature effects, wind loads and fruit loads put a strain on wires and they occasionally need tightened. Simple ratchet type tensioners do a fine job and are usually available where wire is purchased. Excessively tensioned wires can adversely affect your entire end bracing assembly.

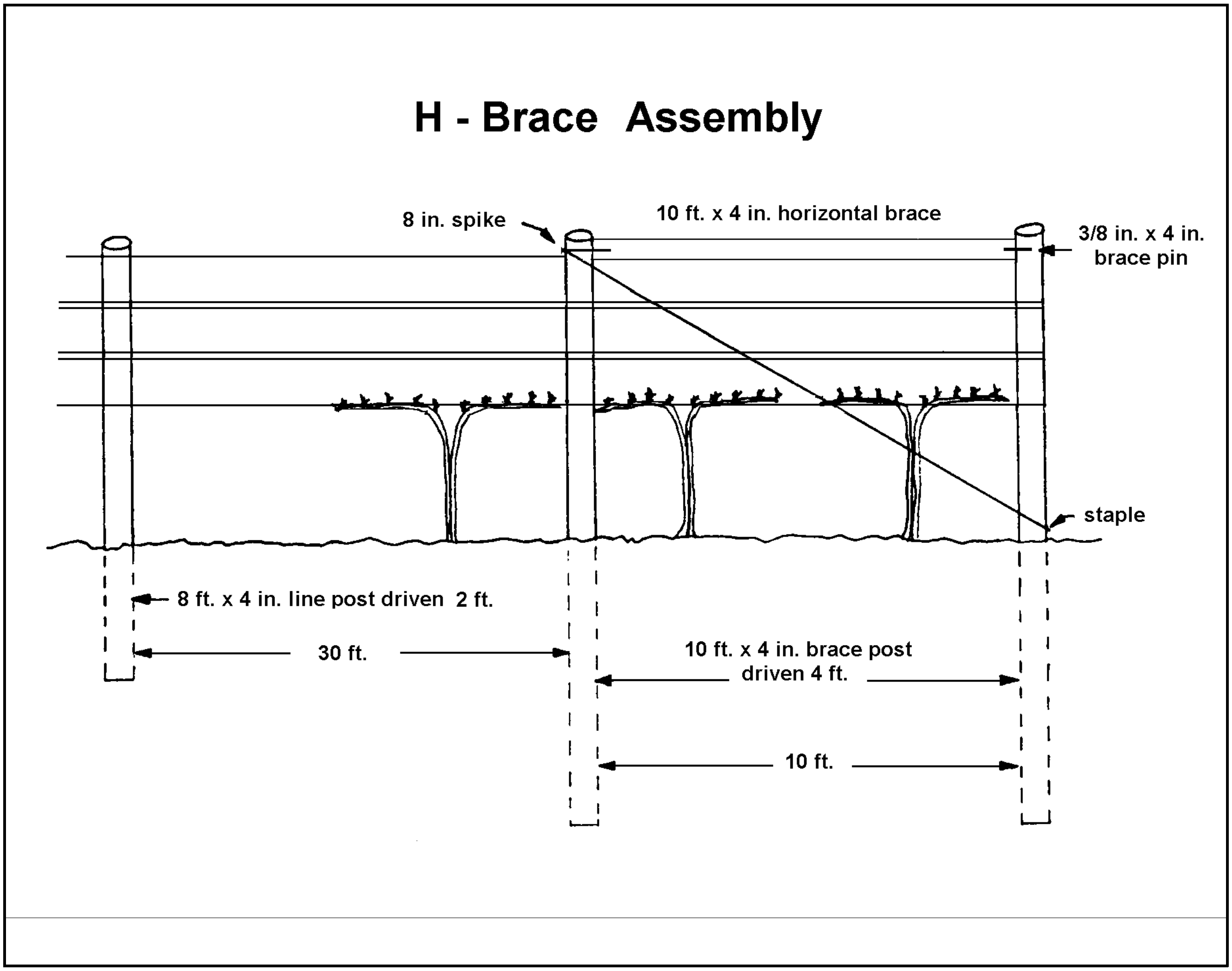

Figure 7. "H-Brace" trellis brace assembly. Vine planting within the end brace assembly is possible.

The End Brace Assembly: Bracing the end of your trellis is the most important component of the trellis system. Improper bracing can lead to failure and costly repairs. Trellis failures can be prevented by avoiding the following common mistakes: Inserting and bracing posts into deep-ripped trenches, excessive tensioning of the trellis wires, tractor/implement abuse and inserting end bracing posts to depths less than 3 feet. Figures 7 and 8 describes two end bracing assemblies.

The main difference between the H-brace and the tie-back is planting efficiency and greater protection. The H-brace enables vine planting to the end of the vineyard row without vine training modifications. The tie-back assembly is equally as strong as the H-brace, has lower up front costs but does not allow adequate training space for efficient vine management. Tie-back or "dead man" anchoring posts are more prone to tractor blight than the H-brace assembly.

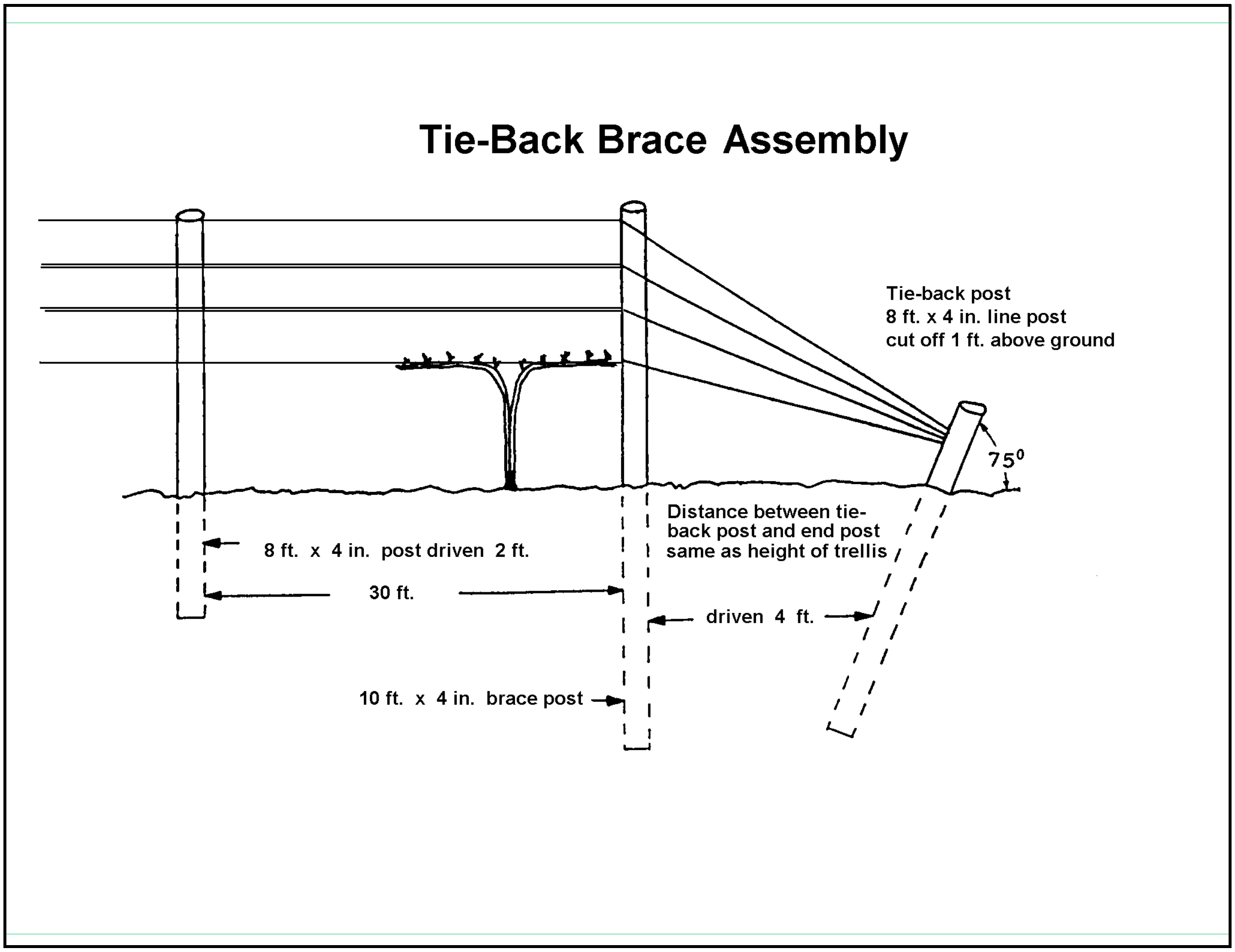

Figure 8. "Tie-back" trellis brace assembly. No vine planting within this type of end brace assembly.

Planting - The First Year

The goal of the planting season is to establish a strong root system at the proper depth. This is accomplished by careful attention to a few major points.

The fully dormant rooted cuttings should have a substantial root system and reasonable top growth. They should be long enough so that two buds of the previous season's growth are above ground and the bulk of the roots begin at a depth of 12 to 14 inches (see Figure 6). The rooting depth is critical; shallower roots will respond too quickly to winter and spring soil temperature changes and lead to winter killing or frost damage. Uniform rooting depth also is very important for controlling drought stress and properly maturing the crop for consistent wine quality.

The cuttings must be carefully protected before and during planting to avoid drying and overheating. This is even more critical if the vines have started to grow due to overly warm storage at some point. Generally it is best to avoid the coldest winter temperatures. Spring planting (April-May) is the best time to plant in Colorado. In any case the vines should be planted before high temperatures occur. Cuttings should be stored in a cool place (40^{o}F) and kept moist until planting can begin.

The roots can be lightly pruned to fit the size of the hole and to remove any dead or decayed tissue (Figure 9C). At planting, the

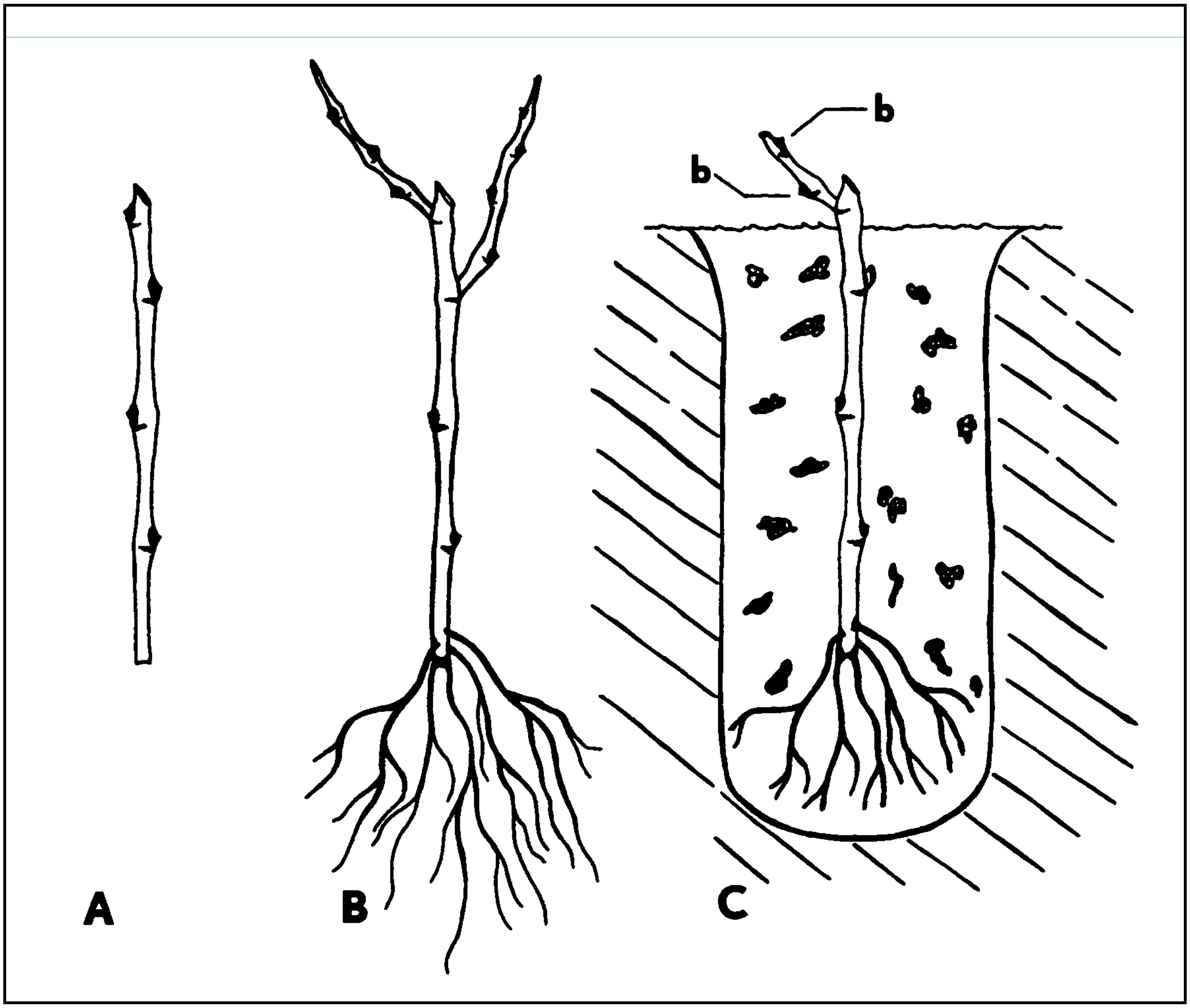

Figure 9. Grape propagation plant materials: A) Grape cutting (14 to 16 inches) with sloping cut at tip end to ensure proper orientation. B) One-year-old own-rooted cutting as received from nursery with some shoot and root growth. C) Properly planted rooted cutting; note that dead or damaged roots should be removed and the remaining roots prevented from bunching. Two buds [b] are left from nursery growth.

cuttings should be set in water (i.e., in tubs or drums) until they are actually placed in the hole, but should not be kept in water more than one day. The vines should be set an inch or two below the desired 13 to 14-inch depth, then add a few inches of fine soil and then gently tug the vine up to arrange the roots in a slight downward orientation. Any bunching or twisting of the roots should be avoided to prevent the vine's self strangulation as it grows.

The vines should be irrigated immediately after planting, making sure that water reaches the roots. Failure to deliver water at planting and over the first few months of a vine's life commonly results in an inadequately prepared vineyard and leads to poor growth and establishment.

Throughout the remainder of the first growing season, maximum growth of the young vine should be encouraged. This can be done by providing a balance between the water and oxygen needs of the developing root system; over- and underwatering should be avoided. The water status of the soil from which the limited root system actually is drawing can be determined with soil probes or with tensiometers placed at the proper location. Vines do not use a great deal of water, but irrigations must be long enough for water to reach the deep roots. Once the vine is planted, an irrigation schedule should be established. Surface irrigation every 2 weeks (6-8 hour sets) is very effective for the establishment year. Drip irrigation of 15 gallons per vine per week is also recommended for the establishment year. These recommendations are for deep clay loam soils. More frequent irrigations may be necessary on sandy well drained soils.

Optimum growth requires the removal of competitive weeds. Generally, bindweed and alfalfa are the biggest problems and should be removed by mechanical or chemical means within at least a 3 foot radius of the vine.

The vine's growth and winter hardiness will be compromised if powdery mildew is not controlled in mildew-susceptible varieties -- especially the *Vitis vinifera* varieties. Powdery mildew occurs in all grape growing areas of Colorado and applications of mildew-effective fungicides at two to three week intervals from June through August are wise preventative measures (see Disease Management, Section IV). During the initial stages of acclimation, (when green shoots begin to turn tan in color) the vines are allowed to dry to encourage good wood formation toward the base of the shoots. An irrigation after leaf fall is encouraged to prevent winter desiccation of the soil and subsequent root injury. Mulching or throwing up a few inches of soil over the crown of the vine can provide protection against winter injury. The vine is best pruned in the spring (March) to leave only one shoot with two buds (see Figure 10B) and if growth has been encouraged, it now has a root system that can support vigorous growth in the most crucial year of the vineyard's life - the training year.

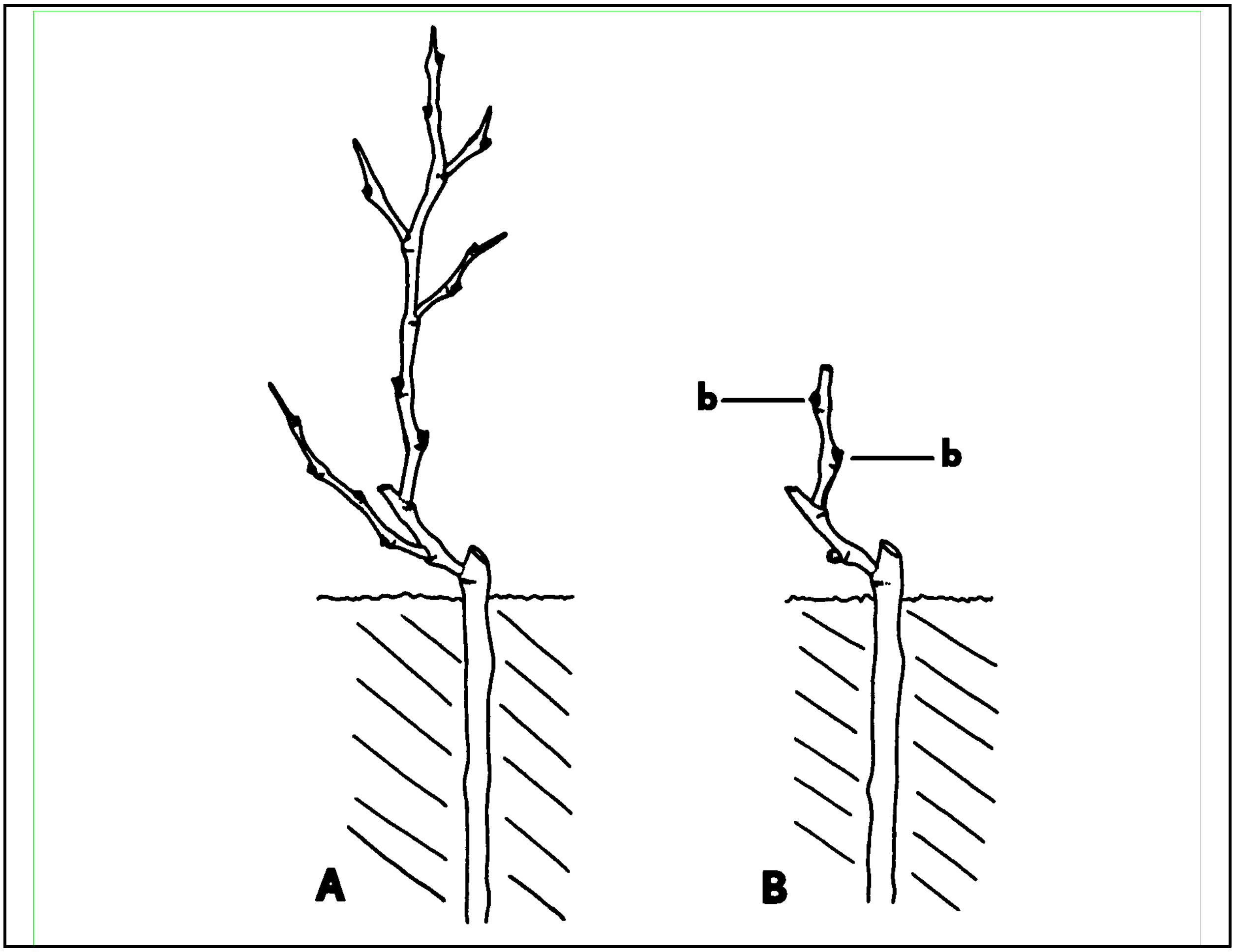

Figure 10. A) Growth at the end of the planting season. B) Above ground portion of vine following first pruning; note two buds [b] from first year vineyard growth are retained.

What About Grow Tubes

The grow tubes or plastic shelters have become a very popular method for training newly planted vines in California and other grape growing regions. Colorado has also joined the trend with several growers beginning to use the tubes in 1995. The grow tubes are plastic shelters available in various colors (white, blue, green, etc.) and sizes. Typical stock sizes are from 24 to 44 inches high with diameters of 2-3/4 inches to 4-1/2 inches. The grow tubes have been reported to enhance growth, reduce training costs and protect vines from chemical sprays and rodents. Suppliers recommend the grow tube to be placed over the young vine at planting. They also recommend the grow tube be pressed into the soil 2 inches and tied to the grape stake or wire for stability and micro climate maintenance.

Growers in Washington state find the plastic shelter useful, especially with young interplants that are struggling. Recent unpublished work at UC Fresno, California suggest the narrow tubes (less than 3-1/2") increase temperatures to extreme levels causing foliar burning. Colorado growers have had good and bad experiences with the plastic shelters. Some Colorado growers excessively burnt their vines with grow tubes and they claim late planting to be the major cause. Other growers had positive experiences, claiming first year growth was better than they had ever seen. Removal of the tubes was a topic of confusion. Some growers removed the tubes when burning was evident while others waited until early fall. Growers who used the tubes were planing on single trunk, not double trunk training. Double trunk training may be more challenging with grow tubes. Most growers felt the grow tubes were beneficial but expensive. Grow tubes normally range in price from $.40 to $1.40 each plus the cost of installation and removal.

It appears that grow tubes will be used by some growers in Colorado regardless of the pros and cons. The tubes are expensive and more experience under Colorado conditions is needed. Correct grow tube use may be a cultural practice that can favor early vine development and enhance vine establishment; however, incorrect use could be detrimental.

The Training Year

Perhaps because there is no crop, grape growers tend to give insufficient attention to the new vines during their second year. The cost of this mistake will be felt throughout the expected 30 to 40 year life of the vineyard. The goal of the training year is to establish the framework of the vine so that future pruning will be efficient and crops of the future will be properly supported. Although the vine looks like it did at the time of planting, the carbohydrates stored in its expanded root system have prepared it with enough energy to develop a trunk and cordon arms or canes. If the vine's environment is kept entirely weed free and the steps of training are carried out in a timely and accurate manner, the vine will reach training height and be ready to produce a modest crop the following year.

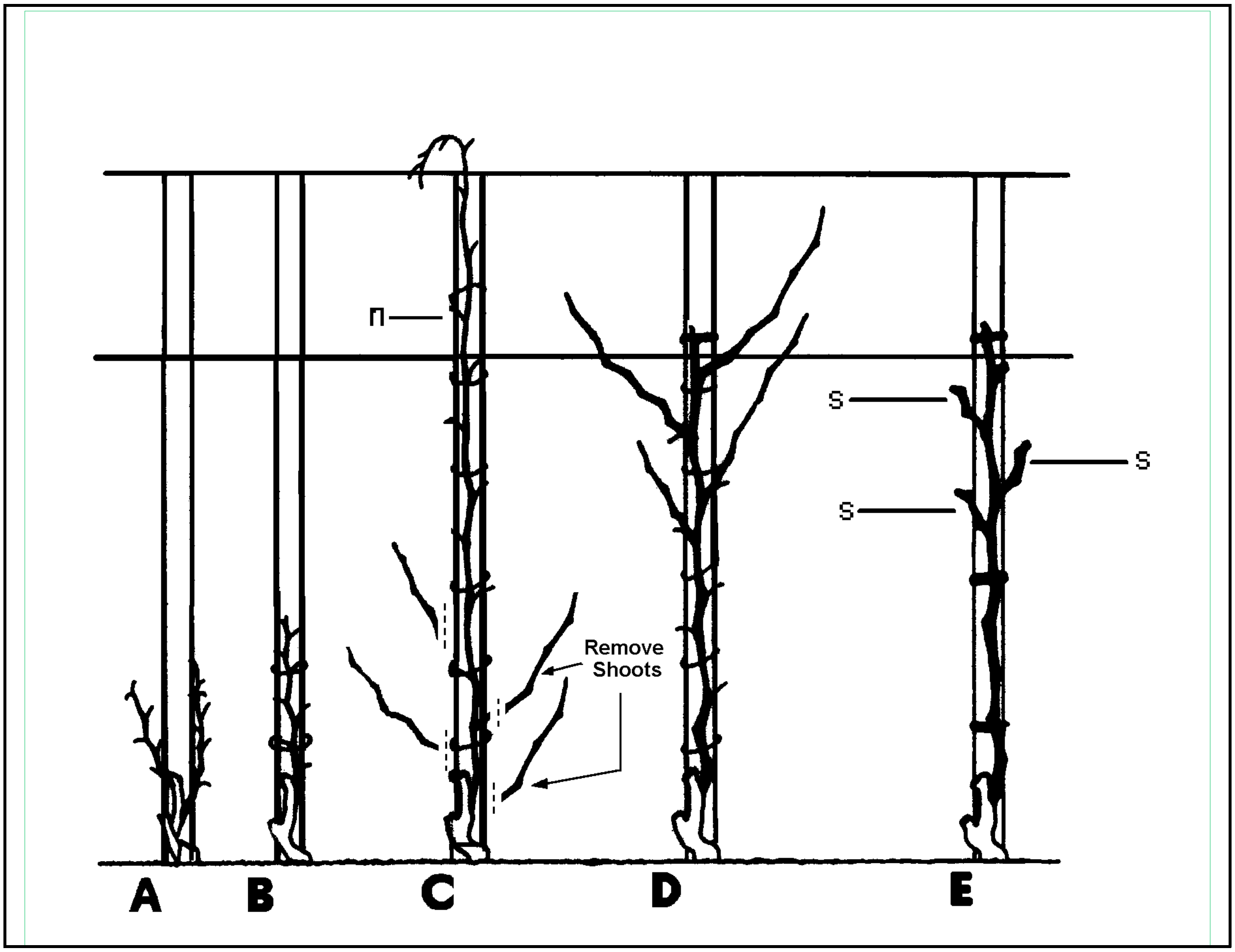

Figure 11. Grapevine training during the second season. A) Early growth (6 inches) before choosing a shoot to train. B) Strong, well-positioned shoot tied after removal of other shoots. C) Shoot tied to form a straight trunk -- growth is 18 to 24 inches above lower wire; it will be topped at the node [n] just above that wire. Note that all lateral side shoots on the lower two-thirds of the trunk have been removed, directing growth to the trunk. D) Growth at the end of the second season in which the trunk and laterals were established. E) Vine pruned in March, retaining three two-bud spurs [s]. Short, lateral canes are often retained on very vigorous vines.

A shoot is selected when it is about 6 inches long and all the other side shoots are removed (see Figure 11C). Remove only the lateral side shoots at each leaf axil, not the leaves. The chosen shoot is carefully tied to a support as it grows so that a straight trunk is formed. A five to six year old vine will be strong enough to support much of its own weight <u>if</u> its trunk is straight. If it is not straight, the vine will **never** help bear the load and will put inordinate strain on the trellis system with crop weight and wind action. The system in which a permanent stake is placed at each vine requires frequent tying to make a straight trunk. Having a good permanent stake at each vine is very handy for any future retraining needs. Obviously, the training support must be in place <u>before</u> growth begins the second season.

As the shoot grows, it should be firmly tied (without crushing or breaking the tender tissue) a few inches behind its growing tip at approximate 6-10 inch intervals. This may require a tie every five to eight days if the vine is growing well. By late spring, the vine will be growing as fast as one inch per day. The best way to tie is with commercially available ties or flexible tying tape.

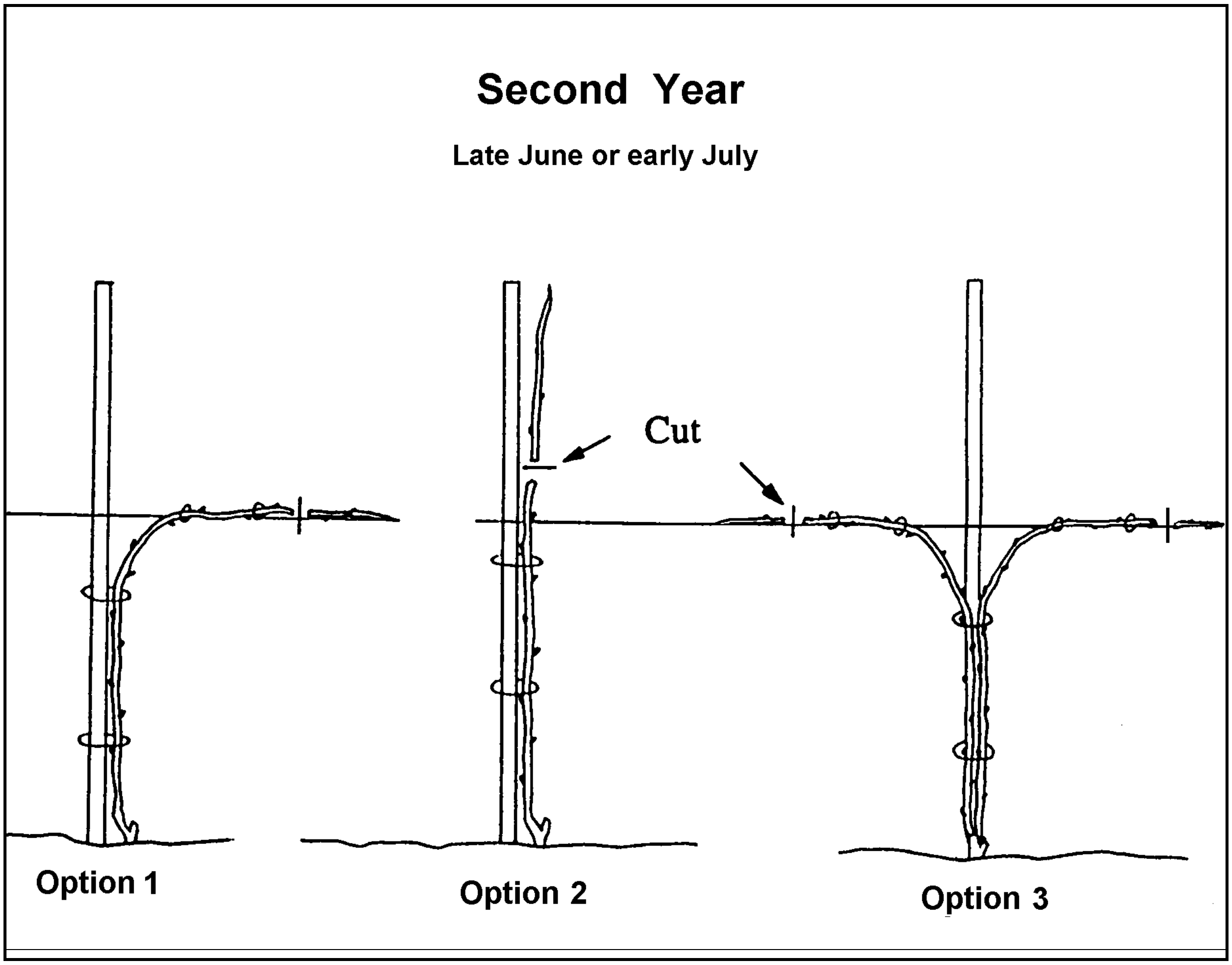

Figure 12. Second year training options.

Young shoots with less than 15 inches of growthare very susceptible to breakage. Care should be taken when tying and forming the trunk. Each vine must be visited every week and new shoots or buds arising from the crown of the trunk must be cut off and laterals removed up to the "head" training height (lower wire). All fruit inflorescences are removed but the leaves on the newly formed trunk should be retained to strengthen it.

Three common second year training options are described above (Figure 12). Previous editions of this guide suggest that once the cane has grown 18 to 24 inches above head training height, it should be cut back to the point at which the vine will be headed (See figure 11). This forces laterals in the axils just below the cut. This method does work however, lateral spur growth development for cordon trained vines is delayed. A method that gives a 2-3 week advantage on cordon arm and lateral spur development is either option 1 or option 3. Option 2 works well for the classic head trained cane pruned vine. Option 1 and option 3 are more appropriate for cordon trained vines. Option 1 is often referred to as a single trunk unilateral cordon. Option 3 is referred to as a double trunk bilateral cordon. Option 1 would be used in high density vineyards (4 feet between vines) with low vigor vines. Option 3 is better adapted for cold climates. Most viticulture areas of Colorado occasionally experience temperatures cold enough to cause trunk injury. The double trunk system (option 3) provides for some additional protection. Frequently, when cold temperatures are damaging, one of the two trunks remain uninjured and thus retains a partial crop. The advantage of option 3 is quicker lateral spur development and potential retention of a partial crop as a result of cold injury. Nearly all vinifera vineyards in Colorado have multiple trunks. Multiple trunk training is a cold climate viticulture management tool (see Retraining Winter Damaged vines) that is an effective method of controlling vine vigor on injured vines with "out of balance" shoot to root ratios.

During the training season it is again important that the vines have adequate water available through May, June, July and August. Depending on the soil type and irrigation system, water should be withheld in late August or early September to encourage the formation of wood and the cessation of succulent growth. Often, fruit clusters can occur on the two nodes left from the previous year. These may aid in slowing vegetative growth in the late season. If the vine is not growing well by midsummer, the clusters should be removed to minimize the growth difference from the more vigorous vines.

Pest and disease control also is crucial during the training year (see Pest Management / Control, Section IV). Cut worms and Lygus bugs may feed on the growing point of the vine. Although the vine will regrow from a lateral if the apex is destroyed, valuable time and a straight trunk will be lost. At any sign of cutworm damage, carbaryl baits can be sprinkled around each vine. Lygus injury is best halted by applying an insecticide such as diazinon.

Powdery mildew must be controlled during the training year. A main shoot heavily scarred with mildew has a much smaller chance of surviving the next winter. The normal mildew program should be followed (see pages 47-51) and continued later in the summer since residue on the fruit is not a problem. Again, a post-leaf fall irrigation is desirable.

Pruning after the training year should be started after the coldest part of winter and, if possible, during March when all winter damage can be assessed.

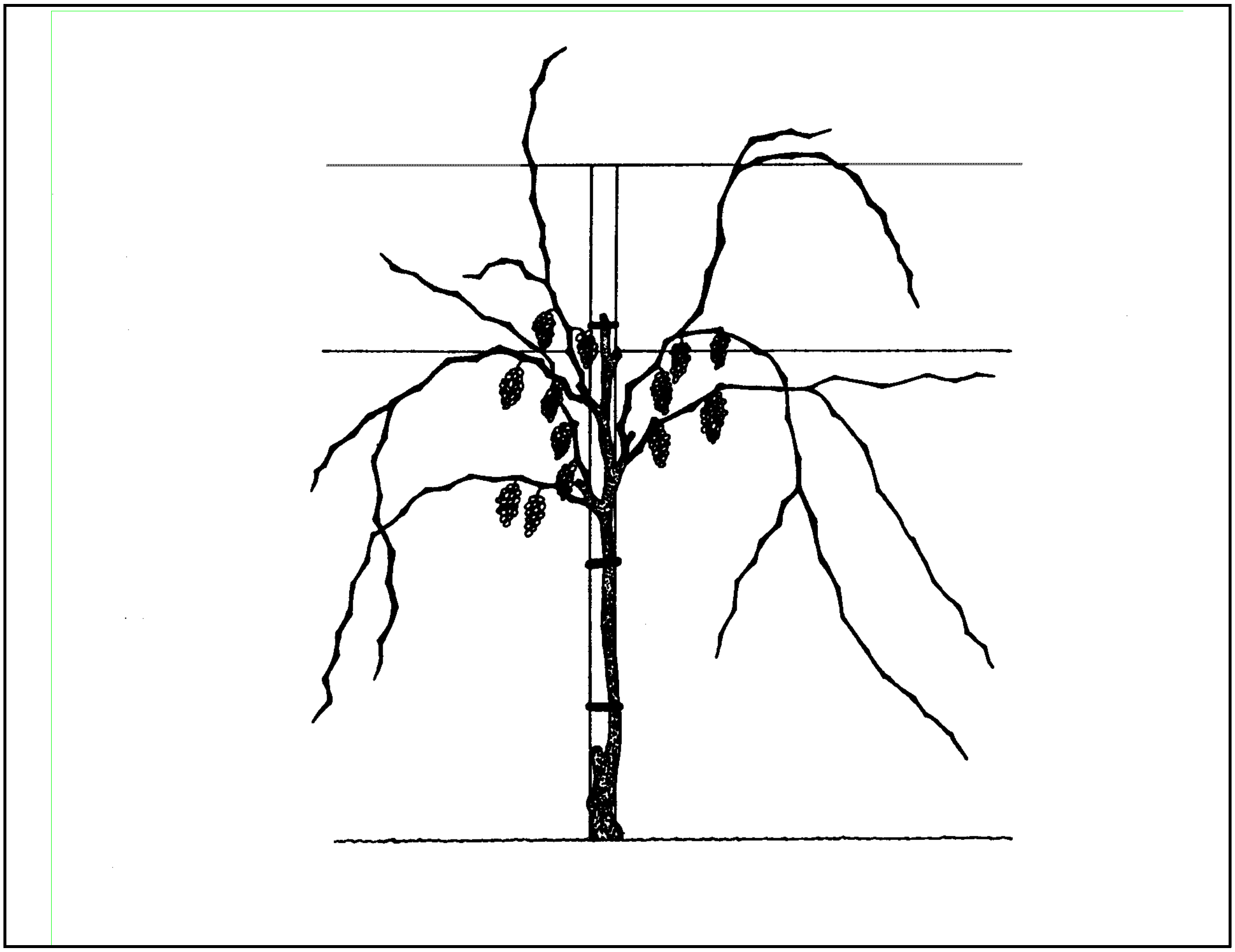

Figure 13. Vine at conclusion of third season growth on a two wire trellis.

The Third Year

The vineyard should produce a small crop in the third year, but generally it's best not to rely on it in for financial planning. The quantity will be small, and the pattern of its maturation will be unlike that of a more mature vine. Most of the care for a third year vine is like that for a mature vineyard with the following points of emphasis. It may be wise to tie shoots to the wind-catch wire when they are around 24 inches long. Wind breakage is more significant when there are fewer shoots. The use of moveable catch wires for canopy manipulation has provided excellent shoot breakage control, sunlight penetration and air circulation. Removing suckers is always important, but is required to a greater degree with a young vine. During the third year, periodically break off the shoots on the lower two thirds of the trunk to encourage better growth in the head area. Grapes from three year vines can ripen earlier than the characteristic time for a mature vine and acid content can be lower. In order to get the best use of the crop, carefully monitor acid content to obtain the best possible sugar/acid balance. Do not judge future wine quality based on fruit from the third or fourth year grapes. It will probably be lighter and not develop the full character that is present in older, more mature vines.

Pruning after the third year emphasizes both selection of two strong canes which will fill as much of the trellis wire as possible and selection of well-positioned renewal spurs (Figure 14).

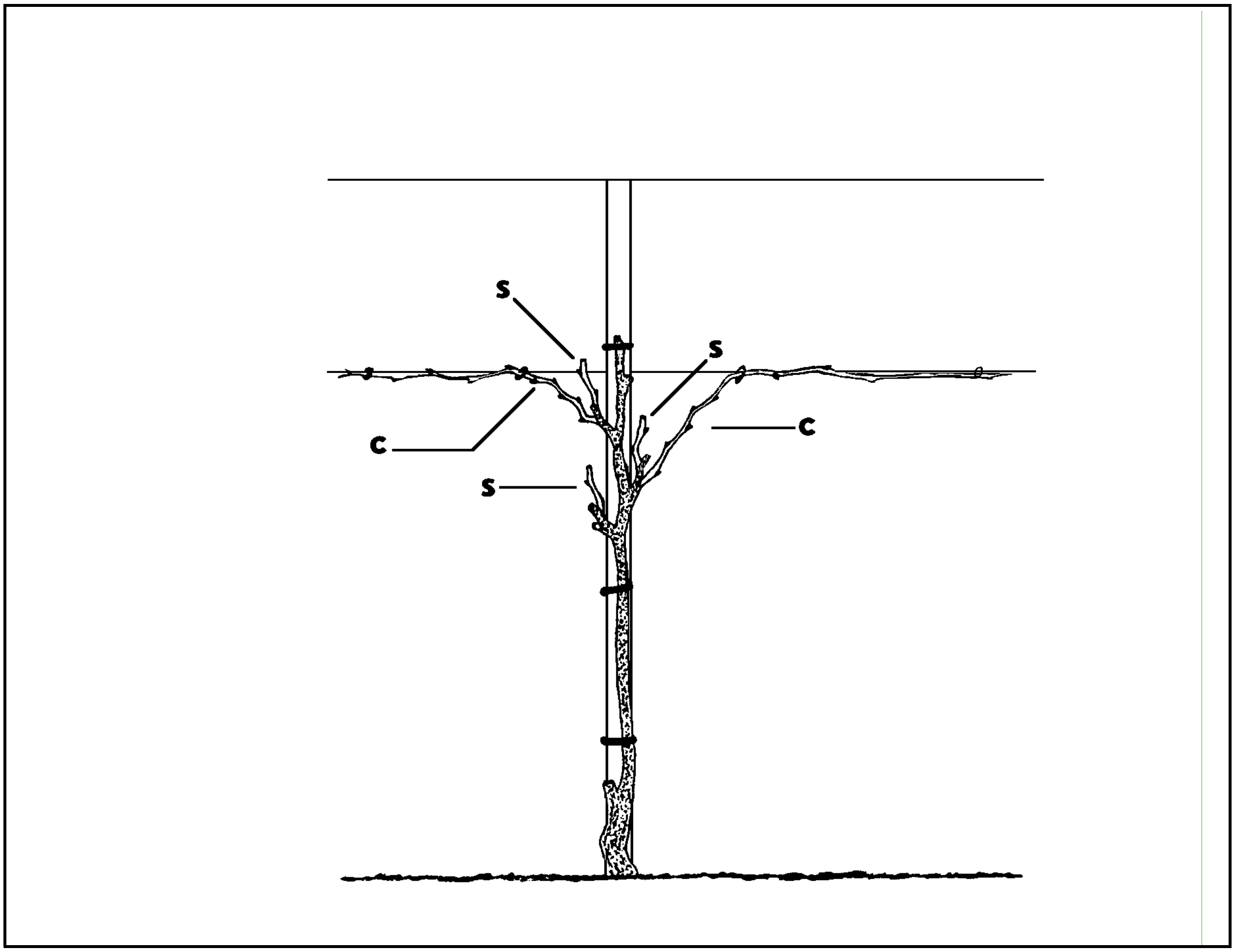

Figure 14. Vine pruned to two canes [c] and three replacement spurs [s] before start of fourth season.

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Maintaining a Vineyard

In this section, the various components of vineyard management will be discussed separately. Optimum management is based on a complete understanding of your vineyard site, and the vines needs. These discussions are intended to emphasize the special concerns of high altitude arid viticulture.

Water Management

Wine grape yield and quality are determined by climate, soil and cultural management practices including irrigation. Poor irrigation management can result in a water stressed or over vigorous condition resulting in unbalanced growth, reduced yields and inferior fruit quality.

For practical purposes, rain can be ignored as an input to the water status of a vineyard in Colorado. Rains do occur, but almost never wet the soil to a depth that can benefit a properly planted grapevine. Thus, the water supplied by irrigation not only keeps the vines alive, but also is the major tool the viticulturist has to optimize winter hardiness and wine quality.

Grape vine water stress can occur if the supply of water to the roots is less than the evaporative demand. The cause for the stress may be low available soil moisture, high evaporative demand conditions, unbalanced shoot/root systems, a poorly developed root system, high salt levels or a combination of these. Unlike tomatoes or squash, immediate signs of current season water stress are not clearly visible with grapevines. Symptoms are typically observed after repeated episodes of water stress, which cause reduced shoot and fruit development.

During the early part of the season (May-August) the vines should be given a good supply of water to promote growth. Humidities are very low in Colorado so water is transpired very rapidly. Few growers can precisely control the amount of water they apply and, even if they can, it is better to calibrate the irrigation through some direct measure of the soil water status in the rooting zone. Grape vines do not require as much water as do many tree fruits, but this should not be taken to an extreme. As a point of reference, on a deep, fairly heavy soil, three to five 12-hour furrow irrigations are sufficient for mature vines between May and September. The last irrigation is timed to allow the vines to experience mild stress that encourages a switch from rapid, vegetative growth to the maturation of the crop and the wood on the canes. If drip irrigation is used, a rate of 12-15 gallons per vine per week for mature vines is typically sufficient. With drip irrigation, reducing the rate per vine per week by 40-50% approximately two to three weeks before harvest will also encourage fruit and shoot maturation. For example, an irrigation rate of 14 gallons per vine per week would be reduced (40%) to 8.4 gallons two to three weeks before harvest. It is, however, very easy to overstress vines under Colorado conditions; in this case the crop will stop maturing and the canes also will be less winter hardy. Finding the middle ground between excess growth and excess stress is the main challenge of learning to grow grapes in each individual vineyard. Parts of a given vineyard may have different requirements. As a starting point, the middle of August is an approximate time to stop irrigating many Colorado soils so that they dry to some degree through September. If the cut-off is too early, one may see the loss of leaves and a marked slowing of sugar accumulation by the fruit. If the cut-off has been too late, the basal portions of the canes may fail to become brown and woody and fruit may retain very high acidity (some varieties will retain high acidities under any circumstances).

Occasionally, winters are sufficiently dry in Colorado to cause the killing of roots through desiccation. To prevent this type of winter killing, it is best to restore the water in the soil with a late irrigation. This is best timed after the first frost so that there is no chance of shifting the vines back into a vegetative pattern. Sometimes the irrigation system is closed down before a frost; in this case still irrigate on the last day practical as it generally is too cool for the vines to become active again. If the crop is still present, a decline in both sugar and acid may occur through dilution in following irrigation; however, the effect may only last a week or so.

Protection Against Winter Injury

There are several ways that vines may be damaged in the winter. Two that have been mentioned are best prevented through water management. The killing of green tissues at the first frost is best prevented by encouraging hardening off of the canes. The killing of roots or above ground tissues through winter desiccation is best prevented by a late irrigation to recharge the soil.

The killing of buds or canes and even trunks by very low temperatures is minimized by the same steps described above, but is less easily controlled. As mentioned earlier, avoid areas subject to sudden temperature drops and pick sites with good cold air drainage in order to minimize this problem. One way to prevent winter damage by extreme cold is to take the vines off the trellis and bury them under 6 inches or so of soil. This practice is very expensive and is not common.

A final type of winter damage may be the one that causes more damage than any other type in Colorado. It is termed "false spring damage". The parts of Colorado protected from the coldest temperatures and rapid changes of winter temperature sometimes experience winter periods of very mild temperature. This can lead to soil warming and reduce vine hardiness. The best cure for protection against winter injury is to grow a healthy vine. Vines that are stressed by poor cultural practices are vulnerable to winter injury.

In Colorado, the bright winter days warm the dark trunks of many vines well above air temperature. This can result in damage when the temperature suddenly declines at sunset. As with fruit trees, painting the trunk with white latex paint can help minimize this. Training the trunk on the north or northeast side of a stake also accomplishes the same goal of preventing heat loading.

Frost Protection and Damage Treatment

In Colorado, grapes actually are less subject to spring frost damage than in many important grape growing regions of the world. They also are in less danger than the traditional fruit crops of the area. This is because they tend to break bud two weeks later than peaches, which reduces the time and risk of frost injury. Wind machines are the method of choice to frost-protect a large commercial scale vineyard.

Heaters: University of California tests show that, for hard frosts, adding a small number of heaters can provide more warming than use of wind machines without heat. For example, 8 to 12 heaters per acre to support a wind machine can provide an additional 1-1/2 or 2^{o}F more than with the wind machine alone, because the wind machine distributes heat that otherwise would is partly lost by updraft from the heaters.

Wind Machines: The theory behind wind machines for frost protection is based on the assumption that temperatures in and above vineyards are assumed to increase with height during nights with little cloud cover and light surface winds. The purpose of a wind machine is to mix air vertically and transport it horizontally displacing cold air at vine height with warmer air brought down from above. Effective operation of wind machines requires that a sufficiently strong temperature inversion exists. Site specific inversions can be determined by placing one thermometer at fruit height and the other at the top of the wind machine. Late spring frost protection should begin when air temperature is 31°F and should be terminated when the air temperature outside the treated area is at least 32°F. Wind machine protection in early spring (just before bud swell) may also be beneficial. Vines are in a transitional stage at this time and lose their mid-winter hardiness and become susceptible to injury with temperatures in the low to mid-twenties.

Delayed Pruning: Pruning grapevines in late February or March (delayed pruning) is a cultural practice normally recommended for Colorado conditions. The objective of delayed pruning is to permit some compensation in the event of bud or cane/trunk injury during December, January and February. Thirty years of weather data recorded at the Orchard Mesa Research Center in Grand Junction indicate severe arctic cold spells (0°F or lower) occur before the 15th of February. If pruning can be delayed until after mid February, uninjured tissue (bud, cane) may be more available than if pruning occurs in the dead of winter. A decision to delay pruning must be factored in your overall management strategies because with large acreage it is simply not possible to wait until March and hope to finish before bud-break. An alternative is to prune the hardiest varieties first and delay pruning with the least hardy varieties.

Rough pruning, (removal of poorly positioned canes and rank growth) in January and February followed up by quicker less congested pruning during normal spring pruning season is a frequently used management strategy for efficiency. Regardless of whether you rough prune or not, pruning should be completed before bud break which usually occurs the 3rd week in April for the Mesa County area.

Late Pruning: Late pruning (after the buds on the apical parts of the canes have started to grow) delays the leafing out of the buds on the retained spurs and can protect vines from early frosts. This delay may vary from three days to two weeks, depending on temperature. When it is very warm, the delay is short; when it is cold, the delay is longer. Shoots that grow mainly on the apical portions of the canes can be allowed to grow 3 or 4 inches without injuring the basal buds or vine in general. In large vineyards, delayed pruning may present labor problems, especially during seasons when vines burst into rapid growth. If shoots should grow considerably more than 3 or 4 inches before pruning, the vines may be weakened and the crop reduced.

Treatment of Frosted Vines: Treatment of frosted vines requires patience. Frost damage to grapevines becomes apparent within a few hours, but the degree of injury to clusters cannot accurately be determined until after fruit set. In many frosted vineyards it is best to do nothing, but in others shoot removal may be beneficial.

When vines are frozen, look to the secondary or tertiary buds or dormant latent buds. Some crop can be expected from varieties where these buds are fruitful, even if shoots that develop from the primary bud are frozen. Frozen shoots should be removed immediately after a freeze to enhance growth from secondary growing points. When growth does occur, secondary and tertiary buds usually initiate shoot growth in about two weeks. Secondary growth is best if shoots are less than 6 inches long when frozen.

Pruning

A complete discussion of pruning philosophy is not possible here. However, the essential goal of pruning is to match the production of a vine with its growth potential. Pruning is the removal of living shoots, canes, leaves and other vegetative parts of the vine. It does not include removal of flowers or fruit. The purpose of dormant pruning is to balance the leaf surface area with the capacity of the vine to produce a mature crop. The purpose of summer pruning is to thin out (remove shoots) and/or to reduce shoot length for increased light and air exposure.

Pruning in Colorado should begin in March. Thirty years of weather data at Orchard Mesa Research Center indicate the severe cold temperatures of December, January and February will be over by March. The threat of cold temperatures (below 0^{o}F) is minimal and any winter damage can be assessed and pruning adjustments made (see Retraining Winter Damaged Vines). Pruning should be complete before bud swell. If pruning occurs during bud swell, crop loss can occur by physically rubbing off the tender buds when removing unwanted canes. The actual removal of the "unwanted" pruned canes can be quite abrasive to the "wanted" remaining buds. Extra care should be used.

Pruning Intentions:

1. To establish and maintain the vine in a form that will facilitate vineyard management.
2. To produce fruit of a desired quality.
3. To select nodes that are fruitful.
4. To regulate the number of shoots/ clusters.
5. To regulate the vegetative growth of the vine.

In Colorado the two most common pruning systems are: A) Cordon trained, spur pruned and B) Head trained, cane pruned.

A. Cordon training/spur pruning: Cordon trained vines currently represent more than 50% of the Colorado industry. Once established, a cordon trained vine is much easier to prune than cane pruning. Less decision making is needed when pruning, i.e. It is easier to see what to cut out. Cordon training works well with a vertical shoot position trellis system. Excellent spray penetration and sunlight exposure are some of the benefits of cordon pruned vines trained to a vertical shoot positioned trellis. A cordon trained vine will have permanent cordons attached to the head wire. Cordons are simply modified horizontal trunks with vertical spurs. Spurs provide fruiting and shoot renewal functions. Figure 12 theoretically demonstrates the second or third year process of cordon training an ideal vine. The goal of second year training is to form the two cordon arms and if good growth occurs, develop vertical shoots from those cordon arms. The vertical shoots will be the fruiting wood for the next season. If an arm does not extend halfway to the next vine, a terminal (apical) bud is allowed to form a shoot which is trained as an extension of the arm.

One of the most critical operations to cordon training is to remove all shoots growing from the underside of the new cordon arm. This procedure directs the remaining growth upright and enables adequate spacing between spurs (typically 4-6 inches). As the shoots grow, tuck them between the double catch wires to maintain the vertical canopy. This procedure is important and must be done on a timely basis to help stabilize the arm and prevent it from twisting under the weight of the shoots and prevent wind damage.

Pruning an uninjured cordon trained vine is straight forward. To prune the vine, remove the shoots that grew from the cordon arms, leaving short (2-3 bud) vertical spurs spaced 4-6 inches evenly along the upper side of the cordon. Retain enough buds to balance the vigor of the vine. A moderately vigorous vine such as Chardonnay would typically have a range of 28 to 40 buds, depending on soil and site conditions.

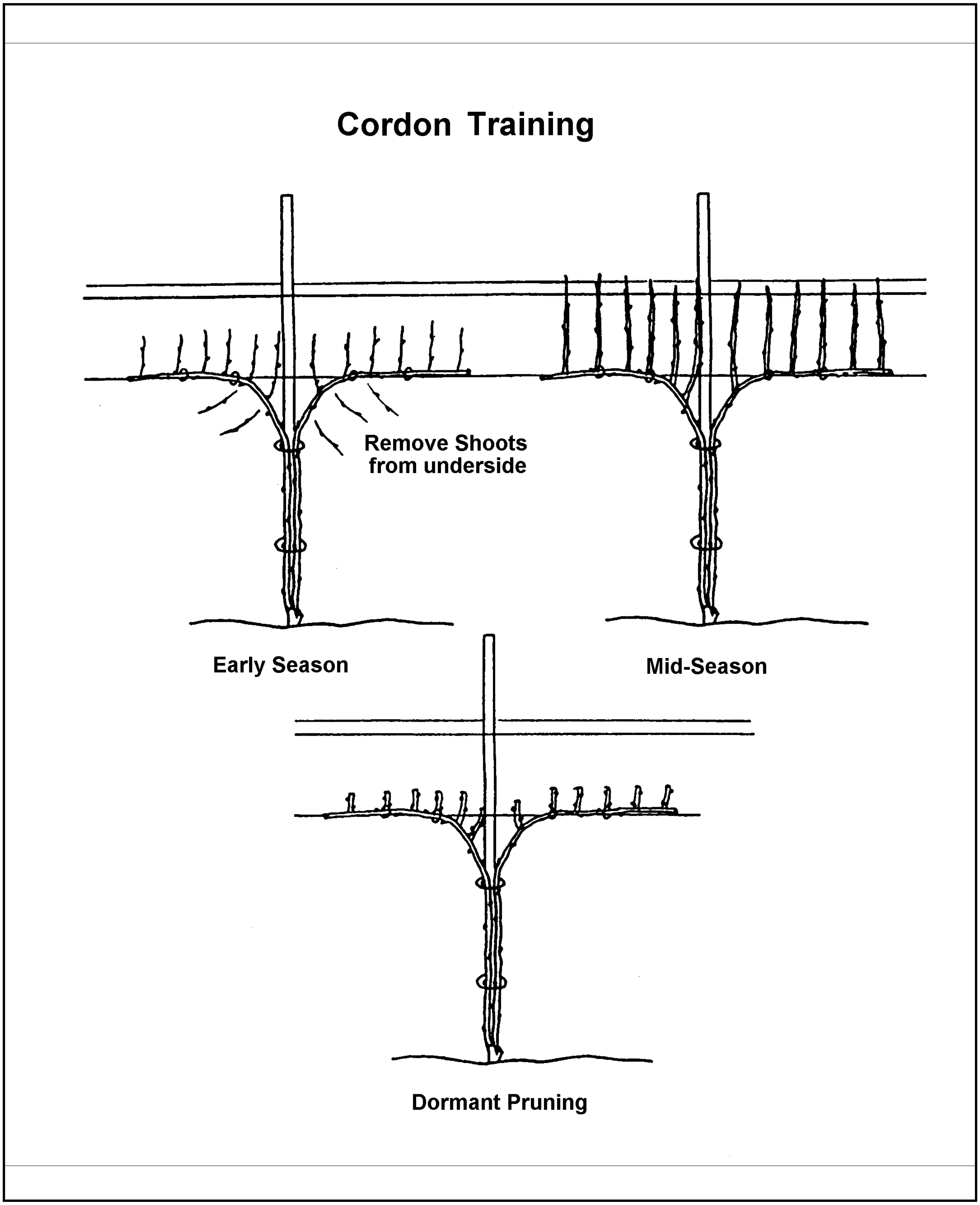

Figure 15. Cordon training, the second or third growing season depending on vine vigor.

The spur renewal process over the years builds short arms at each growing point along the cordon. These short arms should be replaced with a new shoot arising at the base once the short arms reach 3-5 inches in length.

B. Head trained, cane pruning: The buds on canes that grew in the previous season are the source of fruiting shoots. Each shoot will produce two to three clusters. The level of vigor on mature vines in Colorado usually warrants leaving two canes and two to three replacement spurs; this means that approximately 40 to 60 buds are retained. Figures 16 and 17 demonstrate a head trained cane pruned vine.

The canes that are kept are of medium thickness, with neither short nor long spaces (internodes) between buds. The canes chosen are those positioned 4 to 8 inches below the wire. These new canes will be trained and tied to the wire. If part of the cane is allowed to be higher than the rest, it may result in a failure of the low buds to develop. The canes are also selected to fill the entire trellis system. In the case of a vigorous vine, two canes are wrapped together on the lower wire. The upper (wind-catch) wire is present only to allow the young shoots to have support in order to prevent "rolling" of the cane in the wind. Renewal spurs are chosen so that the canes they produce from their two to three buds will be

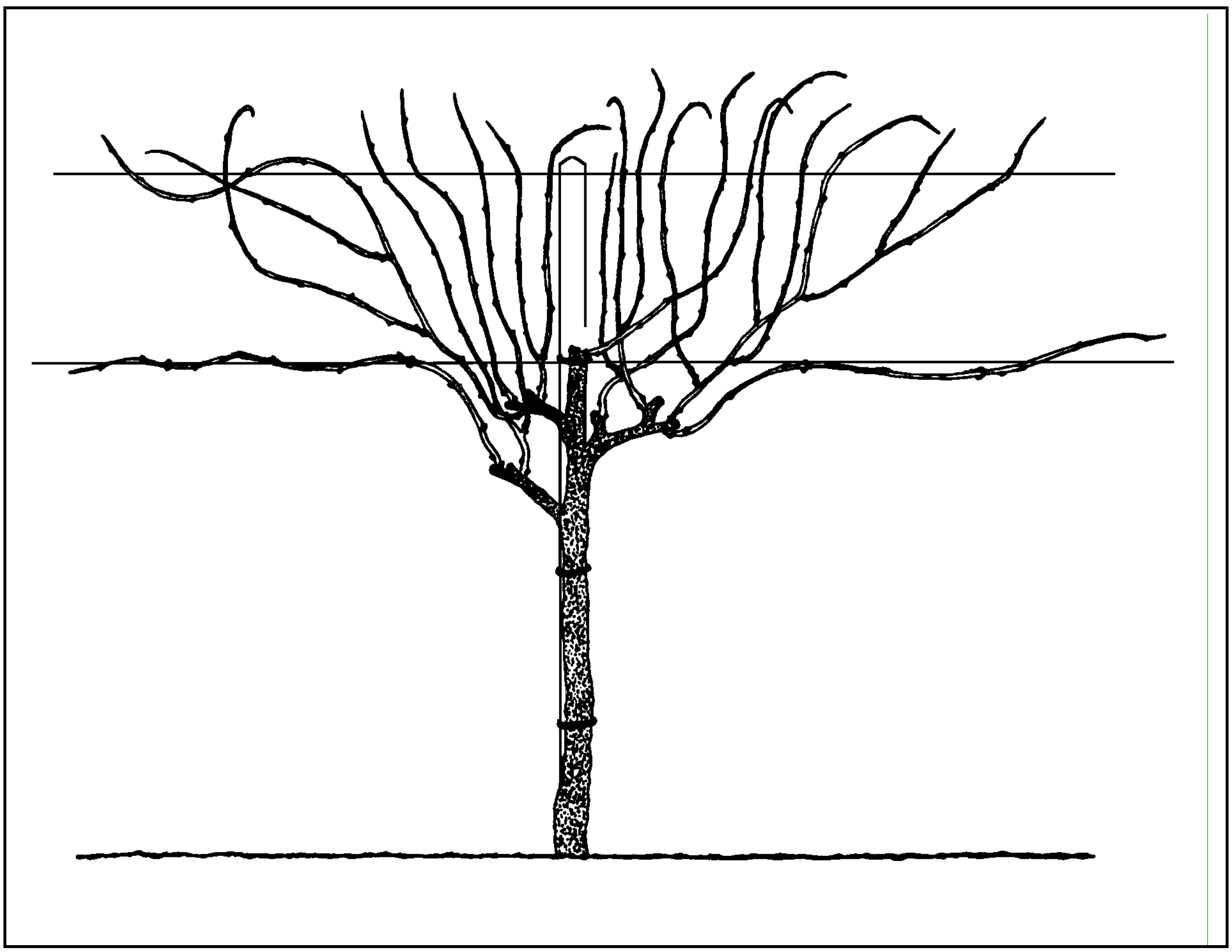

Figure 16. Head trained,cane pruned mature vine showing growth at the end of the fourth season.

in desirable positions to form the canes to be kept in the following season. Over the years, the head of the vine is kept in the same spot - around 4 to 6 inches below the lower wire. The special considerations for pruning in Colorado mainly concern winter damage. If pruning can be delayed until late March and April, it often is possible to identify canes that have died and to retain live canes instead. However, if the vine is damaged, all above ground parts often are uniformly affected. Live canes will have a moist, bright green color when scraped with knife. Often, the small diameter portions of a shoot are brown and dead while the thicker basal portion is healthy. The opposite is never true. Sometimes, the color of scraped canes is ambiguous -- neither green nor distinctly brown. If no bright green canes can be found, one should prune the vine normally because it is difficult to predict whether it will grow normally or require retraining from ground level. Extremely low temperatures can kill buds without killing canes, and it is a good practice to cut into buds at random before pruning to determine the level of damage present and to leave additional buds if necessary.

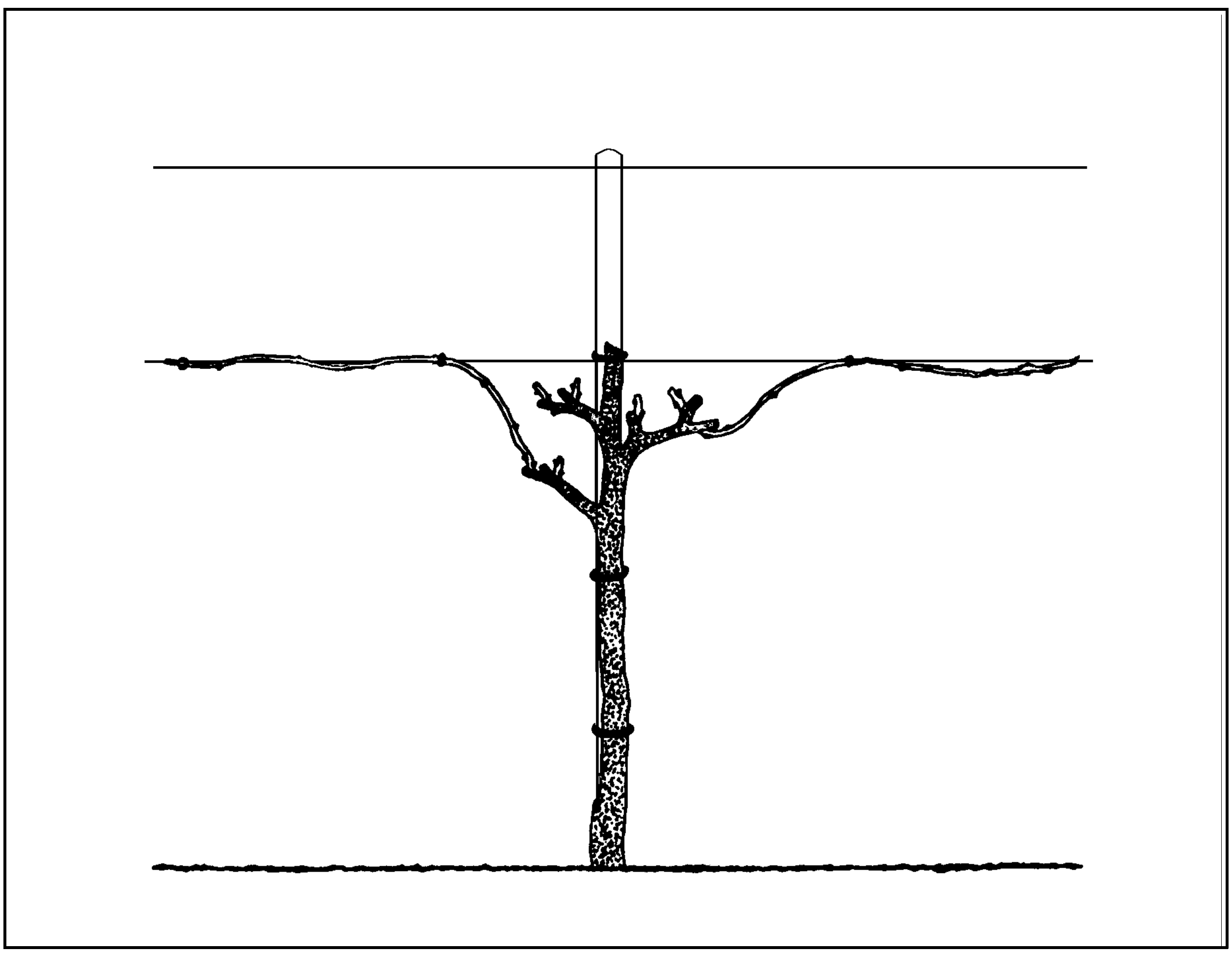

Figure 17. Head trained, cane pruned mature fourth season vine (start of fifth season).

Bleeding:

Near the end of winter or the beginning of spring the vine may bleed after being pruned. Bleeding is the exudation of sap from cut canes and a phenomenon that has no reported harmful effects on the vine. The sap exudate comes from the cut ends of the vessels of the xylem tissues (water and mineral conducting pipelines). Bleeding may occur at any time during active growth if a major portion of the top growth of the vine is removed. Heavy bleeding is most noticeable when vines are pruned at bud swell or later. Winkler reported as much as 5 gallons of sap exudate was recovered from individual vines when new cuts were made every other day. The major contents of sap exudate is water, sugars, mineral nutrients, solutes and the plant hormones cytokinin and gibberellin. The significance of these hormones and other compounds is not known. This bleeding condition depends on the activity of living root cells. The time of cane bleeding in the spring coincides with renewal root activity and or growth. Vine root growth initiates when soil temperatures attain 48°F.

In Colorado, we observe minimal bleeding of vines pruned during mid-dormancy when root activity is non-existent. Drying or suberization of the cut xylem vessels may occur during this time of dormancy when root activity is low and when xylem vessel water movement is minimal. In normal years, bleeding will not occur if you prune your vines the first two weeks in March. Soil and air temperatures in the fruit growing districts of western Colorado at this time are still cool enough to hinder renewed root activity.

Retraining Winter Damaged Vines

Unless extreme deep ground freezing occurs, a winter damaged vine will regrow from below ground level. Essentially, the idea of retraining is the same as in the original training in terms of the need to tie a shoot frequently to a support to form a straight trunk. The difference with an older vine is that the root system will support extremely vigorous regrowth. Canes that grow very rapidly tend to be winter tender and may be killed the next year. See figures 18 and 19.

Steps to retrain winter damaged vines that are self-rooted: If you suspect your vines have been winter injured, make an actual tissue assessment. To help identify injured tissue, use a razor blade and cut horizontally through buds. Buds that are brown or black (not green) are typically injured. Using a knife or sharp pruning shears, scrape through the bark and into phloem and cambium tissue (typically 1/8 inch deep in enough). Cane tissue that is injured will generally be brown. All live tissue will be moist. Occasionally, trunk tissue is damaged from cold air that stratified in a layer near the ground and cane tissue is injured. As the vine begins to grow in the spring and all carbohydrate reserves are used up, the canes and buds begin to desiccate because of trunk injury below. Injured trunk tissue will have a similar dark brown oxidized appearance but you may have to scrape (cut) through several layers of bark to expose live tissue. Live trunk tissue will have more of a light-green to white-cream colored appearance rather than the definite green color of live cane tissue.

Once an overall assessment has been made and injury is evident, retraining must begin with removal of injured tissue. If trunks and canes are partially injured and show signs of "weak life", it is generally more productive to remove these weak tissues. Helping the vine decide where to put its energy by removing injured weak tissue will lead to quicker vine recovery and more efficient (labor savings) retraining decisions.

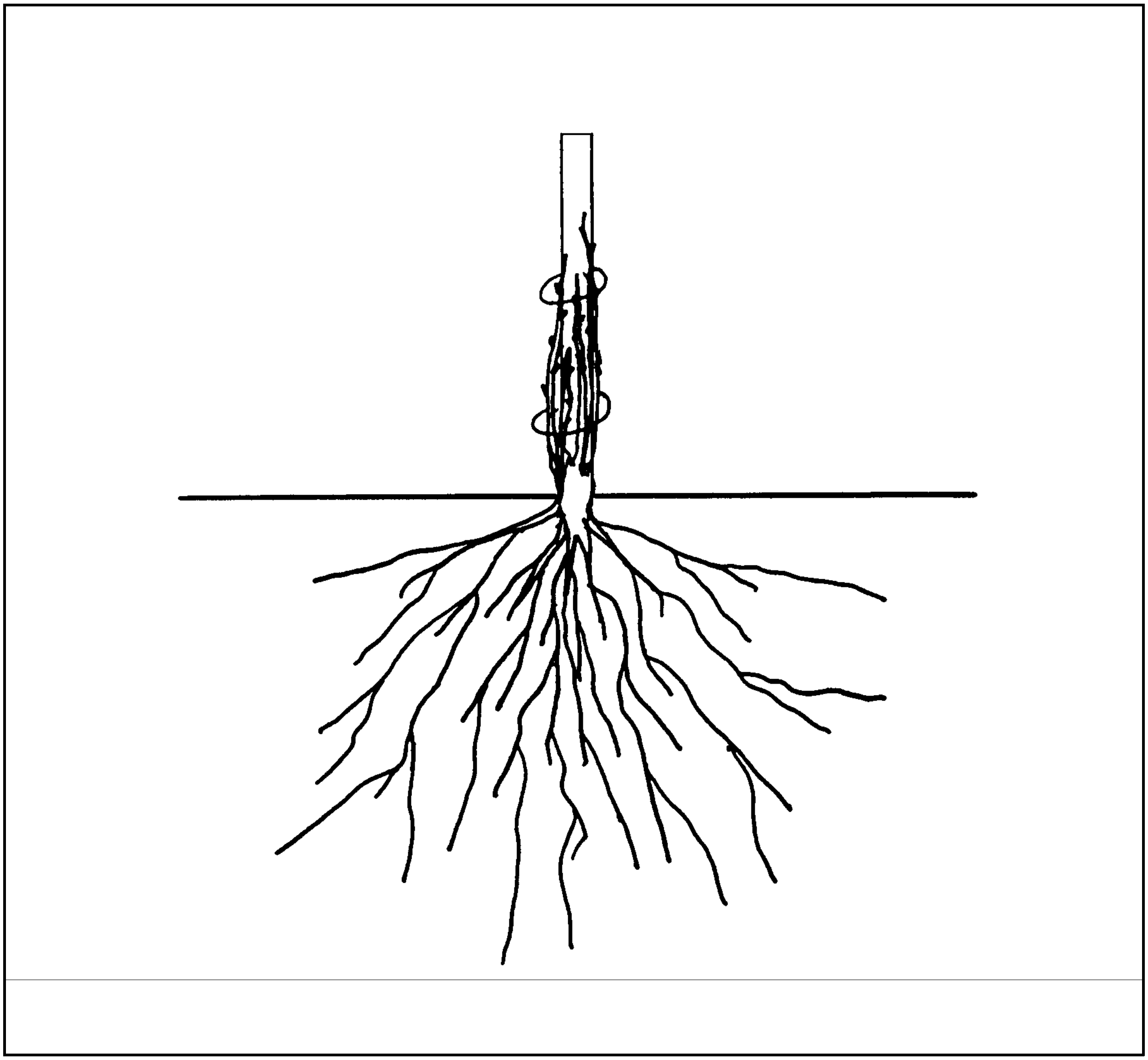

Figure 18. Retraining winter damaged vines. Select and tie shoots for the development of a multiple trunk.

Healthy vines that have been in the ground for 2 years or more that have been injured to ground level can benefit by incorpo-rating a multiple trunk system. A multiple trunk training system will help balance the root/shoot ratio and reduce "bull" canes and the unwanted "winter kill" cycle. Vigorous "bull" canes are winter tender canes and should not be selected for retraining. Shoots that are pencil size in diameter and have internode lengths of 2.5 to 4 inches are preferred. Dividing the growth will help control vigor and depending on variety and age, there may be a need for 2-6 trunks the first retraining year. The following year, half of those trunks may be removed and eventually one or two trunks will be all that is needed to balance the root/shoot ratio. It is the first and second growing seasons after winter injury that controlling vigor is vital.

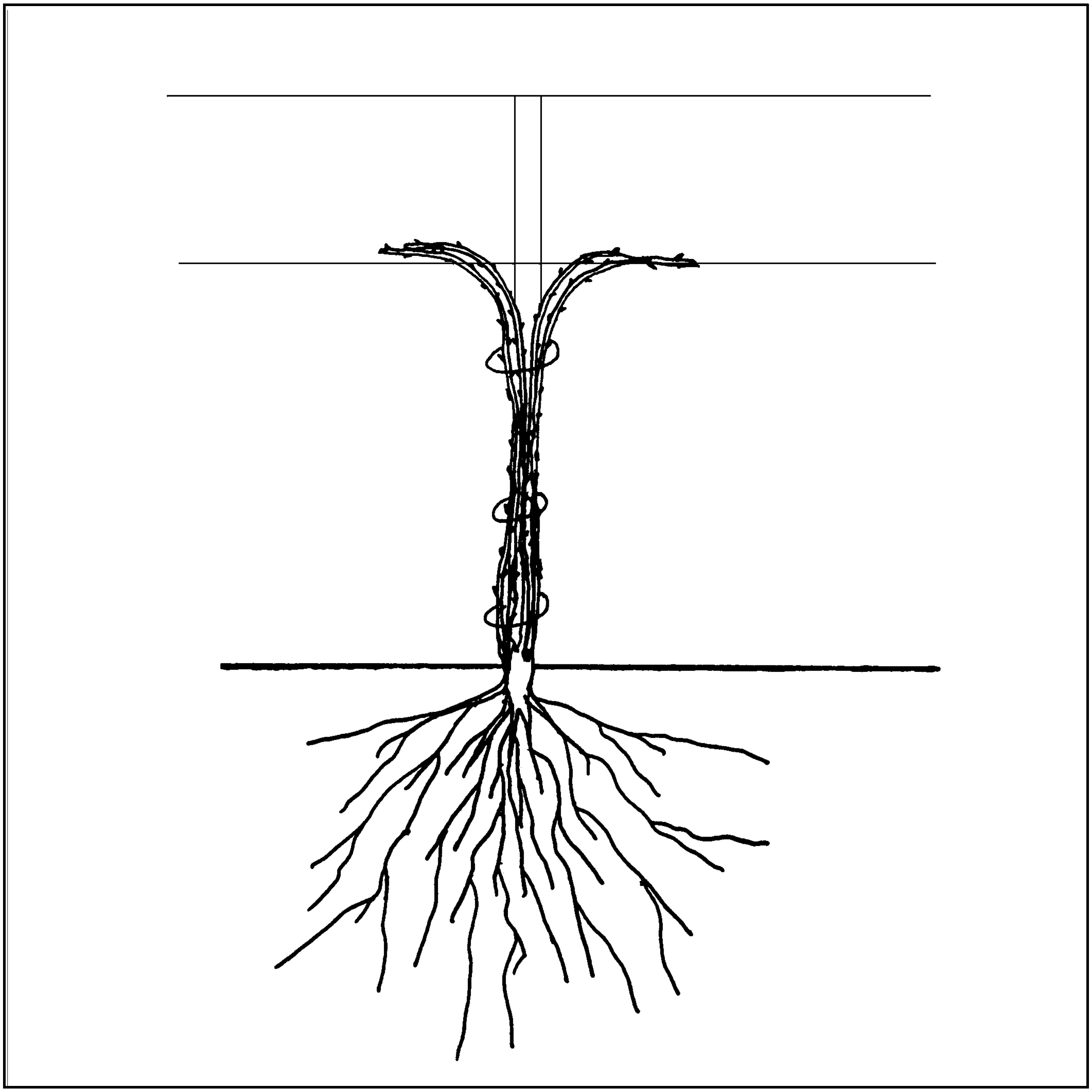

Figure 19. Retraining winter damaged vines. Dividing growth with multiple trunks will help control vigor and avoid the "winter kill cycle."

Management practices that minimize winter injury

1. Site selection: Having the land and deciding to grow grapes on it is not site selection. Avoid planting grapes in valleys or low lying areas. Look for a site that has good air and water drainage, preferably >5% slope.
2. Varieties: Diversify, avoid planting the entire vineyard to winter tender varieties.
3. Cultural management: Cultural decisions that help prepare the vine for winter or "harden off" the vine should be carefully incorporated. Decisions that favor vigor control enhance vine hardiness. When irrigating, always include a dry down period (especially in deep heavy soils). This dry down time provides a slowing down or stopping of shoot growth which helps the vine initiate fall acclimation responses (lignification of tissues). Always apply a late fall irrigation to prevent mid-winter desiccation. Trellis modification that encourages upright canopy development or split canopies favor sunlight penetration which increases the development of "sun canes" rather than "shade canes". Sun canes develop fruitful buds and hardier bud and cane tissues.

Shoot Tying and Suckering

As young shoots reach above the second wire in spring, it is a good practice to tie two to three of the shoots of each cane to that wire to stabilize the whole cane. This prevents it from rolling in the wind later in the season and exposing the fruit to sunburning. The shoots may attach to the wire by tendrils, but not with sufficient support in windy sites. For this tying process the tape guns and temporary stapled tape mentioned before are ideal since they must be removed at the next pruning. Two or three pairs of moveable catch wires can keep shoot tying to a minimum and allow for excellent sunlight exposure and air circulation. Suckers (shoots appearing at ground level or on the lower 2/3 of the trunk) should be removed while green and easily broken off. This will be necessary during most seasons and can be done while passing through the vineyard to tie shoots. Sucker removal channels more energy into the fruit and facilitates many other maintenance activities. If a systemic herbicide such as Roundup is to be used, it is critical that all green tissue near the ground be removed.

Shoot Thinning

For maximum air and sun exposure of the fruit and shoots, shoot thinning may be necessary. Shoot thinning is the removal of unwanted shoots. Vines typically grow more shoots than the nodes left at winter pruning. These extra shoots develop from buds at the base of the spurs or out of old wood and often are not fruitful. In Colorado, it is not uncommon to retain some of these shoots to renew growth from winter injured spurs/buds that never developed. Shoot thinning on moderately vigorous vines is typically started when new growth has reached about 15 inches and can continue until soon after set. New shoots may be forced from buds on the cordon or head of the wire if shoot thinning is carried out too early. If shoot thinning occurs too late, the energy used to develop the shoots to be removed is lost and the redirected energy is of less benefit to the shoots in more desirable locations. Vines are commonly thinned along the cordon wire so that they are evenly spaced at a distance of 3 to 5 inches. In Australia, vines are typically shoot shoot thinned to about 15 shoots per meter (5 shoots per foot).

Leaf Removal

Leaf removal in the fruit zone can improve fruit composition, spray penetration, enhance fruit color and reduce disease by increasing the exposure of the clusters to sunlight and air circulation. Normally, removal of one to three leaves per shoot is sufficient. Leaf removal trials at the Orchard Mesa Research Center indicate minimal sunburning occurs if fewer leaves are removed on the west side of the canopy. Afternoon sun can be extremely hot in western Colorado.

The ideal time for leaf removal is 3-4 weeks before veraison (Veraison is the time when berries begin to color). Lateral leaves may develop and require the practice to be repeated later in the season if leaf removal occurs too early. Avoid exposing shaded fruit in mid-late summer as sunburn can occur. Fruit clusters exposed to the sun in the early season are less prone to sunburn. Mechanized leaf removal is currently practiced throughout Europe, South Africa, Australia, California and in some vineyards in Colorado. The machines perform best with positioned canopies such as vertical shoot positioned trellis.

Crop Thinning

Crop thinning is a final adjustment technique of crop regulation that results in the most significant fruit quality improvement. Crop thinning adjustments may be necessary to mature the fruit earlier or change wine style. Vigorous varieties such as Seyval blanc and Dechuanac have high initial fruit set and continue to produce abundant flowers late in the season which must be removed for proper fruit composition and maturation. The earlier the thinning, the greater the benefit to the remaining inflorescence. Early inflorescence thinning, i.e., before flowering, is an operation that is rapid and easily visible. Bunch thinning or cluster thinning is done after flowering and set. This operation involves removal of undersized, poorly-set or immature clusters. Researchers in Italy (Ferrini et.al. 1995) have recently shown the best time to cluster thin "Sangiovese" grapes was at the veraison stage. They found at that time, quality is not impaired, clusters are more visible, thinning is faster and more accurate.

Hedging, Trimming or Topping

Hedging, Trimming or topping consists of cutting off shoot tips during the early to mid summer. Late season trimming should be avoided since lateral regrowth may be stimulated and cause a delay in fruit maturation. Trimming to less than 10-12 nodes may impair fruit ripening. If trimming is not performed previous to a late season topping, healthy leaves could be removed from the canopy exterior exposing previously shaded older unproductive senescing leaves and thus lowering fruit ripening potential. Non-positioned canopies are very prone to this practice.

If vine trimming is needed for increased light exposure, spray penetration, harvesting or to ease the application of bird netting, etc., alternative practices should be considered. Controlling vine vigor through proper irrigation management, fertilization, use of an improved trellis system, or matching variety to site are better viticultural strategies than vine trimming. Vine trimming is a temporary "band- aid" solution to vineyard canopy problems.

Nutrition Analyses and Foliar Sprays

Grapevines have fewer mineral deficiencies and a lower plant food demand than many other horticultural crops. Grapevines can adapt to a wide range of soil types and, if soil depth, texture, and water conditions are favorable, will survive and bear salable crops in soils with poor fertility.

Sixteen elements are known to be necessary for normal plant growth: carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, boron, iron, manganese, copper, molybdenum, and chlorine. Plants take three of these, carbon, oxygen, and hydrogen, primarily from air and water. The other 13 are absorbed from soil by the roots and divided into two groups, macronutrients and micronutrients. The last seven elements listed above are micronutrients and are used in smaller quantities than the macronutrients.

The function of each element in the plant's metabolism is beyond the scope of this publication; however, the vineyardist generally can determine deficiencies and/ or excesses with the proper laboratory diagnostic methods. Laboratory soil analysis is used to appraise vineyard problems related to Ph, salinity, and certain toxicities. Soil analysis is not a reliable means of determining nutritional problems and fertilizer requirements. Field research has repeatedly shown inconsistent relationships between soil nutrient levels and grapevine needs.

Tissue analysis (TA) is a much more effective and reliable means to determine vineyard nutrition than soil analysis. TA determines the concentrations of nutrients the grapevine is able to remove from the soil. A typical complete TA will assess levels of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn), boron (B), iron (Fe), and sometimes sulfur (S) and sodium (Na), all expressed either as percent or as parts per million (ppm). TA is another tool that helps the vineyardist establish a guideline for proper vine nutrient levels.

Sample timing is extremely important; samples must be taken during bloom time, the nearer to full bloom the better. The plant part to sample is the leaf petiole, and petioles from leaves opposite the blossom clusters toward the base of the shoot are preferred. Each sample should represent not more than five acres; areas of different soil types and vine strength should be sampled separately. A representative sample consists of 75 to 100 petioles (one per vine) from vines uniformly distributed over each area. Put each sample in a new, clean brown kraft paper bag, label it with pertinent information -- e.g., name, date, variety, location, and foliar sprays used or fill out an information sheet supplied by the laboratory. Both soil and tissue samples can be sent to the Soil Testing Laboratory, Colorado

State University, Fort Collins, CO 80523. Information on current costs per sample can be obtained from your county Cooperative Extension office.

Critical nutrient levels have not been established for Colorado conditions, and interpretations of the analysis can be compared only to other viticultural areas with similar conditions until further research has been accomplished.

Nitrogen

Nitrogen is acknowledged to be one of the most important and most likely limiting nutrients in grapevines. Nitrogen is the essential element used in greatest amounts by vines. Nitrogen is needed for growth and development. Grapevines use nitrogen to build essential compounds including proteins, enzymes, amino acids, nucleic acids, and pigments including chlorophyll and anthocynanins of fruit.

Once absorbed by the vine, nitrogen can be lost through fruit harvest and annual pruning of vegetation. Previous research has determined that on average, each ton of fresh grapes contains about 3.5 pounds of nitrogen. A harvest of 5 tons/acre would remove approximately 18 pounds of nitrogen per acre. The depletion of nitrogen would be even greater if cane prunings are removed from the vineyard. (Canes contain about 4.5 pounds of nitrogen per ton of grape.) Most soils will eventually be depleted of readily available nitrogen if supplemental additions are not made. Nitrogen depletion will occur most rapidly with soils low in organic matter content (typical in western Colorado). Soil higher in organic matter content can more easily convert organic nitrogen to available forms (nitrate and ammonium ions) capable of being absorbed by the vine.

Symptoms of nitrogen deficiency:

The classical symptom is a light green color of leaves, as opposed to dark green leaves of vines receiving adequate nitrogen. If the leaves show this uniform light green color, it will be most noticeable on basal to mid-shoot leaves. Newly developing leaves often have a pale green color and should not be confused with nitrogen deficient leaves.

Some growers confuse nitrogen deficiency with iron deficiency. In western Colorado soil pH is typically in the range of 7.3 to 8.4. High pH soils like these make iron unavailable to the vine which is often confused with nitrogen deficiency. Symptoms of iron deficient vines are easy to detect. the classical symptom is a pronounced intervenal leaf yellowing. The veins of a moderately iron deficient grape leaf remain green. In Colorado, Iron deficiency is typically visible by late June. **Nitrogen deficiency** on the other hand shows complete fading of green color including the veins. Other symptoms that point to nitrogen deficiency are a slow rate of shoot growth, short internodal length, and small leaves. Insufficient nitrogen can also reduce crop through a reduction in cluster, berries and berry set. Note that other factors such as drought, insect pests, disease and overcropping can also cause similar nitrogen deficiency symptoms.

Nitrogen and vine cold hardiness:

The belief that any added nitrogen will reduce cold hardiness of a vine is a misconception. The addition of moderate amounts of nitrogen (20-40 pounds of actual nitrogen per acre) will not reduce the vines cold hardiness level and will likely improve their overall performance.

Correcting nitrogen deficiency:

Maintaining an appropriate nitrogen status is based on past experience, vine performance and supplemental use of bloom-time analysis for nitrogen concentration. Adequate nitrate-nitrogen levels at bloom time range between 350 - 1200 ppm for most grape varieties. Site, variety and year to year differences may exist. This data is based on leaf petioles taken from opposite clusters at full bloom. If nitrogen fertilization is needed, application of 20-40 pounds of actual nitrogen per acre on sandy loam soils is a good starting point for mature vineyards. Young vineyards (first and second growing season) in need of nitrogen fertilization typically require no more than 30 pounds of actual nitrogen per acre. It occasionally takes two years for added nitrogen to have an impact on vine performance. This is because much of a vines early-season nitrogen needs depend on nitrogen stored in the vine from the previous

Time of Application:

Nitrogen fertilizer should be applied during periods of active uptake to minimize loss through soil leaching. This includes the period form bud break to veraison, and if leaf fall has not occurred, immediately after fruit harvest. Nitrogen is very mobile in the soil and applying nitrogen while the vine is dormant and not actively absorbing nutrients should be avoided.

Multiple applications of nitrogen are preferred over one mega spring application.

Applying Nitrogen:

Apply nitrogen within 1 -2 feet of the vine or where absorption can be aided by irrigation. Nitrogen should be immediately incorporated into the soil by discing, irrigating or if planned accordingly, apply it before a rain. Incorporating nitrogen into the soil minimizes volatilization and hence loss. Application can be achieved by banding, injecting through the drip system or hand tilling the soil around the vines. Banding with a modified tractor-mounted fertilizer spreader works well for large vineyards without drip injection capability. Incorporating nitrogen by hand tilling a ring 15 - 20 inches from trunks is practical for small vineyards.

Calculating Actual Nitrogen:

There are several forms of nitrogen fertilizer commercially available such as Urea (46%), ammonium sulfate (21%) or ammonium nitrate (35%). Recommendations for actual nitrogen must be translated into rates based on commercial formulations. for example, a recommendation for 45 pounds of actual nitrogen per acre would require 98 pounds of urea fertilizer/acre (45#/46% = 98) or 128 pounds of ammonium nitrate fertilizer/acre (45#/35% = 128) or 214 pounds of ammonium sulfate fertilizer/acre (45#/21% = 214).

Foliar Sprays:

A properly applied foliar spray program usually focuses on micronutrients and can be beneficial. Before applying any nutrient spray, a laboratory analysis of petiole samples from affected and normal leaves and a soil analysis should be performed and evaluated. This allows you to base your decision with more evidence than just visual symptoms. Foliar spray products are not cheap and may be of little benefit if improperly applied. Micronutrients can be extremely toxic even in small amounts. They can kill vines if applied in excess. Some nutrient-deficiency symptoms can be confused with factors other than nutrient supply. Care should be taken before applications are made to verify visible symptoms by tissue analyses.

Consider your foliar spray program as a supplement to basic root feeding. The micro-nutrients most commonly applied in foliar form are manganese, zinc and iron. Boron also can be considered, but deficient levels are not common in Colorado soils. Macronutrients generally are not effective or practical as foliar fertilizers and should be soil-applied either by spreader, hand, or drip system. Correcting a deficiency and controlling growth are major concerns in Colorado, and trying to achieve this with a combination tank mix of N, P, K, Mn, Zn, Fe, and B may lead to increased vigor problems and, hence, increased winter damage. "Witches brew" tank mixes of pesticides and foliar nutrients should be avoided as phytotoxicity and berry scarring have been reported in California. The following is a brief summary of materials, rates, and trial studies for Mn, Zn, and Fe as foliar nutrients. The information was gathered from the Wine Advisory Board Research Report (Oregon) and the UC-Davis publication #4087, Grapevine Nutrition and Fertilization.

Zinc deficiency may be corrected by applying a foliar spray two or three weeks before bloom (10 to 15 cm shoot growth or near tight cluster stage); this helps improve berry set. The vines should be sprayed with enough volume to wet the flower clusters and the underside of the leaves. Treatments applied with a dilute sprayer (100 to 150 gal/acre) result in more Zn absorption than a concentrate sprayer application (20 to 30 gal/acre) when comparable rates of Zn are used.

A number of products containing 50 percent Zn are available under various trade names. These products (basic zinc sulfates) will be neutralized to prevent foliage burn. Zinc sulfate (36 percent Zn) alone has no neutralizer and must be used with caution to prevent foliage burn. Studies in California have shown that neutral zinc products containing 50 to 52 percent Zn to be the most effective on a label rate per acre basis. Chelated Zn (EDTA 14 percent Zn) materials are available, but are a little more expensive on a cost per acre basis than the basic zinc sulfates. The zinc sulfates are fully soluble in the spray tank, whereas basic zinc sulfate is not and requires good agitation to remain in suspension. Soil application beneath drip irrigation emitters may be more effective since it provides more concentrated placement with more continuous wetting for zinc movement into the root zone. Deficiencies were nicely corrected in a drip irrigation trial where rates of liquid zinc sulfate (12 percent Zn) at 4 to 9 fl. oz. per vine and liquid zinc chelate (EDTA 6.5 percent Zn) at 0.25 to 1.8 fl. oz. per vine were tested. However, a foliar spray treatment in this moderately deficient trial vineyard was equal to the best drip soil treatments (zinc sulfate) and would be the most cost-effective treatment.

Manganese deficiency rarely is a problem, but can occur in soils with high Ph values such as those in many Colorado vineyard sites. A Mn deficiency has little practical effect on vine yields since it appears in late season on <u>older</u> leaves that contribute little to vine function. The symptoms begin on the basal leaves as a chlorosis between the veins. The only effect appears to be a reduction in leaf chlorophyll. Manganese sulfate at 2 to 3 lbs per 100 gal of water applied as a foliar spray at the loose cluster stage has corrected the deficiency in some California vineyards. Higher rates should be avoided as it may cause minor leaf burn. Manganese chelate products have been used as foliar sprays with some success.

Iron deficiency is considered one of the most difficult nutritional problems to correct. Foliar spray treatments of Fe chelates at manufacturer recommended rates or of ferrous sulfate at 4 to 6 lbs per 100 gal of water result in a temporary correction, at best. Because Fe is <u>nonmobile</u> in plants, a spray benefits only existing foliage. If chlorosis is severe and persists, repeated applications at 10 to 20-day intervals may be necessary. Experience in Colorado has found that soil treatments with Fe chelates work best and tend to last longer; however, they are expensive.

Estimating Grape Yields

Crop estimation, also called crop prediction, is the process of projecting as accurately as possible the quantity of crop that will be harvested. Why estimate the crop? Obviously, growers need to know how much crop they produce. Also, growers would like to know whether their vines are overcropped or undercropped in order to conduct the necessary adjustment. This is especially important in cold areas such as Colorado where winter freeze and spring and fall frosts could change the crop quantity each year.

The formula described below is the most popular and easy to understand system to estimate yield. This system is used successfully in other winegrape growing regions of the country. This system provides only an "estimate" of yield which should never be considered "final". Components of yield vary each year depending on the year, site, variety, and cultural practices. The following formula can be used to estimate crop with reasonable accuracy:

$$PY = (NV \times NC \times CW)/2000$$

Where PY = predicted or estimated yield (in tons per acre)
NV = actual number of vines/acre
NC = number of clusters per vine
CW = cluster weight (in pounds).

According to the formula, the grower needs to measure the following 3 parameters each year: the actual number of vines per acre, the number of clusters per vine, and the cluster weight. These parameters are discussed below with examples.

1) Actual number of bearing vines per acre: the maximum number of vines per acre is determined by the row and vine spacing. For example, a vineyard spacing of 5 x 10 feet will have 871 vines per acre. Almost always the "actual number" is lower than the "maximum number" of vines per acre due to vines missing for several reasons such as diseased vines, winter-injured vines, etc. For these reasons, each year growers need to physically count the missing vines, subtract that number from the maximum number to get an accurate count of the bearing vines. If 10% of the 871 vines/acre (i.e. about 87 vines) were missing or nonbearing then the actual number of bearing vines/acre is 871-87 = 784.

2) Number of clusters per vine: this number will depend on how many nodes (buds) are left after pruning. The number of clusters per vine can be counted as soon as they are visible (i.e. two weeks before bloom) or as late as berry set (i.e. BB size stage). The advantage of doing an early count is that clusters are readily visible and are not obscured by leaves. The number of vines on which to count clusters depends on vineyard size and uniformity. For example, in 1 to 3 acre-vineyards with vines of a uniform age, size, and pruned to the same bud number, only 45 of the vines need to be counted. For practicality, 10 to 20 vines could be used; however, bear in mind that the higher the number of vines selected for cluster count the more accurate the yield estimate will be. In larger, non-uniform vineyards, more vines should be selected. All the clusters on the sample vines should be counted. Also, the vines should be selected methodically, e.g. select every 10th vine in every other row.

3) Cluster weight: this is the component of yield that varies the most from year to year. It is influenced by environmental conditions. For example, wet weather during bloom could cause poor set and may lead to low cluster weight; also a dry summer tends to reduce berry size and thus may decrease average cluster weight. Other factors that may affect cluster weight include cultural practices (irrigation, fertilizers), diseases, insects, and birds. Cluster weights at harvest are a key part of any yield prediction program. The goal of obtaining cluster weight at harvest is not to predict the yield that year, but to provide records for yield prediction in subsequent years. Clusters can be collected from picking bins after harvest. This is an easy way to sample clusters from the bin but not as accurate as sampling clusters from the vines. The same vines used for cluster counts could be used for cluster weights. Clusters from each sample vine are picked and then weighed. The average cluster weight is obtained by dividing the total cluster weight per vine by the number of clusters per vine. Growers who do not have these data (but hopefully will in the future!) could use estimates of cluster weights shown in Table 5 on the next page (source: CSU-OMRC and Washington State University).

4) Example of predicted yield of Chardonnay for 1997 harvest at OMRC:

-spacing = 5 x 10 feet or 871 vines/acre
-missing/nonbearing vines = 1% or about 9 vines/acre
-actual number of bearing vines = 871 - 9 = 862 vines/acre
-average cluster count = 45 clusters/vine
-average cluster weight (based on 1996 harvest) = 0.3 lbs.
-predicted yield = (862 x 45 x 0.3)/2000 = 5.8 tons/acre

Even with thorough sampling, accurate vine counts, and many years of average cluster weight data the actual crop tonnage at harvest can vary. However, accuracy with this system is very good and usually falls between 75 - 100%.

Table 5. Average cluster weights for wine grape varieties in Washington and Colorado.

Variety	Cluster Wt. (lbs.) in WA	Cluster Wt. (lbs.) At OMRC*
Whites:		
Chardonnay	0.3 - 0.45	0.3
White Riesling	0.25 - 0.3	0.34
Gewurztraminer	0.25 - 0.3	0.2
Semillon	0.4 - 0.5	0.46
Muscat blanc	0.4 - 0.5	0.57
Viognier	–	0.27
Sauvignon blanc	0.25 - 0.3	–
Pinot blanc	–	0.3
Chardonel	–	0.23
Seyval Blanc	–	0.24
Vignoles	–	0.18
Reds:		
Merlot	0.3 - 0.45	0.36
Cabernet Sauvignon	0.3 - 0.4	0.37
Cabernet franc	0.4 - 0.45	0.29
Pinto noir	–	0.34
Shiraz	–	0.28
Sangiovese	–	0.61
Dolcetto	–	0.4
Malbec	–	0.36
Norton	–	0.12
Lemberger	0.4 - 0.5	–

*Cluster weights taken at OMRC are based on 1996 harvest data.

Harvest Timing

The greatest potential of any wine grape variety is realized only when it is harvested at the proper time. The maturity of grapes is usually based on three parameters: sugar content, acid content and Ph. All of these change over time, and the rate at which they change is based largely on the temperature regime in which the grapes exist. Each parameter and its means of measurement is discussed below.

Sugar Content: Grape sugar content remains low until a midseason point, usually in July or August in Colorado, at which time it begins to increase rapidly. This stage is called veraison. From that point on, if nothing else is limiting, the sugar content will increase over time and do so more rapidly at higher temperatures. The best way to measure sugar is with a hand-held refractometer which uses the degree to which light is bent by the dissolved sugar in the juice to give a quick visual measure of the "dissolved soluble solids." The scale on these instruments is given in ^{o}Brix or ^{o}Balling which for practical purposes can be considered to be percent sugar by weight. These really are worth their approximate $150 to $250 cost since they can measure the sugar content of the juice of single berries.

A hydrometer is a less expensive device which, when floated in a cylinder of juice, sinks to a level dependent on the juice density which also corresponds to sugar content. Around 50 to 100 ml (2-3 fl. oz.) of juice are required to do this test.

The alcohol content of a dry, finished wine is approximately 0.55 times the sugar content at harvest. White wine grapes are usually harvested between 18 and 24 percent sugar depending on the intended style of the wine. Red wine grapes are generally harvested at 21 to 25°Brix.

Acidity: The organic acid content in grapes (mostly malic and tartaric acids) increases through the early season until a point near veraison. From that point on, acid is lost through the grape skins by evaporation, and that process occurs more rapidly at high temperatures. Acidity is more difficult to measure, but choosing the best time to harvest depends upon having a good estimate of acidity. A sample of juice of known volume (usually 10 milliliters) is diluted with distilled water to make 40 milliliters. This mixture is then stirred while adding a base (sodium hydroxide or NaOH) of known strength (usually 0.1 Normal). In the example described here, the number of milliliters of base required to raise the pH of the juice to 8.2 is divided by 10. This results in a number called the percent acid (grams/ 100 ml). The standard strength base can be purchased and the pH 8.2 end point can be determined by a color change of an indicator solution. If measured in that manner, it is not necessary to have a pH meter available. The desired acid content of a wine varies greatly with the intended style of the wine; high acids (above .9 percent) can be useful in sweet finished wines and for those who have a taste for high acid dry wines. Acids that are too low are of greater concern (i.e., below .7 percent for white and .6 percent for red).

pH: The pH of a wine is only indirectly related to acidity; pH tends to increase after veraison. But, if pH becomes too high, the wine will not be stable. The optimum pH range is 3.0 to 3.4, but it is difficult to measure pH accurately enough using specially treated papers. A pH meter, an electronic device, is a rather expensive piece of equipment, but it is standard in any commercial winery lab. Most home winemakers function without a pH meter.

Sampling: Sampling is critical in determining crop maturity. You can determine the sugar content of a single berry with a refractometer, but there is a wide variation in maturity between berries even on the same cluster. To make an accurate estimate of the sugar, acid and pH of a crop, draw a representative sample taken from as many parts of the block, as many vines, and as many clusters in different sun exposures as possible. Younger vines and vines that are somewhat more water stressed will have higher sugar and lower acid. Clusters exposed to the sun will be higher in sugar and lower in acid than those on the inside of the canopy. Often there are two size classes of berries (especially on cultivars such as Chenin blanc) that differ greatly in maturity. In order to get a good estimate for picking, it is recommended that at least 200 berries be plucked with an effort to spread the sample across all the variations which might exist. It is easier to sample exposed clusters and exposed berries, so one tends to overestimate sugar content and underestimate acidity. It is also important that the grapes be squeezed to approximately the same degree to which they will be when actually pressed since higher sugar juice is released with only mild crushing. Unless it is very hot, weekly sampling is sufficient to follow trends in maturity. A few samples carefully collected on a weekly basis are better than many inaccurate ones collected on a daily basis.

Pest Management/Control

All too often in the past, only limited attention has been given to options for pest management. With the increasing concern for chemical toxicities and consumer risk and the decreasing number of chemical control options, the wise grower will consider all of the available options and their cost (risk) : benefit relationships. Sometimes an option may provide a lower level of pest control that may in fact still be satisfactory; conversely, an option that provides the greatest control probably will be the poorer choice if satisfactory control at lower environmental or monetary cost is available through other options. Remember, the goal should always be satisfactory control at the least combined environmental, health, and monetary cost.

Color identification sheets for some diseases and insects are appended to this guide.

Disease Management

Climatic conditions have a large role in disease development and occurrence. The warmer and wetter the climate, the more numerous and severe disease problems are likely to be for the grape grower. Colorado generally has an arid to semiarid climate, with 7 to 20 inches annual precipitation in areas where grapes might be grown. Thus, even in the wetter areas (i.e., 15 to 20 inches precipitation per year), disease problems should be manageable with advance planning and attention throughout the growing season.

Of the eight grape diseases reported or suspected in Colorado, two (grape powdery mildew and crown gall) are very common throughout the state. Three others (Botrytis bunch rot, sour bunch rot, and Verticillium wilt) occur with varied frequency and distribution. Occurrence of one virus disease, grape leafroll, has been confirmed in several western Colorado vineyards planted with non-certified nursery stock. Suspected observations of two other diseases (Eutypa dieback and nematode-vectored fanleaf degeneration) have been reported but not yet confirmed. Occurrence of downy mildew, Phomopsis leaf spot, and black rot is highly unlikely in western Colorado and not too likely even in eastern Colorado, although some of the Front Range areas might have sufficient summer humidity and rainfall to allow them to occur.

Powdery Mildew: Grape powdery mildew (caused by the fungus *Uncinula necator*) is an important disease in almost all grape growing regions of the world, but it is the most important in relatively dry climates. Under Colorado conditions, powdery mildew is the most common and most destructive single grape disease. *Uncinula necator* originated in North America and thus the native grapes are generally less severely damaged by mildew infection. Grapes which originated elsewhere in the world, particularly the *V. vinifera* cultivars, are often highly susceptible and easily damaged by powdery mildew since they were selected for centuries in the absence of that pathogen. Hybrid cultivars vary in their mildew susceptibility.

Powdery mildew fungi infect a wide variety of crops, but each species can be quite specific. The mildew that infects grapes does not infect any other Colorado crop and the powdery mildews of other crops (e.g. apples, cucurbits, roses...) do not infect grapes. Powdery mildews are unique among fungal pathogens in that they do not require free moisture for spore germination or for penetration of the host plant. The spores are spread by wind. After arriving on the plant surface they germinate and grow a short distance before forming a structure called an appressorium. From that structure a small peg is formed that penetrates the cuticle and epidermal cell wall. A specialized feeding structure called a haustorium develops inside the penetrated cell, but that is the extent of fungal development inside the plant. After an infection is established the continuing growth of the fungal colony is on the surface of the plant. Hyphae radiate from the first penetration site and periodically penetrate more cells to establish more haustoria for nutrient uptake. As the colony develops, columns of barrel shaped spores are produced. When colonies grow large enough to be visible or when multiple colonies are present, the infected plant surface develops a white to gray, felt-like to powdery appearance. The entire process from infection to sporulation can take anywhere from 5 to 21 days, depending on temperature. Powdery mildew grows most rapidly at moderate temperatures (~70F) and is very slow at extremely high temperatures (>90F). Mildew responds to leaf temperature, not air temperature and transpiring leaves are usually much cooler than the surrounding air.

Almost any green tissue of a grapevine is susceptible to mild infection including tender parts of the shoot, blossoms, leaves, berries, the rachis and pedicles. Immature tissues are always more susceptible. Severe shoot and leaf infection can reduce yield, reduce overwintering hardiness or stunt growth, but the most common form of mildew damage concerns the fruit. When berries are infected, the epidermis under the colony develops a network of russeted scars. This can be unsightly (a problem for table grapes). More importantly, if the berry is still expanding the damaged portion of the skin fails to grow and the berry cracks. This enhances secondary infection by fungi and acid bacteria. Even without cracking, severe fruit infection reduces yield, and the presence of mildew spores and mycelium can impart off-tastes to the wine. Berries are susceptible to infection from before bloom until veraison. When berries have around 11% sugar, they can be considered safe from further infection and the mildew present on the berries will soon die. Even so, the rachis remains susceptible.

Like all powdery mildews, Uncinula is an obligate parasite -- it can only live and grow on the host grape tissue. It overwinters in two ways. Mycelium can enter the developing buds and remain alive inside of the bud scales to grow again the following spring. When the necessary mating types are present, the fungus can also survive in its resistant, sexual spore bearing structures called Cleistothecia. These small (the size of a pinhead) structures can sometimes be found on leaves and fruit late in the season. They have appendages with hooked ends which can catch on the bark of the cordon or trunk. Cleistothecia which remain on the vine can mature and produce ascospores there in the spring, and these can be forcibly ejected following rains to infect the emerging grape shoots. It is not clear how much overwintering inoculum in Colorado comes from cleistothecia and how much from infected buds.

Whether originating from infected buds or from Cleistothecia, even a small population of powdery mildew can build up through the season because of the relatively short infection cycle described earlier. To the grower, powdery mildew infection often appears to have occurred suddenly, but actually it was building logarithmically long before it was found. It is for this reason that powdery mildew control methods must be practiced pro-actively -- long before infections can be found in the vineyard.

The key to a successful powdery mildew control program is the assumption that mildew is always present in the vineyard and must either be prevented from spreading or repeatedly killed-back so the epidemic does not develop to levels that will damage the crop. Begin spraying as soon as practical after buds emerge in the spring and continue steadily until veraison. Overall mildew "pressure" varies from year-to-year based on overwintering conditions and on the temperature pattern of the given season, but any grower who neglects to maintain a good mildew program will eventually suffer severe damage.

There are currently three registered classes of fungicides for powdery mildew control on grapes. Each has its own advantages and weaknesses so that the optimal control program often uses 2 or 3 classes at one point or another during the season. Each class is described below:

Sulfur: Elemental sulfur is the oldest known fungicide and was the mainstay of mildew control until recent times. It is recognized as suitable for "organic" production. Sulfur particles on the plant slowly sublimate (change from solid directly to gas) and generate sulfur compounds which can kill germinating spores of powdery mildew. Sulfur is a completely preventive fungicide and is only effective immediately in the vicinity of the particle. Excellent coverage is necessary for control with sulfur. Sulfur is available either as a dust (use rates 5-15 lbs/acre) or as a wettable powder for water application (use rates 2-6 lbs/acre). Dusts have the advantage of potential high speed application and penetration of dense canopies but they have the disadvantages of substantial drift which can damage neighboring crops and irritate neighbors. Sulfur dust should be applied on a 7-10 day cycle. Wettable sulfur can be used on a slightly longer spray interval (7-14 days) and does not have problems with drift. It takes longer to apply and can be more difficult to deliver to all parts of the canopy. With either kind of sulfur, high temperatures (>90F) can speed sublimation to the point that leaves are damaged. Very low temperatures (<55F) do not allow enough sublimation to be effective. Sulfur is highly susceptible to rain wash-off and must be re-applied after any significant rain. When using sulfur for mildew control, the basic goal is to keep a coating of relatively fresh sulfur on the entire vine as consistently as possible. The faster the vine is producing new, unprotected tissue, the more frequent the sulfur applications must be to reestablish the protective barrier. Sulfur does not kill established mildew infections, it simply slows the progress of the epidemic.

Sterol Inhibitors: There is a class of synthetic, systemic fungicides variously referred to as SIs (Sterol inhibitors), EBIs (Ergosterol biosynthesis inhibitors), or DMIs (Demethylase inhibitors). All these names are more or less specific descriptions of the kind of fungal enzymes which are inhibited by the fungicides. All of those available for use on grapes inhibit the same enzyme in the ergosterol biosynthesis pathway which is important because strains which become tolerant to one DMI fungicide are also more tolerant to other DMI products (cross resistance). These fungicides are all applied in water and move to a certain extent from cell-to-cell in the plant and with the transpiration stream. The systemic movement is not sufficient to move fungicide to new tissues, but it does help overcome small inconsistencies in spray coverage. DMI fungicides can be very potent tools for powdery mildew control and are particularly valuable during bloom and immediately after when berry tissue is expanding so rapidly that sulfur protection is difficult to maintain. DMI fungicides can kill a young mildew colony (1-3 days), but are not able to kill established, sporulating infections. Although they have this curative action, they should be approached as protective fungicides and used on a 14-18 day spray schedule. Tolerance to DMI fungicides is well documented, but is not a dramatic all-or-nothing type of resistance. Even so, it is best to limit the total number of DMI sprays used in a spray program, to use other fungicides as part of the program, and to avoid using DMI fungicides later in the season when the selection pressure is applied to a large mildew population. As new classes of systemic fungi-cides are introduced, the same general guidelines should apply. Do not rely on a single mode-of-action throughout the season and use potent systemic treatments early to mid-season before larger mildew populations are present.

Impact Fungicides: A class of powdery mildew control tools has been introduced recently that is described as "impact fungicides". These are materials that are capable of killing mildew spores and mycelium during direct contact of the spray solution or suspension. These materials are almost strictly curative in their activity because they have no effect on new spores that arrive after

Standard Fungicide Programs

The most highly recommended fungicide programs for grape powdery mildew control are as follows:

Standard DMI program:

1. Wettable or dusting sulfur starting at budbreak and continuing on a 10-14 day pattern (7 days for dust) until bloom or 10" shoot growth.
2. DMI applications every 18 days from bloom or 10" shoot growth until the total, annual dosage/acre has been applied (usually around 3 sprays).
3. Sulfur applications on a 10-14 day interval (7 day interval for dust) until veraison.

Standard Sulfur Program:

1. Wettable sulfur starting at budbreak.
2. Dusting or wettable sulfur on a 7-14 day cycle until veraison.

Older recommendations (first written in 1905) began the program at 6 or 12 inches of shoot growth, but recent research indicates that much better control is usually achieved by starting the spray program earlier.

These programs are commonly modified by grape growers for various reasons.

DMI program modified for resistance management:

- Alternation: sulfur sprays inserted between the DMI the spray dries. Any type of impact fungicide is based on emulsions of either plant oils or paraffinic mineral oils. The mineral oils are not very compatible with a spray program that also includes sulfur. Under some conditions, a sulfur treatment as much as two weeks before or after an oil application can lead to severe burning of leaves. The other type of impact fungicides are potassium salts of naturally occurring fatty acids. These materials are compatible with the use of sulfur and can be particularly useful for "rescue" applications when mildew infection is "flaring up" in isolated areas or because of failure of the previous preventive control program. A spray program (10-14 day interval) using only curative fatty acid products has been shown to give season-long mildew control. Fatty acids are also attractive alternatives when conditions are too hot for sulfur or if the winemaker is concerned about sulfur residues carrying over to the must at harvest. Oils (and to a lesser extent fatty acids) effect the appearance of the waxy surface of the berries. This does not effect their resistance to other diseases or resistance to water, but it is generally considered unsuitable for table grape production.

Crown Gall: Crown gall, a bacterial disease caused by *Agrobacterium tumefaciens,* can be a significant problem in some Colorado grape plantings. Galled vines frequently have poor shoot growth and fruit production, and portions of the vines above the galls often die prematurely. *Vinifera* grapes appear to be most susceptible to crown gall attack and damage, but some *V. labrusca* cultivars (e.g., Niagra, Dutchess, and Isabella) also can become heavily infected. Hybrids that are often infected include Aurore, Chancellor, and Cayuga White. In Colorado, Merlot appears to be more susceptible to crown gall than Riesling.

The bacterium lives in soil but, when present at a plant wound, it invades the host cell and transforms it into an undifferentiated gall type of growth. The galls interfere with normal sugar and water transport in the host and, depending on the location and size of the gall, can kill the plant or stress it so that it becomes non-winter hardy. Injuries for gall initiation are most common in the nursery and during planting, but winter freeze-cracking of trunks provides another potential entry point in Colorado.

Crown gall has been controlled on some hosts by use of another bacterium that produces an antibiotic that inhibits some strains of the pathogen. Unfortunately, the common grape strain (biovar 3) is not sensitive to this antibiotic. Thus the biological control option (strain K84 of *A. radiobacter*) is not effective in controlling grape crown gall. An eradicant chemical such as kerosene or Gallex can be used on the gall itself to kill gall tissues, but treated vines should be checked for gall recurrence over the next year or two since new galls can develop at treated sites.

Use of management practices that reduce winter injury can be helpful because the development of crown gall is frequently associated with the occurrence of freeze injury. Freeze cracking injury in the field allows the formation of galls on mature vines; this occasionally kills the trunk outright, and the vine must be retrained from root suckers. Thus, in sites prone to severely cold winter temperatures, growers should consider burying young vines in the fall to reduce freeze injury and possible "hilling" of trunks in the fall to protect the crown tissues (and to protect replacement buds from freezing just in case they are needed for trunk renewal the next season). Any galled wood should be removed from the vineyard and burned.

Recent research also has shown that the pathogen can become systemic within grape tissue and can be introduced into previously non-infested soil by planting infected grape plants. This points out the need to plant only pathogen-free vines, especially in new planting ground. Such a practice should help minimize crown gall occurrence in replanted ground and avoid the high incidence of disease that has often been experienced in new plantings.

Botrytis Bunch Rot: Botrytis bunch rot or grey mold generally is present in all vineyards, but only occasionally causes problems in Colorado vineyards. Varieties with tight clusters (Chenin blanc, Muscat blanc, Gewurztraminer, Pinot noir, Rougeon, Sauvignon blanc, and Riesling) are usually the only ones damaged in Colorado and usually only in seasons with cool, unusually wet summer weather. Both yield and quality can be reduced. Table grapes can lose substantial fruit quality in the field, in storage, or in transit, but wine grapes suffer even more serious damage to quality because of the chemical changes within the grapes brought about by infection. Wines made from diseased fruit tend to be less clear, have off-flavors and do not age well.

Affected bunches also can be affected by the vinegar bacterium, *Acetobacter* sp., and a common saprophytic fungus, *Aspergillus niger* in what is known as sour bunch rot (see next entry).

Control can be obtained through two non-chemical management options. Leaf removal around the developing fruit clusters will increase air circulation and decrease humidity levels within the canopy. This will reduce the liklihood of bunch rot getting started. Secondly, varieties with very tight clusters may be cluster thinned by removing selected berries when young; this opens up the clusters to allow more air movement through them and thus reduce the potential for bunch rot.

Sour Bunch Rot: Sour bunch rot may cause damage to varieties with tight clusters (Chenin blanc, Muscat blanc, Gewurztraminer, Pinot noir, Rougeon, Sauvignon blanc, Riesling) in seasons where hot August weather is accompanied by rains. Broken berries attract the vinegar fly that carries the vinegar bacterium, *Acetobacter* sp. The berries rot and develop an objectionable vinegar order. The fungus *Aspergillus niger* is often involved in the complex. This disease has no real control except by avoiding berry breakage by birds or other factors. To date, it has not occurred in sufficient abundance in Colorado to adversely effect wine quality.

Verticillium Wilt: Verticillium wilt is caused by the fungus *Verticillium dahliae*. It occurs only sporadically in Colorado, primarily in vineyards planted in soils in which susceptible crops (e.g., sweet cherry, apricot, tomato, strawberry) have been grown.

Symptoms of Verticillium wilt mimic those of drought stress. Shoot wilt, collapse, and death can be extremely rapid by mid-summer, and leaves and young berries just dry up and remain attached to the dead cane. The diagnostic symptom, however, is the greyish to brownish discoloration of the vascular elements within the base of the collapsing cane. This discoloration, best seen by cutting the bottom portion of the cane on a diagonal (an oblique cut), appears as greyish to brownish streaks associated with or within the vascular bundles.

The reason for the drought stress type symptoms and the vascular tissue discoloration is that the *Verticillium* fungus colonizes and plugs up the vascular tissues. Thus, as the need for water transport increases with increasing summer temperatures, the infected vine simply cannot supply enough water to the heavily colonized canes fast enough to keep up with demand. As a result, the affected canes simply wilt and die.

This disease is mostly a problem in young plantings between their second and sixth leaf. By the sixth leaf, vines that exhibited symptoms earlier but did not die recover and are not affected thereafter. At that point, the disease generally is no longer a problem within the vineyard. Although early fruit production can be reduced and full production delayed by the disease, no effect on yield has been shown in vineyards that no longer show symptoms of Verticillium wilt. Thus specific control measures for the disease do not appear warranted other than avoiding any sites where the disease has actually killed grapevines.

Eutypa Dieback: Eutypa dieback is also known as "dying arm" (formerly "dead arm"). It is one of the most destructive diseases of woody tissues of commercially grown grapes. The causal fungus, *Eutypa lata* (synonym = *E. armeniaca*), and the disorder are most common in areas of higher rainfall and severe winters, but can be expected in areas where the annual precipitation is above 10 inches per year. Occurrence in areas with less than 10 inches precipitation per year is unlikely, but since many of the grape plantings within Colorado are likely to be within areas where apricots are grown, the possibility of the disease does exist.

Characteristic symptoms of Eutypa dieback begin with early season growth, when shoot growth is 10 to 20 inches in length. Affected shoots are deformed and discolored, with much dwarfed internodes, and the leaves smaller than normal, cupped and chlorotic. The leaves often develop small necrotic spots and tattered margins with age. The diagnostic feature of Eutypa infection on arms with such symptoms is a wedge-shaped zone of dark-brownish dead sapwood extending into the wood when the wood is cut in cross-section.

Control is available through a drenching spray of benomyl applied at pruning to any large wounds or cuts on woody tissues (i.e., not the annually produced canes, but rather any tissue that is two years old or older). This material is effective in preventing spores from germinating and gaining a foothold for infection; thus, it must be in place before the spores arrive. Applications must be sufficiently drenching to be absorbed and taken up into the vascular tissue to be effective, and they must be applied as soon as possible after the wound or cut is made. Manual treatment of such wounds at the time of pruning will have the highest probability of success. In Colorado's more arid climate, those chances should be relatively high.

Virus Diseases: The two virus diseases known or suspected to occur within Colorado are **grape leafroll** and **fanleaf degeneration**. In both cases (the same is true for most other virus diseases) problems can be avoided by planting only certified clean stock such as that grown in the Pacific Northwest and in certified programs in California. The various viruses, in addition to the symptoms for which they are generally known, appear to reduce the winter hardiness of the vines. In addition, some grape viruses are spread by dagger nematodes that occur within our fruit producing soils. Thus importation of non-certified nursery stock could import a potential virus problem that could spread within vineyards and last in the soil even after the diseased vines are removed. **NON-CERTIFIED VINES** or vines from questionable sources **SHOULD NOT BE PLANTED OR USED FOR PROPAGATION**.

Grape Leafroll Disease : Grape leafroll, which results from infection with the grape leafroll virus, causes chronic damage to affected vines. Leafroll infection does not kill affected vines, but yield loss of 20 percent has been reported to occur each year for as long as the diseased vines were maintained within the vineyard. The disease is widely distributed because of past propagation from diseased mother vines, but was not known to occur within Colorado vineyards before the 1989 season. However, one confirmed occurrence in an entire planting of Lemberger and a second in a second leaf Cabernet franc planting in Mesa County illustrates the need to order only certified virus-free grapevines.

The disease is characterized by the occurrence of colored leaves (yellow for light fruited varieties or red to red-purple for dark fruited varieties) with green veins and downward rolled leaves. These symptoms develop in late summer beginning with the leaves at the base of the cane and proceeding toward the tip. However, since similar symptoms also can be produced (to some extent) by cane or vine injury (from cane borers, crown gall, mechanical damage, crown rot, etc.), careful examination must be made to rule out these other possible causes. General size of infected vines and plant structures (leaves, shoots, canes, trunk, and root system) is slightly smaller overall than that of healthy vines. In addition, the disease delays fruit ripening and reduces fruit cluster size and fruit sugar content; fruit color, especially in the red or black cultivars, is pale.

Control of the disease is relatively simple -- removal of the affected vines. No vector for the causal virus is known, and natural spread in commercial vineyards is slow. This strongly suggests that the primary source of infection is the diseased budwood from which vines were propagated. Leafroll is an avoidable disease **if** care is taken to plant **only** virus-free vines.

Fanleaf Degeneration: Fanleaf degeneration, the oldest known virus disease of *vinifera* grapes, varies with cultivar tolerance to the virus. Sensitive cultivars are severely affected with infection causing decreased yields (up to 80 percent losses) and fruit quality, progressive vine decline and shortened productive vineyard life, reduced graft take and rooting ability of cuttings, and lower tolerance of adverse weather conditions (e.g., winter hardiness, heat and drought tolerance, etc.).

Diagnosis is complicated by the fact that the virus can cause any of three distinct symptom syndromes. These focus primarily on leaf shape and color patterns, shoot growth patterns, and fruit production effects.

The first symptom syndrome, infectious malformations, includes the most severe symptoms and is the best known of the symptom syndromes. Its most obvious effects are malformations of the leaves and shoots that appear in the spring and continue throughout the season, with a slight lessening in severity of the leaf symptoms severity during the summer. Leaves are variously deformed, often asymmetrical and puckered, with the leaf base tending to be more flattened (less of an angular notch at the leaf base) and the veins less separated to give the leaves a more open, fan-like appearance (from which the disease derives its name). The leaves also may have a chlorotic mottle. Shoots are commonly malformed with shortened internodes, a zigzag or snake-like growth pattern, double nodes, abnormal branching, and fasciations. Fruit set in vines with such symptoms is poor, and the fruit bunches are fewer and smaller than normal with shot berries and irregular ripening.

The second symptom syndrome, yellow mosaic, exhibits little or no malformation of shoots or leaves, but it does result in small fruit clusters with some shot berries. Its main characteristic is the bright chrome yellow discoloration of early spring vegetative structures (leaves, shoots, tendrils, and inflorescences). The discolorations range from scattered yellow spots to rings or lines to extended leaf mottling to total yellowing. Affected vines are easily spotted within the vineyard in early spring, but are less obvious by summer in areas with hot summer weather whey they begin to produce normal, green foliage.

The third symptom syndrome, veinbanding, consists of mid- to late-summer discoloration in mature leaves and severely reduced fruit yield (to virtually zero). No shoot or leaf malformations are produced, but chrome yellow flecks develop along the main veins of some (but not all) mature leaves. The flecking then spreads somewhat into the interveinal areas of the affected leaves. Fruit set is poor and the clusters are straggly.

Grape fanleaf virus (GFLV) is spread primarily by a dagger nematode, *Xiphinema index*. The virus has no known natural weed hosts -- only grapes. However, the nematode can acquire the virus in a single, brief feeding on an infected vine and can remain inoculative for up to eight months, even in the absence of host plants. Added to this is the ability of grape roots to remain viable (and, thus, as sources of inoculum) for many years after the mother vine is removed. This makes control <u>extremely difficult</u> once the nematode and infected grape roots are present within a planting.

The best control for fanleaf degeneration is to plant only <u>certified virus-free</u> stock. Once the nematode <u>and</u> infected grape roots are present, the ecological cycle of the nematode / virus / grape complex must be broken. This usually requires a prolonged fallow period with rigorous weed control <u>or</u> eradication of the vector nematodes with soil fumigants <u>or</u> both. Soil fumigation (at high rates) works better in shallow than in deep soils, as some nematodes can survive below the depth the fumigant penetrates. Rootstocks resistant to either the virus or the vector nematode or both are being developed and should be considered for use in renovated vineyard plantings with a history of fanleaf degeneration.

Insect & Mite Pest Management

Insect and mite pest problems have not been severe enough in Colorado to require a regularly scheduled spray program. However, with the continued increase in acreage planted to grapes, this could change. Grape pests known to occur within Colorado vineyards or orchards include: grape leafhopper, grape berry moth, grape cane borer, grape mealybug, grape skeletonizer, sphinx moth, thrips, cutworms, cottony maple scale, thrips, and mites. *Phylloxera* is not known to occur currently in Colorado. With proper care in selection of plant sources and careful examination of all materials before planting, it is hoped that this pest can be kept out of Colorado. Leafminers are an occasional problem in backyard grape plantings but have not been a problem in commercial plantings to date.

Climbing Cutworms: Several species of climbing cutworms may be found chewing on grapes in Colorado. These pests hide in the soil or debris beneath the grape trellis by day and move up the vine at night to feed on buds just as they are swelling and pushing in the spring. Their feeding leaves small (1/16 to 1/8 inch) tunnels into a bud; this kills the bud and results in crop loss. Sprinkling a suitable carbaryl (Sevin) bait around the trunk of each vine usually will stop this damage. If the worms are living on the trunk itself, a spray may be necessary.

Grape Berry Moth: Grape berry moths can be important pests of grapes in Colorado and can cause serious fruit losses in some areas. The larval stage of this insect enters young berries and causes them to wither as they mature. The insect typically is found in American grapes such as Concord and in hybrids, but also can be found in vinifera grapes.

There are two generations of the moth each year, with peak flights in mid-June and late-July. Adult moths emerge in late May from overwintering pupae and lay eggs singly on small developing grapes or cluster stems. If the berries are too small, the larvae will make webs on the cluster stems and feed there until the berries are of sufficient size to enter. Entry of the larvae into the berries of some grape varieties causes the berries to turn red in response; this can be helpful in identifying the problem early. Full-grown larvae pupate on the ground or on the leaves, and a second generation of moths becomes active in late July. This second generation usually is the most injurious. Eggs are laid on the berries, and emerging larvae invade the fruit. Pheromone traps are available that can help determine periods when adult moths are flying and laying eggs. Insecticide applications are suggested for approximately 10 days after flight periods begin. Concord growers have had good success in controlling the problem with sprays of carbaryl (Sevin) at those times. *Vinifera* grape growers should watch for this problem to determine if they need such sprays.

Grape Leafhopper: Although this distinctive, orange and white mottled leafhopper is usually encountered at some level in vineyards, it seldom reaches sufficient populations to materially damage the vines. The nymphs of this pest suck the juice from the leaves and cause them to become blotched with white spots. Infested vines may show a lack of vigor. Its droppings are undesirable on table fruit and, if enough stippling of leaves occurs due to its feeding, the crop could be delayed in maturity.

Adult grape leafhoppers overwinter beneath leaves and trash near vineyards. In May the adults migrate to the grapes, feed, and lay eggs just under the lower leaf surface. After hatching, the young nymphs feed on the leaf undersurface and cause the typical leafhopper damage. There can be a partial second generation late in the summer.

Grape leafhoppers are relatively easy to control with insecticides when the nymphs are present. These include carbaryl (Sevin), azinphosmethyl (Guthion), methomyl (Lannate) and diazinon. There also are some natural controls (e.g., an *Anagrus* wasp that parasitizes leafhopper eggs).

Grape Flea Beetle: These bluish-black shiny beetles feed on the interior of developing primary grape buds and, in this way, prevent development of primary grape canes. They overwinter in trashy or wooded areas and emerge in the spring to feed and lay eggs on the vines. The eggs hatch to produce light brown larvae that feed on the upper leaf surfaces. Mature larvae drop to the ground to pupate in the soil, and a second generation of adult beetles emerges in July to August.

Control is obtained primarily through insecticide applications to kill the feeding larvae. Methoxychlor is labelled for this use on grapes.

Mealybugs

The grape mealybug *Pseudococcus maritimus* has been identified in vineyards of western Colorado by B.C.Kondratieff and W. Cranshaw (Technical report #TR94-1 Department of Entomology, CSU 1994). Populations have increased during the last three years and it has become a production threat to vineyards of western Colorado.

Mature, fully grown mealybugs are 3/16 of an inch long, pinkish red, covered with a white powdery wax. Filaments of wax extend from the sides and rear of the oval, somewhat flattened bodies. Eggs are yellowish to orange, laid in a cottony eggsac under bark or in protected locations. Newly hatched nymphs (crawlers) are brownish and lack the powdery wax cover. Mealybugs overwinter as eggs in their cottony white ovisacs, or as young crawlers beneath the loose bark of the vine. In spring the eggs hatch and the crawlers move to the base of the spurs and out onto the new growth. Once mealybugs reach maturity in mid June most females return to the vine trunk and lay eggs in the protected regions beneath the loose bark. The second generation will hatch a month later and will be responsible for a noticeable population explosion. It is this brood which will cause the majority of the damage as well as lay the eggs that will overwinter.

Vineyard monitoring for mealybug infestations is important and simple. Mealybugs prefer vigorous vines and can be detected in spring and summer by the presence of honeydew and/or sooty mold on the trunk and below the vine. The presence of honeydew should trigger a closer examination of the vine for eggsacs, crawlers, and adults. In mid-summer, fruit clusters that touch old wood should be examined closely for evidence of honeydew, and black sooty mold. It s common for mealybug populations to explode mid-summer and then decline just as rapidly due to the presence of natural predators. If control is necessary, it is best achieved with a dormant spray which can be followed by a summer treatment. It is important to note that summer treatments are only effective if applied before the insects are half grown and their waxy covers are still permeable.

Mealybugs have two generations a year. The first overwinters as eggs or as nymphs; the second is produced in mid-summer and, in turn, lays the eggs that constitute the overwintering generation for the next season. In spring the young nymphs move to the base of the spurs and then out onto the green portions of the vine to feed on foliage and fruit. After maturation in early June, most females return to protected areas to lay eggs that hatch about a month later (early July). The second or summer generation nymphs then move out to the green portions of the vine to feed, and it is primarily this brood that produces the bulk of the fruit damage. As the second generation females mature, some may deposit their eggs on fruit and leaves; most, however, return to old wood or protected locations to lay their overwintering eggs.

Achemon Sphinx Moth: Caterpillers of the Achemon Sphinx moth have caused occasional damage to grapes in Colorado. The larvae are voracious feeders and can quickly defoliate sections of a vineyard if large numbers are present.

This pest is related to a better known cousin, the tomato hornworm. The adults, also known as hawkmoths, approximate the size of a hummingbird and have a similar, darting, hovering flight as they fly and feed on flowers at dusk. The achemon sphinx moth has about a 3 to 4-inch wingspan, a body and forewings that are a marbled brownish-gray with well-defined dark brown spots, and hindwings that are a rich rosy pink with a brown border and dark spots. The larvae are green or reddish, about 2.5 to 3 inches in length.

Control is rarely needed, but applications of *Bacillus thuringiensis* (Dipel, Biobit, Thuricide) are very effective against sphinx moth if made before the larvae become too large. Other insecticides are also effective if applied at early stages.

Thrips: Thrips are primarily a problem for table grape production, and then only rarely in Colorado. Feeding by western flower thrips during bloom and early postbloom can result in scarred fruit that is not salable. Feeding by large numbers on young shoots in the spring can stunt these shoots and may thus require control.

Thrips are small insects with fringe-like wings (instead of the membranous wings of many other insects). Adults generally are about 1/16 of an inch in length and can occur in three color phases: light, intermediate, and dark. The dark form predominates in early spring while the light and intermediate forms are most common later. The light form is the most numerous. The two nymphal stages last one to two weeks, during which they feed on both stem and flower or fruit tissues. It is this feeding that produces the fruit scarring. Two additional stages (prepseudopupal and pseudopupal) occur in the soil debris. The emerging adults feed primarily on pollen so far as is known. There are five to seven generations per year, with a population peak coinciding with grape bloom. The western flower thrips over-winters in the adult and nymphal stages.

Thrips populations can be determined by counting adults or nymphs knocked out of the flowers or fruit clusters. Generally, if more than 10 adults are observed per cluster, control sprays may be needed on those cultivars more susceptible to damage.

Grape Cane Borer: Grape cane borer, perhaps better known as the branch and twig borer, is at most only a minor pest in Colorado's vineyards; its presence is suspected in Fremont County, but this has not yet been confirmed by examination of actual insect specimens. It is a wood-boring beetle, *Malalqus confertus* LeConte, that also attacks other woody plants such as fruit and ornamental trees and shrubs.

On grapes, it derives its common name from its method of feeding and the resulting damage; the adult beetle burrows into weak grape canes at a crotch or bud axil and proceeds to mine out the woody tissue. This causes shoot wilting and flagging and, occasionally, partial breakage at the feeding point when shoot growth reaches 8 to 10 inches in length. These broken shoots often remain hanging down from the spur after breakage. Such wilted or wilted and broken shoots should be closely examined for any evidence of feeding holes or, possibly, the feeding adult beetle.

The adult blackish brown beetle is small to medium sized, 0.3 to 0.6 inches in length, cylindrical in shape with an obviously narrowed "waist" between the abdomen and thorax. The eggs are smooth, white, and cylindrical with a slightly pointed end. The larvae also are whitish, but covered with fine hair and heavy bodied with a curved "C"-shape that is larger toward the head end. The larvae also can do equally serious damage to vines through their feeding on both dead wood and living tissue; they plug their feeding channels with excrement and chewed wood frass.

The eggs are laid singly in cracks and crevices of the roughened trunk or arm bark during late spring/early summer (approximately May in Colorado). The larvae emerge two to four weeks later and establish themselves within the wood of the vine trunk or arms. They feed for the next 10 months or so, and then burrow toward the tip of the arm (usually in mid-spring) where they prepare a hollow cell and pupate for one to two weeks before emerging as adults.

Chemical control can be obtained through two to three applications of carbaryl (e.g., Sevin) at seven to ten day intervals when adults are emerging, but this should be considered only as a last resort. Satisfactory control usually is obtained through attention to vineyard and area sanitation. Newly hatched larvae enter dead or dying areas on grape trunks and arms, so much of the problem can be controlled by keeping vines healthy and by removing any dead or dying portions. Prunings should be collected and burned before bud-break in the spring in order to eliminate overwintering larvae before they pupate. Brush and wood piles should not be allowed to accumulate near vineyards and also should be burned before mid-March.

Grape Leaf Skeletonizer: Grape leaf skeletonizer is reported to occur within Colorado, but damage from this pest is not common. The bulk of the damage is due to vine defoliation by the larvae. Under certain conditions, it can feed on the fruit and this injury then leads to bunch rot that usually destroys the entire fruit cluster.

Adult skeletonizer moths are about 5/8-inch long and have a wingspan of 1 to 1.3 inches, a characteristic bluish-black to greenish-black color, and comb-like bristles along the antennae. The caterpiller larvae are strongly gregarious and habitually feed side-by-side during their first three instars and sometimes in the fourth instar. The larvae display a unique swarming behaviour even at time for the first three molts; they move away from their feeding site (often to an undamaged leaf or to the stem or shoot), form a round assembled mass, and then molt. The larvae become increasingly banded in appearance with successive molts with band colors of brown to blackish purple; body color between the bands is initially pale brown, but finally a bright yellow just before the larvae spins its silken cocoon. The larvae also have many long, dark hairs on the body that seem to be poisonous; workers who brush against the hairs often develop skin welts similar to those produced by contact with stinging nettle.

The skeletonizer overwinters in the pupal stage and has two complete (and sometimes a third partial) generations each year. Initial emergence from overwintering pupae occurs in late April to mid-May, and the first generation larvae are usually found in early May to late June. The second generation runs from late June to late August or early September.

Control is readily obtained with chemicals used for lepidopterous larvae on grapes. A stomach poison, such as cryolite, is preferred because of its long residual activity and low toxicity to natural enemies. Application of *Bacillus thuringiensis* (Biobit, Dipel, Thuricide) also gives good control of grape leaf skeletonizer if treatments are properly timed.

Cottony Maple Scale: Scale insects are rarely observed on grapes in Colorado. The only species observed on grapes here thus far has been one incidence of cottony maple scale. The main problem caused by this pest is the production of a great quantity of honeydew which, in turn, makes the grapes sticky and sooty in the same way that grape mealybug does.

The adult female cottony maple scale is about 1/5-inch long, flattened, oval or oblong, a pale or dark brown with a large cottony egg sac that is about two to three times as long as the body. They could be confused with grape mealybug if care is not taken in examining the insects. As the scale female continues to lay eggs, the egg sac enlarges; it remains for some time after the female has died and the crawlers have dispersed to the undersides of leaves. In late July or early August, they mature; the males develop wings and mate with the wingless females. The mated females then crawl back to young canes for overwintering.

Control is best accomplished through dormant sprays such as those for grape mealybug.

Eight-spotted Forester: Larvae of the eight-spotted forester moth feed on grape leaves and can defoliate vines when quite numerous. Serious injury, however, usually is rare in Colorado. Fully grown larvae are about 1 inch in length and have distinct markings of orange, yellow, black, and white. After feeding is completed, larvae drop to the ground to pupate. The adults are black with white and yellow spots on the wings.

Mites: Mites have not been observed as a major problem in Colorado vineyards. They do best in dry, dusty conditions so that raising of dust in the vineyard in mid-summer should be avoided.

The McDaniel and two-spotted mites overwinter primarily as adult females in soil and trash near the base of woody plants. The extent to which the mites may survive the winter on the trunk or branches of fruit trees or vines is unknown for western Colorado. It is generally thought that any mites on the trunk migrate down to emerging cover-crop vegetation early in the season. At this time mite populations exhibit a preference for herbaceous plants and seem to attack fruit plants only secondarily, later in the summer. Because the two-spotted mite spends half the growing season on the cover crop, considerable control can be achieved through cultural practices such as minimizing or eliminating weeds around and under the vines.

Each adult female produces 40 to 100 eggs, and the average adult life span is 15 to 30 days but may be up to two months. Unfertilized females produce only male young. Under average growing conditions, probably 10 generations of mites are produced in a season. As temperatures become cooler in the fall and the days shorter, the females turn orange and congregate in branch crotches and under bark scales. Mite populations experience considerable mortality over winter.

The injury caused by mite populations is largely confined to foliage feeding. This feeding causes collapse of plant cells and loss of vigor in the vine. When infestations are heavy, the mite populations retard fruit color development to such an extent that fruit quality may be downgraded. High mite populations also can affect bud formation.

Nematodes: Nematodes are microscopic, multicellular, unsegmented, parasitic round worms that live in the soil and feed on roots of various plant species. Some general symptoms of nematode injury to grapevines are overall vine decline, yield reduction, weak vigor, greater sensitivity to stress, poor root development, off-color, and knotted roots. These symptomatic conditions are often confused with water stress and nutrient deficiencies. Unfortunately nematodes do not cause specific symptoms on above ground tissues and thus nematode detection without laboratory analyses is impossible. Nematodes can also transmit a variety of viruses (e.g. tomato ringspot virus, grape fan leaf virus).

The following is a list of potentially damaging nematode genera found in orchard/ vineyard soils of western Colorado (Mesa, Delta counties). The listed nematodes were identified in 1963, 1985 and 1992 by the Colorado Agriculture Experiment Station.

Helicotylenchus spp. (the spiral nematode),
Meloidogyne spp. (the Root-knot nematode),
Paratylenchus spp. (the pin nematode),
Pratylenchus spp. (the root lesion nematode),
Tylenchorhynchus spp. (the citrus nematode),
Xiphinema spp. (the dagger nematode).

Currently, none of the above mentioned genera have been specifically connected with declining vine growth in Colorado vineyards, however poor vine growth could be associated with these multi-host parasitic roundworms.

The intent of this Guide is not to give a description of the life cycles and associated symptomatic injuries of each genera of nematode but to inform the vineyardist of the problems that may occur. Since many vineyard sites in Colorado are being planted in orchard ground, it would be of benefit to get a laboratory analysis of the species present and the population levels. Various laboratories throughout California and the northwestern states offer a nematode detection service.

Methods for controlling nematodes are mainly limited to resistant rootstocks (see table 3), preplant fumigation and clean nursery stock. Cover crops have been demonstrated to reduce nematode population levels. Research trials at the University of California Kearney Field Station has shown that the cover crop Cahaba white vetch exhibits nematode resistance and nematicidal properties.

Soil fumigation studies in California have determined that the preplant fumigants methyl bromide and 1,3-D, when properly applied, give effective control, but nematode populations frequently recolonize quickly following incomplete fumigations.

It is important to recognize that fumigants are not only becoming less available (EPA registrations canceled) but also upset the total microflora and fauna of the soil. The need for well balanced healthy soil, thus a healthy root system, is significant for wine productivity and longevity.

Weed Management

It is beneficial to take steps to reduce perennial weed infestations **before** planting. This will greatly help to control these perennial weeds later. Annual weeds also can be controlled prior to planting if proper steps are taken in the preparation period.

Most weeds between grape rows can be controlled by cultivating, disking and mowing; however, weeds in the row are more difficult to manage. Special hydraulic oes that retract to miss the vines (e.g., Clemons, Weed Badger) can be used to mechanically remove these weeds as can hand hoeing. Most growers, however, prefer the partial use of chemical herbicides. Several herbicides are compatible with grapes, including soil active types (dichlobenil, diuron, napropamide, oryzalin, simazine, trifluralin) and foliar active types (glyphosate and paraquat). All must be used carefully and in accordance with their label requirements.

In Colorado native bindweed is the most common problem weed, and in orchards it is usually managed with herbicides containing 2,4D (e.g., Dacamine, Weedar). This herbicide is **NOT REGISTERED** for use in vineyards and is very detrimental to grapes by causing grotesque leaf distortion and reduced growth. Vine death can result from 2,4-D applications. Spray drift and contaminated tailwater can cause damage in vineyards that have not been sprayed directly.

Glyphosate (Roundup) provides excellent control of weeds in the vine row and can be applied next to the trunks **IF** suckers have been removed and **IF** applied before canes drop towards the ground. Vines can be killed if the herbicide is sprayed on green tissue! During retraining of damaged vines, special precautions must be taken to avoid spraying the shoots at ground level.

Bird Control

Birds of many species (e.g., starlings, robins, blackbirds, and finches) are attracted to ripening grapes. This leads to both crop loss and bunch rot. A flock of 20,000 blackbirds in a two acre vineyard for 30 minutes can cause very significant damage. The problem is severe in small vineyards and in those with neighboring trees. There are numerous noise and decoy methods available to keep birds away, for example, scare eye balloons, mylar reflective tape, plastic bags, electric fencing, recorded distress calls, 12 volt programmable electronic bird deterents and propane canons. However, the most reliable method is plastic netting. Plastic bird netting typically comes in 5,000 ft. rolls that are 14 or 17 ft. wide and are 3/4 inch mesh. The plastic bird netting is draped over an entire vineyard row (posts, trellis, vines, etc.) and tied. The plastic netting can be virtually a bird-proof enclosure when anchored to the ground or gathered under the vines and tied. the plastic netting is lightweight (approx. 3 lbs. per 1,000 sq. ft. of 3/4 inch mesh size) and can be applied by hand or by machine. Most growers complain severely when applying or removing the netting by hand, expecially if the wind is blowing. The netting snags and hangs up on what seems like everything in the vineyard (twigs, leaves, posts, wire, your shoes, watch, etc.). Machine applicators make applying and removing the 5,000 ft. X 17 ft. wide rolls an easy task. One roll of 3/4 inch mesh by 5,000 ft. X 17 ft. wide typically costs about $700.00.

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Wine Grape Varieties for Colorado

Variety selection based on your palate is not good viticultural judgement in Colorado or any wine growing region. Unestablished markets and unsuitable climates are two very important reasons worth considering before selecting a variety to plant in Colorado (see table 6, Relative Cold Hardiness of Grapevines Grown in Colorado). The climate of a region and particular site strongly influence the survival, the maturation of grapes and the quality of wines which come from them. Planting varieties without established markets could leave the grower out in the cold with no home for his crop. Since the 1990 edition of this guide, more wineries have opened and new markets established. This increased market has been favorable for some varieties and not so for others (see Figure 4). Research trials at OMRC have demonstrated several varieties can be grown quite well viticulturally and enologically. Many of these varieties are of the European wine grape species, *Vitis vinifera* which is generally recognized as producing the best wines. Others are hybrids between *Vitis vinifera* and native American grape species such as *Vitis labrusca*, *Vitis rupestris*, *Vitis aestivalis*, and *Vitis riparia*. These hybrids were bred for resistance to disease and pests and for increased winter hardiness. Generally hybrids are somewhat more winter hardy than *Vitis vinifera* varieties and many bear prolific crops. The wine quality of the hybrids is often very good but sometimes is described as lacking a distinct character. Currently, the market for hybrids is extremely limited and most wineries are only interested in *Vitis vinifera* grapes. All of the varieties listed below are grown in well drained moderately fertile clay loam textured soils.

White Wine Varieties - *Vitis vinifera*

Chardonnay. This grape makes the renowned white wines of Burgundy. It is one of the most winter hardy members of *V. vinifera* and generally of the highest commercial value. Chardonnay reaches high sugars (22-24^{o} Brix) in Colorado with desirable high acidity (8-10 g/l TA) Currently, Chardonnay is the most widely planted wine grape in Colorado representing 30% of the entire acreage and has an established market. Chardonnay is an early ripening variety typically harvested the first two weeks in September. Mature clusters are small to medium sized (.2 - .4 lb.) and amber colored with good sunlight exposure. Chardonnay is a moderately vigorous grower. The only drawback to Chardonnay is its slightly earlier budbreak that can result in crop reduction by frost as the variety has poor fruitfulness in secondary buds.

Riesling (White Riesling, Johannisberg Riesling). This major variety of Germany has a medium to hardy winter hardiness rating. Several vines survived the 1989 freeze of -22^{o}F with moderate trunk damage. It matures fairly late, but reaches 20-22^{o} Brix in the Grand Valley and usually retains 10 g/l TA. This is a suitable balance for a wine that can be bottled with residual sugar. Colorado Riesling is characterized by its ability to develop the floral bouquets like those found in German Rieslings. Riesling vines are moderately vigorous with small to medium clusters (.15 - .25 lb.). Because it ripens late, this variety should be planted in sites with longer growing seasons. Riesling currently tends to command a lower price per ton than Chardonnay while yields are comparable.

Pinot blanc. This variety is moderately hardy in Colorado and matures early. It is a low to medium vigor vine that has very desirable sugar : acid balances with potential as a varietal or blended wine. Pinot blanc clusters are small (.2 - .3 pound) and tight and thus subject to occasional bunch rot. Because of its low - medium vigor this variety is well suited for higher density plantings.

Gewurztraminer. This early ripening, orange-skinned variety is most famous in Alsace, France. It is winter hardy and can bear a large number of clusters. Gewurztraminer is a medium vigor, small (.2 - .35 lb.), tight clustered variety. Picking costs are often higher for this variety because of the difficulty removing the short stemmed clusters. This variety can be harvested at desirable balances (i.e., 19-20^o Brix, 7-8 g/l TA) with careful monitoring of its maturity in September. The variety has shown significant promise to produce its distinctive aromatic qualities. It tends to command a somewhat higher price than Riesling.

Muscat blanc (Muscat Canelli). This aromatic, early ripening variety has potential to do well in Colorado although it is less winter hardy than the preceding four varieties. As with Gewurztraminer, careful monitoring can allow harvest with sufficient sugar and desirable acid levels. Muscat blanc is a medium to high vigor vine with medium sized clusters (.40 - 1.00 lb.) and medium-large berries. Presently there are relatively few producers of the variety in the U. S. although the market is expanding.

Pinot gris. Pinot gris also know as Pinot grigio in Italy, when ripe is a grayish-rose colored variety similar to Gewurztraminer. Pinot gris evolved from Pinot noir and thus retains similar low to medium vigor growth characteristics. The small clusters (.15 - .25 lb.) ripen early with good sugar, acid and ph balances. Pinot gris is a new variety to Colorado that shows good winter hardiness. Although the market potential is not known the grape is very versatile, and can accommodate several winemaking styles (i.e. barrel fermentation, malo-lactic, sur lie aging etc.) Pinot gris has an established market in Oregon and is becoming popular in Ohio.

Sauvignon blanc. A popular variety traditionally blended with Semillon in France to make a dry dinner wine. Sauvignon blanc is a vigorous variety and has a medium winter hardiness level. Sauvignon blanc ripens early about the same time as Chardonnay. The grape produces distinct flavors of hay or grass common in other grape growing regions. Clusters are medium sized (.2 - .5 lb.). Because of its higher vigor, Sauvignon blanc would benefit from a lower density planting.

Semillon. Semillon is widely planted in the Sauterne or Graves region of France where it is used to blend and soften Sauvignon blanc wines. Semillon is moderately vigorous and produces medium to large clusters (.3 - .75 lb.). The berries are large and amber-yellow in color when ripe. Semillon is medium-tender in hardiness. The canes are larger in diameter than the others mentioned above. Semillon is slow to leaf out in the spring. This variety would also be more adapted to a low density planting.

Siegerebe. An aromatic (similar to Muscat blanc), orange-skinned, early maturing variety that is typically harvested the second week in August with low acids of 6-8 g/l TA. Siegerebe is a cross between Gewurztraminer and Madelaine Angevine. This variety is highly susceptible to bird damage. It is not vigorous and thus is suitable for high density plantings. Although somewhat unknown on the market, this moderately hardy variety could become very important for Colorado.

Rkatsiteli. Rkatsiteli originated in Russia and Bulgaria. It has a low to moderately vigorous growth habit and has performed well in western Colorado. It's upright growth and small diameter reddish canes are distinct. The fruit clusters are loose, slender, small to medium in size (.2 - .4 lb.) and produce wine and floral bouquets similar to Riesling. The berries have an elliptical "football" shape and mature late in the season. Rkatsiteli would be very adaptable to a high density planting on a more vigorous site.
Rkatsiteli has a medium hardiness level. Availability of this variety is limited.

Muller-thurgau. Muller-thurgau is widely planted in Germany and was developed in 1924 from a cross of Riesling and Sylvaner at the Geisenheim institute in Germany. The wine is a pleasant neutral wine and would be best utilized for blending. In Colorado, Muller-thurgau appears less hardy than Riesling. It has a low to moderately vigorous growth habit and ripens earlier than Riesling.

Viognier - Nationally, Viognier plantings total less than 600 acres. Viognier comes from the northern Rhone Valley in France and has recently become a popular variety in the US. Several Colorado growers have planted this variety and produced some good wines with fine floral bouquets. The vine has a moderately vigorous growth habit and has a medium-tender hardiness level. It produces good quality fruit and ripens during mid-season. The clusters are loose and small - medium (.2 - .4 lb.) in size.

White Wine Varieties -- Hybrid Cultivars

Aurore. A popular hybrid in the eastern U. S., it matures very early and is subject to low acidity unless harvested at fairly low sugar. Wines are fairly neutral and would be better utilized for blending. It is winter hardy, but not immune from damage.

Seyval blanc. This hybrid grape has a very vigorous growth habit and is well suited for low density plantings and improved trellising for better canopy management. Seyval produces a fresh, crisp wine that is used to blend or with improved winemaking techniques (oak fermentation, sur lie aging, etc.) made into a richer, longer-lived varietal wine. it is one of the most winter hardy varieties planted in Colorado. Seyval quite frequently needs cluster thinning to achieve high sugars (21-23^{o} brix) and good acids. This medium sized loose clustered variety ripens early. Seyval would be well adopted to colder sites.

Vidal blanc. This vigorous cultivar appears to be very hardy. The crop ripens late and generally retains at least 1 percent TA, which is difficult to utilize in a dry wine style such as that for which the variety is gaining a good reputation in the eastern U. S.

Chardonel. Chardonel, a hybrid developed at Cornell University, is a cross of Seyval blanc and Chardonnay. Chardonel was developed for its superior wine quality, high productivity and cold hardiness. Chardonel looks promising for Colorado. The wine is delicate with light fruitiness and good body with very little flavor characteristics of interspecific hybrid grapes. Chardonel has a moderately vigorous growth habit and its winter hardiness level appears better than Chardonnay (based on 3 years data). Chardonel breaks bud later than Chardonnay and produces medium sized clusters. Thinning may be necessary during years of good fruit set.

Cayuga White. Cayuga, also developed at Cornell University, was released in 1972 as a grape that would produce a European style white table wine. Cayuga is a cross of Seyval and the American species Schuyler. Cayuga grows well in Colorado, producing vigorous growth with large (.3 - .85 lb.) loose clusters and big round golden berries. Cayuga is winter hardy. It is slow to break bud but ripens early. This hybrid produces fruity wines that are slightly low in acidity (5-7 g/l TA) but full bodied. Approximately 3 acres are currently planted to this promising variety.

Vignoles. Vignoles also know as Ravat 51 is widely planted in New York, Ohio and Michigan. Vignoles wines are usually very high in acid and quite often made into a sweet reserve desert style. The growth habit of Vignoles is moderate and upright. Vignoles ripens very early, the clusters are small, the berries are large and fleshy, not juicy. Vignoles is new to Colorado but appears to be winter hardy and might prove to be a good late harvest style wine.

Red Wine Varieties - *V. Vinifera*

Merlot. The Merlot grape produces one of the best wines from Colorado and is the second most widely planted grape in Colorado representing 18% of the entire acreage. In most years, Colorado Merlots are deep colored, very fruity and full bodied. It is often used as a blend to form a soft velvet-like quality to the finish of wines that might otherwise be harsh. Merlot has a moderate growth habit and is medium tender in hardiness. It has small to medium (.2 - .4 lb) clusters that are loose to well-filled and have long stems. Hand harvesting goes quickly as stems are easily cut. Merlot ripens fairly early and can achieve excellent sugar acid balances (24^{o} brix, 8 g/l TA). Merlot has an established market in Colorado and continues to be popular with winemakers.

Cabernet Sauvignon. The cool nights of Colorado and late-season ripening characteristics of this variety tend to produce outstanding color retention and an excellent balance of sugar, acid and Ph. This leads to a well-proportioned, full-bodied wine. It's winter hardiness level is equivalent to that of Merlot, its traditional blending partner. This variety has a vigorous growth habit and small to medium (.2 - .4 lb.) conical shaped loose clusters. It is very easy to pick and because of its late ripening would be a candidate for planting in sites with longer growing seasons.

Pinot noir. This variety, one of the famous red Burgundies, is mentioned because it is generally considered to be the most winter hardy red variety. Pinot noir is a low vigor vine with small tight-filled clusters (.1 - .2 lb.). This variety adapts well to high density plantings. Unfortunately it has yet to demonstrate an ability to develop adequate color and character in Colorado. One should not rule it out with future experience; however, at this time the variety is best suited to sparkling cuvee' or blanc d'Noir wine styles.

Lemberger. This loose-clustered dark pigmented variety shows promise for Colorado with very favorable sugar, acid and Ph parameters. It is increasingly popular in Washington state and has moderately high winter hardiness under normal Colorado conditions. Unfortunately, clean virus free Lemberger stock is unavailable and this should be considered before planting.

Cabernet franc. Cabernet franc is becoming popular with Colorado winemakers as a blending wine. The wine is similar to Cabernet sauvignon yet softer and more subtle and retains the distinctive Cabernet aroma. Cabernet franc does not develop deep skin color. It has a moderately vigorous growth habit and appears slightly more winter hardy than Cabernet sauvignon. The clusters are loose filled and small to medium (.2 - .4 lb.) in size. It ripens later than Merlot but earlier than Cabernet sauvignon. At harvest clusters often appear immature because of the poor skin color, however fruit compositions achieve excellent balances. Cabernet franc is well know in the scientific community as a sensitive indicator plant for diagnosing leafroll virus. When inoculated with the virus, it visibly expresses symptoms (red leaves, green veins) much more profoundly than other varieties.

Sangiovese. This vigorous variety is one of the most widely planted grapes in Italy where it is a major component of Chianti wines. Sangiovese is new to Colorado and its becoming quite trendy in California. This variety ripens very late in Colorado and produces light colored fresh fruity wines. The clusters are large and loose filled with light red-colored large berries. Hardiness levels (based on 3 years data) appear equivalent to Merlot. The vines produce heavy crops that may require cluster thinning to achieve sugars of 20-22^{o} brix. Sangiovese would be a match for a low density planting on sites with the longest growing season.

Shiraz-Syrah. Syrah is a very dark skinned grape that ripens late and in Colorado produces wines with good acid, color and tannins. The clusters are long, loose-filled and conical in shape weighing about (.2 -.45 lb.) each. The hardiness level of this moderately vigorous variety is similar to Merlot and Cabernet. Syrah, also known as Shiraz in Australia would be well suited for the warmest sites with a longer growing season.

Red Wine Varieties - Hybrid Cultivars

Chancellor. Also known as Seibel 7053, produces relatively full-bodied wines, is a loose-filled clustered variety that ripens mid season. It is a medium hardy variety.

Rougeon. A very hardy variety that produces an early well-balanced crop with excellent color. The loose-filled clusters are medium sized (0.35 lb.) and the berries are blue-black in color. This variety survived the 1989 freeze of -22°F with little trunk damage.

Dechaunac. Also known as Siebel 9549, is very prolific, colors very early, but ripens late season and may require thinning to mature the fruit. This variety is extremely hardy, surviving the 1989 freeze of -22°F with no cane or trunk damage and very little latent bud damage. This variety can produce up to 60 lbs./vine and should be considered for low density plantings.

Norton/Cynthiana. Norton also known as Cynthiana produces very good wine with a deep blue-black red color. The small to medium clustered high acid variety was first discovered by Dr. D.N. Norton of Virginia. Norton is an American species *Vitis aestivalis* and is very winter hardy. It's canes are very red in color with small buds. Norton blooms late and appears to have medium vigor.

Table 6.

Relative Cold Hardiness[1] of Grapevines Grown In Colorado

Very Hardy	Hardy	Medium	Medium Tender
Concord	Aurore	Cabernet franc	Cabernet Sauvignon
De Chaunac	Baco noir	Chancellor	French Columbard
Niagara	Cayuga	Chardonnay	Merlot
Norton/Cynthiana	Chardonel	Dolcetto[2]	Muscat blanc
Rougeon	Delaware	Gewurztraminer	Sangiovese
	Foch	Lemberger	Sauvignon blanc
	Seyval blanc	Pinot blanc	Semillon
		Pinot gris	Shiraz
		Pinot noir	Viognier
		Riesling	
		Rkatsiteli	
		Siegerebe	

[1]Hardiness is based on visual assessment and differential thermal analysis of vines grown in a deep clay loam soil at Orchard Mesa Research Center.
[2]Dolcetto is grafted to 1616 couderc rootstock.

Table Grape Varieties

Successful table grape cultivation in Colorado requires optimum cultural practices; but, with certain considerations, they can be grown with the same management skills as wine grapes. The intent of this section in the Colorado Grape Grower's Guide is to provide the grower with additional information for table grapes that has not been addressed previously in the text.

Varietal selection is extremely important and involves considerations of winter hardiness and marketability. Information concerning performance of specific cultivars in Colorado is limited although some information does exist. A summary of vegetative growth and fruit characteristics for 15 of the most popular seedless table grape cultivars that are currently available is provided in Tables 7 and 8. The following descriptions are of several varieties grown at Orchard Mesa Research Center that appear well suited for the wine grape growing regions of Colorado.

Himrod. This white variety is a cross between Ontario X Sultanina (Thompson Seedless) and has excellent quality fruit which is juicy and sweet with pleasant flavor. This vigorous vine is moderately hardy; it survived the 1989 freeze of -22^{o}F with little trunk damage. Himrod tends to shed individual berries when picked; this should be considered before planting large acreages.

Interlaken. A second white variety that is also a cross between Ontario X Sultanina. This vigorous vine bears heavy crops early in the season, has good flavor and is somewhat less hardy than Himrod.

Lakemont. A third white variety of the same parentage as Interlaken (Ontario X Sultanina). It produces large compact clusters with quality that approaches that of Himrod and ripens a week or two later. It has moderate to low winter hardiness.

Suffolk Red. A large-berried, red seedless grape with good quality. It has low winter hardiness and sets loose clusters. It survived the eight winters prior to 1989, but was winter killed to ground level by the -22^{o}F temperatures during January of 1989.

Other seedless varieties (e.g., **Concord Seedless**, **Thompson Seedless**, **Flame Seedless**) have been tested at OMRC. However, their performance has been poor and they cannot be recommended for commercial production. There are many seeded varieties (e.g., **Concord**, **Niagra**, **Steuben**, **Golden Muscat**, etc.) that can be successfully cultivated in Colorado; all have more intense marketing challenges when competing with the more desirable seedless varieties.

Pruning and improving grape quality are two additional areas that should be modified from wine grape production. Pruning and training table grapes depends on variety and the overall objective of the operation. Pruning and training table grapes can be identical to that of wine grapes, but often should be modified to help equalize production for large average crops of high-quality fruit. Most varieties mentioned above are vigorous and should be trained to a pruning system that allows for that vigor such as the Geneva Double Curtain, Four Arm Kniffen and/or Umbrella Kniffen. These systems require more trellis expense but may be better suited for the more vigorous varieties.

Quality of table grapes can be improved by blossom thinning (i.e., removal of flower clusters before bloom and of immature clusters), a cultural practice not typically performed on wine grapes. Like pruning, thinning concentrates the activities of the vine into the remaining parts and strengthens the vine by limiting the crop without diminishing the leaf area. Girdling, also called ringing, is an old practice that improves set, increases size of berries and advances maturation; it should **NOT** be performed in Colorado due to the increased risk of Crown Gall infection.

Table 7. Vegetative growth characteristics of seedless table grape cultivars.

Ripening Variety	Vine Season	Yields/ Vigor	Winter Vine	Hardiness
Canadice	Early	Medium	High	High
Challenger	Mid Season	Medium	Medium	Medium
Concord Seedless	Late Mid	Medium	Low	High
Glenora	Mid Season	Medium	Low	Low
Himrod	Early	Medium	Low	Medium
Interlaken	Very Early	Medium	Medium	Low
Lakemont	Mid Season	High	High	Low
Mars	Early	Medium	Medium	Medium
NY 63878.1	Mid Season	Medium	High	Medium
Reliance	Early	High	Medium	High
Remaily	Late Mid	Medium	High	Low
Romulus	Late	Medium	Medium	Medium
Suffolk Red	Mid Season	High	Low	Low
Vanessa	Mid Season	Medium	Medium	High
Venus	Very Early	High	High	Medium

Table 8. Fruit characteristics of seedless table grape cultivars.

Variety	Color	Flavor	Berry Size	Cluster Size	Cluster Compactness
Canadice	Red	Good	Medium	Medium	Tight
Challenger	Red	Good	Large	Medium	Loose
Concord Seedless	Blue	Fair	Small	Small	Loose
Glenora	Blue	Good	Medium	Medium	Compact
Himrod	White	Excellent	Medium	Medium	Loose
Interlaken	White	Good	Medium	Medium	Compact
Lakemont	White	Good	Medium	Large	Compact
Mars	Red	Good	Medium	Small	Compact
NY 63878.1	Red	Excellent	Medium	Medium	Compact
Reliance	Red	Good	Medium	Medium	Loose
Remaily	White	Fair	Large	Large	Compact
Romulus	White	Fair	Small	Large	Compact
Suffolk Red	Red	Excellent	Large	Medium	Loose
Vanessa	Red	Good	Medium	Medium	Compact
Venus	Blue	Good	Large	Large	Tight

Vine Sources (1995)

In the United States there are hundreds of grapevine nurseries and thousands of retail outlets for grapevines. The following is a representative sample of suppliers from coast to coast that have good varietal selection and certified stock availability.

Arroyo Seco Vineyards Inc. (V)
P. O. Box 395
Greenfield, CA 93927
831-674-2318

Bien Nacido Vineyards (V)
1253 Coast Village Road, Suite 102
Santa Barbara, CA 93108-3790
805-969-5803

Borri Nurseries Inc. (V)
1150 Felta Road
Healdsburg, CA 95448
707-433-6045

Concord Nurseries Inc. (A, FH, V)
10175 Mile Block Road
North Collins, NY 14111-9770
716-337-2485

Duarte Nursery, Inc. (V)
1555 Baldwin Road
Hughson, CA 95326
209-531-0351
1-800-GRAFTED

Fairacre Nursery (A, FH, V)
Rt. 1, Box 1068
Prosser, WA 99350-9788
509-786-2974

FPMS* (V)
Foundation Plant Materials Service
University of California
Davis, CA 95616
916-752-3590

Ge-No's Nursery (V)
8868 Rd. 28
Madera, CA 93637
209-674-4752

Grafted Grape Vine Nursery (A, FH, V)
2399 Wheat Rd.
Clifton Springs, NY 14432
315-462-3288

Inland Desert Certified Grape Nursery (V)
Route 1, Box 1315
Benton City, WA 99320
509-588-3405

Meyer Orchards & Nursery (V)
3785 Gibson Rd., NW.
Salem, OR 97304
503-364-3076

Sonoma Grapevines Inc. (V)
1919 Dennis Lane
Santa Rosa, CA 95403
707-542-5510

The codes after the source name show whether they carry *Vinifera* varieties (V), French-American Hybrids (FH), or American varieties (A).

FPMS is a service unit created to provide virus-indexed plant materials for research and commercial use. Private individuals or companies can contract with FPMS on a fee-for-service basis to have special grape varietal selections heat treated and virus tested as necessary to qualify them for Foundation stock status. Contracts and fee schedules are available from FPMS upon request.

Sources for Vineyard Supplies

A. M. Leonard, Inc. P.O. Box 816 Piqua, Ohio 45356 1-800-543-0633	Horticultural and Viticultural tools
Barnel International, Inc. 1075 NW Murray Rd., Suite 256 Portland, OR 97229 1-800-877-9907	Horticultural and Viticultural tools.
Fruita Cooperative 1650 U.S. Highway 6 & 50 Fruita, CO 81521 970-858-3667	Fertilizer
Grand Junction Pipe & Supply 2868 Highway 6 & 24 Grand Junction, CO 81501 970-243-4604	Irrigation piping and supplies
Munroe Pump 735 South 9th Grand Junction, CO 81501 970-242-6810	Pumps
Orchard Valley Supply Vineyard & Orchard Supply Route 1, Box 41-B Fawn Grove, PA 17321 Phone: 717-382-4612 FAX: 717-382-4612	Complete vineyard materials, supplies and equipment.
Rears Manufacturing Co. 2140 Priarie Rd. Eugene, OR 97402 1-800-547-8925	Vineyard equipment
T. G. Schmeiser Co. Box 1047 Fresno, CA 93714 1-209-268-8128	Vineyard drill, Till and Pak, Culti-Plow, and land levelers.

The Grower Supply Center 2415 Hartford Road Fallston, MD 21407 410-931-3111	Complete vineyard materials, supplies, and equipment.
United Fruit Growers 144 Kluge Ave. Palisade, CO 81526 970-464-5671	Pruning equipment, fertilizer, insecticides, hand tools.
Waterford Corporation 404 N. Link Lane Box 1513 Fort Collins, CO 80522 970-482-0911	Trellis supplies and installation.
Western Implement 2919 North Avenue Grand Junction, CO 81501 970-242-7960	Tractors, implements, hand tools, posts, wire, etc.
Wildlife Control Technology Inc. 2501 N. Sunnyside Ave #103 Fresno, CA 93727 1-800-235-0262	Bird netting

Vineyard Development and Production Cost Assumptions

Projecting the true costs of establishing or maintaining a vineyard is extremely difficult. This is particularly true in the case of small acreages where various compromises can be made to trade labor costs for equipment costs. Many experienced growers, researchers, extension staff, consultants, and retailers were involved in the following cost estimate study. A number of broad assumptions were made to provide a common basis for these costs. First, we assumed that we were establishing a new vineyard on open ground with no improvements. All prices for capital improvements and equipment are new and in 1996 dollar values. Next, we assumed that certified virus free #1 self rooted Chardonnay vines or a similar variety were planted with a production life expectancy of 30 years following a four year establishment period. The sample vineyard is planted at a density of 871 vines per acre. The spacing is 5 feet between vines and 10 feet between rows. The trellis system is a six wire vertical shoot positioned system with one stake at each vine and 4 inch by 8 foot line posts every 30 feet. The traditional 3 post H-brace system was used at both ends of every row for anchoring the trellis.

We assumed that labor used in wine grape establishment and production is valued at $8.00 per hour. This wage rate is determined as the net cost to growers for hired labor which is paid a cash wage of $6.00 per hour with an additional $2.00 per hour for payroll expenses (social security, taxes, workmens compensation insurance, withholding taxes, record keeping, etc.). The cost of an irrigation system can vary widely -- from $500 for a gated pipe system to $1500 / acre for an automated, microsprinkler or pressure compensating emitter system. The automated drip irrigation system itemized is based on a horizontal stainless steel sand media filter with automatic backflush, a centrifical sand separator, a flow meter, a computerized controller and a chemical injector.

Weed control costs are shown using a in the row hydraulic grape hoe. In addition to mechanical cultivation, herbicide application such as glyphosate was figured for controlling the persistent bindweed. The production costs are shown on a per acre basis (Table 10) and assume a yield of 4 tons per acre.

These general assumptions were used to develop the vineyard establishment and production costs that follow. The example cost sheets (Tables 9 and 10) are intended to itemize the major cost factors and indicate their relative importance.

Table 9. Vineyard establishment costs: Mesa County, Colorado, 1996, includes new equipment, drip irrigation, 6 wire vertical shoot positioned trellis and 1 metal stake per vine.

Item	10 Acres
Equipment	
Tractor (40 HP)	20,000.
Truck (3/4 ton)	17,000.
Sprayer (200 gal vineyard airblast)	8,000.
Weed Sprayer (100 gal)	2,000.
Trailer	1,000.
Disk	3,000.
Hydraulic grape hoe (Clemons, badger, etc.)	4,000.
Chopper	1,500.
Auger	1,500.
7' Blade	800.
Springtooth	1,200.
Shop tools	2,500.
Pruning Shears	80.
Misc. Equipment (staples, strainers, tie tape etc.)	1,000.
	$63,580.
Capital Improvements	
Shop & Storage Building (33' x 45' metal building)	9,000.
Irrigation System (automatic, drip), @ $1,500/A	15,000.
5' Grape Stakes, steel epoxy coated 16 gauge, 871/A @ 1.40 ea.	12,194.
Treated Posts, 4" x 8' and 4" x 10' 200/A @ 6.25/post	12,500.
Wire 12.5 gauge high tensile, 4000' roll (12 rolls/A) 6 wire trellis	7,800.
1 yr, #1 self rooted cuttings, 871/A @ $.80/vine	6,968.
	$63,462.
Overhead, Labor ($8/hour) & Materials	
Layout & Mark, (5 Hr/A) + $50 rental	450.
Preplant weed control, (1 Hr + $70 material) /A	780.
Preplant Land Prep., chisel, plow, disk 2X, float, $135/A	1,350.
Post Driving, $2/post @ 200 posts/A	4,000.
Trim & plant @ 21 Hr/A	1,680.
String wires, staple & set stakes @ 40 Hr/A	3,200.
Train and Prune @ 25 Hr/A-2nd yr + 12 Hr/A-3rd yr	2,960.
Cultivate, 5X @ 4 Hr/A (all years)	1,600.
Mildew Control, 4X @ (1 Hr + $16 material) /A	960.
Fuel and Repair, $90/A/yr all years	900.
Water and Taxes, $55/A/yr	550.
	$18,430.
TOTAL	**$145,476.**
Per Acre	**$14,547.**

Table 10. Estimated annual per acre vineyard production costs.[1] (5 x 10 spacing, 871 vines/A)

Item	Detail (per Acre)	Cost/Acre
Fuel and Repair	$90	$ 90.00
Water & Taxes	$55	55.00
Mildew Control	6X @ (1 Hr + $16 mat.)	144.00
Herbicide	1X @ (2 Hr + $60 mat.)	76.00
Pruning	$.22/vine	192.00
Brush disposal	1 Hr	8.00
Canopy positioning	8 Hr	64.00
Suckering	6 Hr	48.00
Mechanical weed control (Hydraulic hoe)	5X @ 2 Hr ea.	80.00
Irrigate	.5 Hr/week (4 months)	64.00
Picking	$94/ton	376.00
Fertilizer, Ammonium Sulfate + micronutrients		50.00
Cultivate, mowing/discing	3 X @ 1.5 Hr each	36.00
Miscellaneous Labor & Supplies		50.00
TOTAL per acre		**$ 1,333.00**

[1]Based on 1996 data and labor costs of $8.00 per hour.

Useful Books and Publications

Below is a list of books and publications that growers should consult as additional background reference material to the Colorado Grape Growers Guide.

General References

From Vines to Wines. 1985. J. Cox. Garden Way Publishing, Pownal, VT. 253 pp.

General Viticulture. 1974. A. J. Winkler, J. A. Cook, W. M. Kliewer, and L. A. Lider. Univ. of Calif. Press, Berkeley. 710 pp.

Grape Growing. 1976. R. J. Weaver. John Wiley & Sons, Inc., New York. 371 pp.

Grape and Wine Production in the Four Corners Region. 1980. E. A. Mielke, *et. al.* Technical Bulletin No. 239, University of Arizona. 116 pp.

Grape Production in Colorado: An Evaluation of Grape Varieties for Wine Production and of Grape Production Risks and Profit Potentials. 1985. R. Hamman and R. Renquist. Report prepared for the Colo. Dept. of Agric. 12 pp.

Knowing and Making Wine. 1981. Emile Peynavd. John Wiley & Sons Inc., New York, NY. 391 pp.

The New Frank Schoonmaker Encyclopedia of Wine. 1988. Alexis Bespaloff. William Morrow and Company, Inc., New York, nY. 624 pp.

Oregon Winegrape Growers Guide, 4th Edition 1992. Ted Casteel. The Oregon Winegrowers Association, 1200 NW Front Avenue, Suite 400, Portland, Oregon 97209. 258 pp.

Proceedings of the Second International Symposium for Cool Climate Viticulture and Oenology. 1988. New Zealand Soc. for Viticulture and Oenology, Auckland, New Zealand. 365 pp.

The Production of Grapes and Wine in Cool Climates. 1987. David Jackson and Danny Schuster. Butterworths of New Zealand. 192 pp.

Rootstock Seminar, A Worldwide Perspective. 1992. Proceedings American Society for Enology and Viticulture, June 1992. Reno, Nevada. 84 pp.

Sunlight into Wine, A Handbook for Winegrape Canopy management. 1991. Richard Smart & Mike Robinson. Wine titles, Australian Industrial Publishers Pty. Ltd. 88 pp.

Viticulture Volume 2 Practices. 1992. Coombe, B. G. and P. R. Dry. Winetitles 2 Wilford Avenue, Underdale SA 5032 Australia. 376 pp.

Frost & Winter Hardiness/Injury

Minimizing Winter Damage: Site selection, vineyard establishment, and maintenance. 1979. W. Wolfe. Proc. Wash. St. Grape Society. 9:67-75.

Pruning Effects on Cold Hardiness and Water Content During Deacclimation of Merlot Bud and Cane Tissues. 1990. R. A. Hamman Jr., A. R. Renquist, and H. G. Hughes. Am. J. Enol. Vitic. 41(3):251-260.

Seasonal Carbohydrate Changes and Cold Hardiness of Chardonnay and Riesling Grapevines. 1996. R. A. Hamman, Jr., I. E. Dami, T. M. Walsh, and C. Stushnoff. Am. J. Enol. Vitic. 47(1): (in press).

Vine Hardiness: A part of the problem of hardiness to cold in N.Y. vineyards. 1971. N. Shaulis. Proc. New York St. Hort. Soc. 116:158-167.

Wine Grape Performance of 32 Cultivars in Western Colorado 1982-1986. 1993. R. A. Hamman Jr. Fruit Varieties Journal 47(1):59-63.

Pest Management

Compendium of Grape Diseases. 1988. R. C. Pearson and A. C. Goheen, eds. APS Press, The Am. Phytopath. Society, 3340 Pilot Knob Road, St. Paul, Minnesota, 55121. 93 pp. [Cost $20.00]

Grape Pest Management. Revised 1991. D. L. Flaherty, *et. al.*, eds. Pub. No. 3343. Div. of Agric. Sci., Univ. of Calif. 416 pp.

Insect and Mite Pests Associated with West Slope Wine Grapes. 1994. B. C. Kondratieff & W. Cranshaw. Technical Report TR94-1. Agricultural Experiment Station, Colorado State University. 12 pp.

Phylloxera Issue. 1990. B. Strik, ed. The Wine Advisory Board Research Report (Special Report) Special Issue (Sept.): 1-17. Published jointly by the [Oregon] Wine Advisory Board and Oregon State Univ. Ext. Service, Corvallis, OR. 17 pp. (+ 4 pp. insert with color photos.)

Vineyard Pest Management: Alternatives for the future. 1992. Publication compiled for the American Society for Enology and Viticulture workshop May 1992. Napa Valley. 33 pp.

Economic/Cost Analyses

Cost Analysis of Selected Wine Grape Vineyard Production Practices in Washington. 1983. D. Kirpes, R. Folwell, and M. Ahmedulla. EB 1200. Wash. St. Univ. Coop. Ext., Pullman, WA. 16 pp. [Cost $0.50]

The Economics of Establishing and Operating a Concord Grape Vineyard. 1990. J. G. Schimmel, R. J. Folwell, and R. Wample. EB1572. Wash. St. Univ. Coop. Ext., Pullman, WA. 10 pp (+ 13 tables). [Cost $0.50]

Wine Grape Vineyard Development in Washington and Economic Perspectives. 1986. S. Lutz, R. Folwell, M. A. Castaldi. EB 1398. Wash. St. Univ. Coop. Ext., Pullman, WA. 56 pp. [Cost $1.25]

Viticulture Trade Magazines

Grape Grower
Published monthly, Munford Publications, Inc., 4974 E. Clinton Way, Suite 123, Fresno, CA 93726-1558, 209-252-7000

Practical Winery & Vineyard
Published bimonthly, 15 Grand Paseo, San Rafael, CA 94903, 415-479-5819

Vineyard & Winery Management
Published bimonthly, J. William Moffett
Box 231, Watkins Glen, NY 14891
607-535-7133

The Wine Spectator
Published biweekly, M. Shanken Communications, Inc.
Opera Plaza, Suite 2040, 601 Van Ness Ave., San Francisco, CA 94102
1-800-752-7799

Wines & Vines
Published monthly, The Hiaring Company
1800 Lincoln Ave., San Rafael, CA 94901-1298
415-453-9700

Wine Business Monthly
867 W. Napa St, Sonoma, CA 95476
707-939-0822
707-939-0833 (Fax)

Grape and Wine Resources on the Internet

1. U. C. Davis
http://pubweb.ucdavis.edu/Documents/wine/venl.html

2. Food Science & Technology Department
http://aruba.nysaes.cornell.edu/fst

3. The Wine Research & Extension at Cornell
http://aruba.nysaes.cornell.edu:/FST/MARKET/wineries.html

4. All About Wine
http://www.aawine.com/index2.html

5. CSIRO Grapevine
http://cgswww.adl.hort.CSIRO.au/

6. Virtual Vineyards
http://www.virtualvin.com

7. Not Just Cows List of Agricultural List Servers
http://www.lib.lsu.edu/sci/njc.html#1 listserv

8. What is Sustainable Agriculture
http://www.sarep.ucdavis.edu/sarep/concept.html

9. Organically-Grown Grapes
http://www.fetzer.com/

10. Wine Business Monthly
http://smartwine.com

11. Wine Wizards
http://www.wines.com