

**Vineyard Establishment and Management in
Oklahoma**

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I. INTRODUCTION

Americans drink less than five gallons of wine per year, compared with fifty gallons of soft drinks. That's about one-tenth of the wine that an average Italian or French person consumes.

In the past 20 years the number of wineries in the United States has tripled to approximately 1600. About half are in California. The remaining half of the wineries touch all of the United States as every state now has at least one licensed winery. United States wine production has increased in value from \$3.3 Billion to \$18.1 Billion over the past 25 years. Wine offerings are noticed more and more at restaurants, in beverage stores, and in homes.

Fossil vines, 60-million-years-old, are the earliest scientific evidence of grapes. The earliest written account of viticulture is in the Old Testament of the Bible, which says Noah planted a vineyard and made wine. Honey and grain are older than grapes as cultivated fermentable crops, although neither mead (from honey) nor beer (from grain) has had the social impact of wine.

Much of Oklahoma's wine industry history is tied to prohibition laws. The prohibition movement's strength grew after the formation of the Anti-Saloon League in 1893. The League, and other organizations that supported prohibition e.g. the Woman's Christian Temperance Union, soon began to succeed in enacting local prohibition laws. Eventually the prohibition campaign was a national effort and finally became the subject of a Constitutional Amendment in the 1920s. Before 1920, there were more than 2,500 commercial wineries in the United States. Less than 100 remained as winemaking operations in 1933. By 1960, that number had grown to only 271.

In 1917, the Oklahoma Legislature passed a law known as the "Bone Dry Law" forbidding the importation of wine or liquors from outside Oklahoma. Catholic, Lutheran and Episcopal churches that needed wine for sacramental purposes combined forces and appealed the new law. After nine months of argument the Oklahoma Supreme Court ruled, on May 21, 1918, that importation of sacramental wine was protected under the principle of religious liberty. The action was watched closely by forces across the country on both sides of the prohibition issue, since by that time pressure was building for an amendment to the U.S. Constitution. The 18th Amendment, which prohibited "The manufacture, sale, or transportation of liquors ... for beverage purposes" was ratified on

January 16, 1919 and went into effect one year later. The next thirteen years saw an increase in crime as smugglers of whiskey, wine and beer battled one another. It also saw a decrease in consumption of beverage alcohol. In the early 1920s, consumption of beverage alcohol was about thirty percent of the pre-prohibition level but began to increase in the last years of prohibition. On December 5, 1933, the only constitutional amendment ever to be repealed lost its effect, when the 21st Amendment was enacted and alcohol was legal once again.

The last 90 years have witnessed wine's industrial revolution. Before the 1940s wine was supplied to people according to their geographic location. After the spread of refrigeration, it was easier for wineries to control the temperature of their fermentation process, which allowed high quality wines to be produced in hot climates. Mechanization also allowed vineyards to become larger and more efficient.

Grapes and a large number of fruit crops have been grown in Oklahoma since the first settlers arrived here. All of the traditional fruit crops of the homeland were planted here and were grown successfully for home use for many years.

Demand for wine grapes in Oklahoma increased in the 1970s then declined in the 1980s. Different varieties of grapes have lasted throughout the years in Oklahoma. Most of these varieties contain native *Vitis* parentage, which enables them to withstand Oklahoma's harsh weather. In the 1970s, Herman Hinrichs, a researcher at the Oklahoma Agricultural Experiment Station, released several grape varieties including 'Cimarron', 'Rubaiyat', 'Sunset', 'Eureka', 'Bounty' and 'Meteor'. The naming and releasing of these new grape varieties climaxed more than 20 years of effort by Oklahoma researchers, including breeding and evaluation of desirable fruit characteristics, vine vigor, disease resistance, productivity, drought resistance, cold hardiness and fruit acceptability for juice, jelly and table use, as well as for wine.

Today, winemakers in North American wine regions are earning recognition for producing some of the best quality wines in the world. Many highly respected European winemakers are investing in American vineyards and partnering in joint ventures. After all of these technological advances the one main goal of vineyardists in Oklahoma and elsewhere continues to be production of high quality grapes for high quality wine without losing the local character and individual flavor of their product. These goals must be the cornerstone of Oklahoma's industry development.

II. MAKING THE DECISION

Planting a new vineyard is an exciting time and can grow into a financially rewarding experience. Much time and effort should go into the planning, budgeting and site selection long before the first vines are ordered. Many items must be checked prior to planting. New vineyard owners need to do the best they can at planning their planting and still maintain the flexibility to make changes as needed.

Develop a Vineyard Plan Before Starting

Considerations for establishing a vineyard need to include market (wine or table), varieties, rootstock, site preparation, trellis construction, irrigation, planting, weed control, vine training system, etc. Other considerations are hand and mechanical labor, marketing plan, selection of equipment equal to the vineyards needs, pest management, varmint damage prevention and other personal needs. All of these factors need to be well thought out and recorded prior to selecting the vineyard site. Preplanning should always include an irrigation water analysis.

Financing

A vineyard is very expensive. One acre established through three years can cost over \$5,000 exclusive of land, equipment, and water well or deer proof fence. The plan should allocate money for vineyard establishment and development as well as education on how to grow grapes.

Vineyard Location

The microclimate, soil and accessibility of the vineyard are critical. A raised elevation with good air movement will help reduce fungus diseases, increase surface water drainage and reduce risk of spring freeze damage. The soil needs to be well-drained. Water and nutrient absorbing roots do not develop in poorly drained soils. Drainage ditches may also be needed in some locations to move the excess rainwater out of the vineyard during periods of high rainfall. The vineyard location should have a good supply of good quality irrigation water.

Vineyard Accessibility

Vineyard accessibility is also important. This applies to vineyard management and may apply to retail customer access if the winery and vineyard are co-located. The vineyard must be checked almost daily and if it is too far to drive, the absence of the owner will result in complications in the management program. Weekend management is not consistent with commercial vineyard needs. Electricity, roads, fences and other factors can also be very important.

Vineyard Size and Economic Risk

Commercial grape production is relatively new to many areas of Oklahoma. New vineyards with commercial objectives should be large enough to test their economic feasibility but not so large that a loss would be financially crippling. Variables include market rejection of new varieties as well as the risk of fruit diseases. Low production or crop loss due to freezes could also limit the potential for profits. An initial planting of one acre or less is adequate for the beginner. This allows the owner ample opportunity to learn how to grow the grapes without a major economic investment at a very serious risk.

New growers tend to plant more grapes than they can properly manage. This frequently leads to confusion, frustration and, ultimately, poor vine growth.

Facilities and Equipment

Roads, electricity, culverts, drainage ditches, deer proof fences, barns, tractor, trailer, shredder, small herbicide sprayer, and other equipment and facilities need to be in place prior to planting.

III. SITE SELECTION

Every vineyard site has its own vine growth and production potential. In addition to climate, and irrigation water, there are many small factors that can later become major problems. Retail sales can be extremely important to profitability. In some cases success or failure can depend on retail sales alone. The vineyard needs to be close to where the manager lives. Viticulture by long distance is very difficult at best. Ideally the manager would live near but not in the vineyard. Living at the vineyard site can be problematic because of the use of pesticide sprays. Close observation and immediate response to vine needs cannot be over emphasized.

Air drainage for spring frost protection is important. Trees or other native vegetation that slow or stop air drainage should be removed during site preparation.

Site Preparation

The vineyard site needs all large vegetation removed well in advance of planting. In September or early October the year prior to planting, perennial weeds such as johnsongrass, bermudagrass and nutsedge must be killed with postemergence herbicide, e.g. glyphosate. Some sites will profit from low mowed native sod middles, while others may require annual planting of winter grasses. The vine rows need to be free of all tree or shrub roots that can sprout. Deep chiseling down the row in the fall may be helpful. This removes roots and breaks plow pans or clay layers. Plowing and discing down the row should follow chiseling. The ideal situation is a site with all vegetation killed and planted to a cover crop, e.g. hybrid sudan, the summer before planting followed by small grain cover the fall prior to planting.

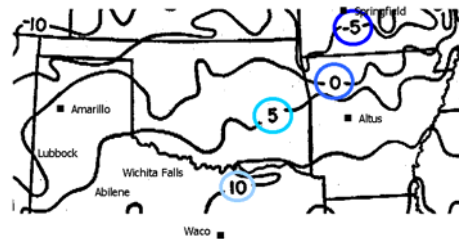
Climate

Climate plays a major role in determining vineyard establishment. Oklahoma's climate varies substantially with location in the state.

Freeze potential and resultant damage to the vine itself can present a major climate related limiting factor. *V. vinifera* (French) varieties as a group are more prone to freeze injury; however, some *V. vinifera* varieties can tolerate low temperatures better than others. American types (e.g. *V. labruska*) are the most tolerant of low

temperatures and seldom sustain injury. French x American hybrids are usually more susceptible to freeze damage than *V. vinifera* but less than American. Early fall freezes can occasionally cause plant damage problems in all of Oklahoma. This is especially true in the first five years of vine establishment. A late spring freeze can also cause serious crop reductions when young primary shoots are frozen. An important climatic factor is the expected minimum temperature (Figure 1), as is temperature fluctuation during the winter. Extended periods above 50°F can predispose some grapes to injury from low temperatures. *Vinifera* grapes are most prone to damage in these situations.

Figure 1. Expected minimum temperature (°F) at various locations.



Disease control problems intensify with rainfall and increase from west to east in Oklahoma. Increased rainfall has the additional negative effect of reducing tractor passage at a time when it is desperately needed for fungicide sprays. Rain and drought extremes will require grape growers to use irrigation to obtain uniform vine growth and fruit development. Rainfall can and does create serious problems when it occurs near or during harvest. In general, the further west a vineyard is located, the less probability of harvest rainfall problems.

IV. SOILS

The soil is key to vineyard success. Chemical analysis of a good soil sample determines nutrient status. Grapes are unique among fruit crops as they can be grown in a wide range of soils; however, they grow better in some soils than others. Most vineyard sites have more than one soil type, which will give different levels of vine growth. The more vineyard managers understand their soil, the better job they can do in obtaining good growth and satisfactory yields. The best way to evaluate soil on-site is to dig into it with a posthole digger or backhoe. This allows evaluation of depth, layering, structure, etc. Several digs are needed to map the range of variation. Soil surveys are available from Soil Conservation Service for each county. The survey will have soil maps with description of soils and capabilities for each soil.

Moderate vine vigor and production can be obtained from marginal soils; however, vineyards on these sites are more difficult to manage. Every dollar used to purchase better soil will be returned many fold.

pH

Soil samples are good for determining the pH of the soil. The ideal pH is in the neutral range of 6.5 to 7.5 and there are many vineyard sites in Oklahoma which have neutral soils. There are some soils which are very acid and require the addition of lime. The soil sample report will have a lime recommendation if it is required. Alkaline soils with a high pH also occur. These soils are high in calcium and are generally ideal for growing grapes. However, there are problems which may accompany high pH, e.g. cotton root rot, iron chlorosis and zinc deficiency. High pH is corrected by adding sulfur rather than lime. Applications of sulfur or sulfuric acid have not proven horticulturally effective. Animal manure fertilization has also failed to lower very high pH soils. The use of rootstocks can help a vineyard tolerate iron chlorosis, zinc deficiency or cotton root rot. Further discussion of pH can be found in OCES Fact Sheet F-2229.

Depth

Deep soil with good internal drainage is ideal. In the harsh Oklahoma climate the greater the root system, the better the vine can tolerate climatic stress extremes such as heat, drought, wind and high light intensity. Deep soil also provides essential nutrient elements for good vine growth. Vineyards on shallow soil will have problems even with concise drip irrigation water management. Droughts will require a very short cycle for delivering ideal daily water requirements. Sudden rainfall periods will force rapid growth at first on shallow soils; however, when the soil becomes saturated, growth stops. Soil depth is best determined by digging straight down with a hand held posthole digger. If the soil is easy to dig, it is good for root growth. If the soil is so hard it cannot be dug, roots will likewise not grow well. The shallow soil, 12" or less, will require very concise water and fertilizer management. Deeper soils, 24" or more, are more forgiving and allow a greater margin for error in both nutrition and irrigation management.

Vineyards on deep well-drained soils make rapid growth, are easy to train, come into full production at an earlier age, and can bear heavy crops. On the other hand, shallow soils, clay soils, or poorly drained soils on flat sites will need special attention for the life of the vineyard.

Texture

Soils are grouped into three types: sand, silt and clay. If there is a combination of two or more it is called a loam. A clay loam is mostly clay, but it also has sand and silt with it. Loams are always better. The sandy soils drain very fast, but have a very low water holding capacity. Clays have high water and nutrient holding capacity, but drain very slowly. Gravel or small rocks in a soil can improve internal drainage.

Structure

Good soil structure can be called soft soil, while poor soil structure or the absence of structure is hard soil. Good soil structure comes from good soil chemistry where clay particles are pushed apart by ionic charges. Soil structure is usually, but not exclusively

limited to clay soils. Clay soils demand good structure; otherwise, they are impossible to manage. The best grape soils of Bordeaux are clay with good structure. These soils have excellent water and nutrient holding capacity and because of good structure they also have excellent internal drainage, which allows good absorption of the water and nutrients. The presence of sodium in soil or water can destroy soil structure resulting in serious problems from water saturation and poor drainage. When the soil structure is destroyed, heavy applications of gypsum will be needed with heavy leaching with sodium free water. Compaction is a poor soil structure problem. It is the result of repeated heavy equipment passage down the vineyard rows. Heavy tractors and sprayers filled with water compact the soil, especially when the soil is moist. Repeated compaction will create hard soil which is very difficult to manage. The use of lighter equipment and less frequent tractor passage in the vineyard will reduce soil compaction.

Internal Drainage

Slow internal soil drainage is a very serious problem. Tile drains below the rows of poorly drained soil can be used successfully but it is best to avoid this problem from the outset. Ideally the soil should be 50% particles, 25% water and 25% air. As the soil air content decreases roots die, active absorption of water across the root membranes stops, salt toxicity increases, and hormone production in the root tips stops. Therefore, the rapid movement of water into and out of the root zone is absolutely essential in maintaining good soil air. The USDA/SCS County Soil Map is an excellent source of information on soil internal drainage. To confirm the SCS Map data on a specific site, dig several test holes with a posthole digger. Fill the holes with water during very heavy rainfall periods to determine how deep the soil actually drains. One hour after filling a hole, the water level will indicate the depth of good drainage. This is the depth of good soil.

Color

Oklahoma soils come in a wide range of colors. It is not fair to say one color is better than others, but there are some soils which have a better history of success. Deep, well-drained, red sandy loam soils are the very best. The red color is from iron oxidation. That is a good sign of the presence of iron, which is good, and the presence of oxygen in the soil, which is better. Gray soils with good internal drainage and good depth can also be very good. However, they need to be tested for both depth and drainage. Black soil is usually clay and also is usually very poorly drained. However, do not rule out black soil because it can have a high calcium content and good soil structure. Brown soil is a combination of red and gray soils, which can be good.

V. FERTILIZERS/NUTRITION

Preplant Nutrition

The objective of preplant fertilizing is to establish the "reservoir" of nutrients from which the plants can draw. This will serve as the long-term source of nutrients as the vineyard comes into production. Soil nutrient content should be established with a soil test prior to planting the vines. OCES Fact Sheet F-2207 describes how to collect a good soil sample. Each county extension office can provide instructions on collecting and submitting soil samples. The turn around time for receipt of results from samples sent to the OSU lab is about 2 to 3 weeks. Additional information on soil sampling and testing in Oklahoma can be found at www.soiltesting.okstate.edu. Recommended amounts of fertilizers to apply preplant can be found in tables 1-4 of Oklahoma Cooperative Extension Service Fact Sheet F-6232, Fertilizing Pecans and Fruit Trees in Oklahoma. Do not apply N preplant. P, K and other needed nutrients are broadcast applied and incorporated during soil preparation operations.

In low pH (acid) soils, calcium is needed in the form of lime. Rates up to 6 tons per acre may be required to bring the soil into the neutral range. The Oklahoma State University soil test report lists the buffer index (BI) in addition to pH. The BI is a measure of the soil's ability to resist pH change. Refer to Oklahoma Cooperative Extension Service Fact Sheet 6232, table 4, for lime requirements based on BI. Low pH soils can also have potassium requirements.

Phosphorous deficiency occurs infrequently in producing grapes. Preplant application of P to deficient soils insures an adequate reservoir for the vine to call upon. Repeat applications over several years may be needed to replenish the soil supply. Excess phosphorous can tie up zinc and iron.

Producing Vineyard

Nitrogen Fertilization. The major nutrient needed by producing vineyards is nitrogen. Its need is determined by observation of plant growth and supported by petiole analysis. Soil depth, drainage, pH, weed competition, cover crops, and other factors can influence the vine's need for nitrogen; thus, adding more to the soil may or may not be the best long run solution to low vigor/ low petiole analysis results. Mature vines bearing 4 or more tons of fruit per acre require 50 pounds of actual nitrogen per acre per year. Apply half at bud burst and half in late May. If freeze or hail destroys the crop, only apply the first application of nitrogen. In some cases irrigation water is high enough in nitrates that little or no additional nitrogen is needed. Each ppm nitrate in irrigation water is roughly equivalent to one pound of nitrogen per acre inch of water applied. It is easy to apply too much nitrogen and stimulate a major vigor problem. Young vines can be killed by October freezes from growth stimulated by nitrogen. Nitrogen should be applied sparingly if at all after July 1.

Sources of nitrogen are Ammonium nitrate 33-0-0; Ammonium sulfate 21-0-0; Urea 42-0-0; and 32% liquid nitrogen for neutral and alkaline soils. For strongly acid soils, use Calcium nitrate 15-0-0.

Tissue Sampling

Soil samples do not adequately reflect nutritional needs for perennial fruit crops, e.g. grapes, after the plant reaches bearing age. Accordingly, tissue sampling is necessary to accurately monitor the plant's nutritional needs and tailor a fertilization program that meets the needs.

The Oklahoma grape industry has grown to the extent that tissue testing arrangements are needed but still not adequate to sustain a laboratory specifically for that purpose. Samples can be sent to many commercial labs. Be sure to collect the sample in accordance with requirements of the lab. Information on petiole analysis and a partial list of laboratories is at www.okstate.edu/ag/asnr/hortla/ftpcns/grapes.htm

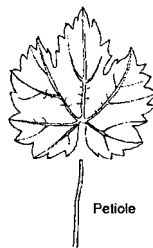
Most eastern USA grape production areas utilize **petiole** samples collected at veraison, i.e. **early to mid July** in Oklahoma, to determine vine nutritional status.

Samples should be collected from uniform areas of the vineyard and should not represent more than ten acres. If the vineyard is not uniform (different soil types, uneven irrigation, presence of nematodes, etc.) more samples should be taken and sent to the laboratory. A change in variety or rootstock within an otherwise uniform ten acre block would require collection of more petiole samples.

The size of the sample should be approximately 100 petioles. Samples can be collected from a select group of vines (reference plot) or by using a consistent pattern across the uniform vineyard block such as sampling from every tenth vine in every fifth or tenth row depending on block size. It is critical that the sample be representative of the vineyard block. Also, sampling from the same vines each year allows the grower to discern seasonal trends in vine nutritional status which could be difficult to identify if the variability in sampling is large.

Petioles used for analysis should come from the youngest fully mature leaf near the shoot apex (shoot tip). The leaf blade should be removed and discarded (Figure 2). Petioles are then placed in a clean, labeled paper bag (small lunch size). A record of all information regarding the sample should be retained by the grower to allow for sample identification and interpretation of results from the laboratory.

Figure 2. Leaf petiole separated from blade.



Petiole samples should be sent to the laboratory immediately. A delay in this process will reduce the accuracy of results. Samples should be kept in a dry and well-ventilated location until they are delivered to the laboratory.

Other items which should be considered by the grower desiring accurate petiole analysis and interpretation of results are: 1) critical values for nutritional status of grapevines in most eastern USA viticulture regions have been primarily developed from research on 'Concord' grapes. Other varieties may have somewhat different nutritional requirements; 2) application of certain fungicides and nutrient sprays can influence petiole sample results. Collection of samples following rainfall or washing of samples with distilled water may help alleviate this concern but careful assessment of lab results should include knowledge of prior spray applications.

Critical nutrient calculations for grapevine petioles sampled at veraison are given in Table 1. The utilization of a well-planned and consistent petiole sampling program will yield important information on vine nutritional status. This information along with proper timing of application can maximize fertilizer use efficiency, vine performance, environmental protection, and vineyard profitability.

Table 1. Specific Element Recommendations for Grapes from Petioles.

Element ¹	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	0.3 - 0.7	0.7 - 0.9	0.9 - 1.3	1.4 - 2.0	2.1+
P (%)	0.12	0.13 - 0.15	0.16 - 0.29	0.30 - 0.50	0.51+
K (%)	0.5 - 1.0	1.1 - 1.4	1.5 - 2.5	2.6 - 4.5	4.6+
Ca (%)	0.5 - 0.8	0.8 - 1.1	1.2 - 1.8	1.9 - 3.0	3.1+
Mg (%)	0.14	0.15 - 0.25	0.26 - 0.45	0.46 - 0.80	0.81+
Mn (ppm)	10 - 24	25 - 30	31 - 150	150 - 700	700+
Fe (ppm)	10 - 20	21 - 30	31 - 50	51 - 200	200+
Cu (ppm)	0 - 2	3 - 4	5 - 15	15 - 30	31+
B (ppm)	14 - 19	20 - 25	25 - 50	51 - 100	100+
Zn (ppm)	1 - 15	16 - 29	30 - 50	51 - 80	80+

¹Values may differ among species for optimal growth. Values from leaves will vary significantly. For petioles taken between July 15 to August 15.

Source: Midwest Small Fruit Pest Management Handbook Ohio State Bul. 861

Petiole Analysis Interpretation

During the ripening period and immediately after harvest, growers need to evaluate each block of vines and record indicators of vine health.

Nitrogen. Remember, nitrogen is the most common limiting fertilizer nutrient. However, some Oklahoma soils may have an accumulation of nitrogen and the nitrogen content of irrigation water also varies.

Phosphorous. Phosphorus deficiency usually requires soil application over a period of years to increase soil P without causing tie up of other elements.

Potassium. In some instances potassium may be needed. The deficiency symptoms are yellow leaf color followed by black bands between the veins on mature leaves in mid-to-late season. It is most common on over cropped vines. Typically the vine will be weak and cannot mature the fruit. If the petiole analysis K level is less than 1.0%, use potassium sulfate to correct the deficiency. Frequently, only a few vines will show the symptoms and may be fertilized individually. It can be applied in the dormant season or early spring. Excess potassium in the fruit can create fermentation problems and it should not be used unless necessary.

Iron. Iron chlorosis is a common problem on high pH soils. Typical leaf symptoms are yellowing of the spaces between the leaf veins with the remainder of the leaf green. Smaller than usual amounts of iron chlorosis can be corrected by applying very low concentrations of chelate micronutrient. Sequestrene 138 Fe or Ferrus Plus 138 Fe can be injected through the drip system. Sequestrene 330 Fe is designed for acid soils only and is of no value to vines on high pH soil. Excess phosphate ties up iron in the tissue.

Experimentation will be needed to determine the minimum level of iron needed to correct the deficiency on any given vineyard. One pound per acre through the irrigation system at budbreak would be a starting point and additional applications biweekly until the symptoms disappear. For spot treatment, mix one tablespoon in five gallons of water and apply one pint per vine.

Zinc. Grapes can exhibit zinc deficiency especially on high pH soils. The symptoms are small, different shaped leaves in bunches with very thin shoots. Berries in the cluster will vary in size from small to large. Small green berries will be on the cluster with normal berries. Higher than normal lateral budbreak will occur on shoots during the growing season. Excessive phosphates can also tie up zinc in the soil.

Zinc deficiency can be corrected with early spring foliar sprays. A common recommendation is NZN at a rate of one pint per acre in 100 gallons of water.

Boron. In rare instances, boron can be deficient. Symptoms are big and small berries in the same cluster. This is similar to zinc deficiency, but all of the leaves will be normal when boron is deficient. When petiole levels are below 20 ppm, boron can be deficient. Common borax which is 34 to 48% boron trioxide using a maximum rate of one ounce per vine in the late fall is frequently recommended to correct B deficiency. Note that Boron can be toxic to grapevines. Individual vines or small plots should be treated rather than complete blocks. Soil or water concentrations higher than 1.5 ppm boron should not be planted with grapes because of phytotoxicity.

Summary. Fertilizer should be used only as needed in vineyards because vigor can sometimes be excessive even without fertilizer. Fertilizer should be used only when weed, water and pruning practices fail to correct weak vine vigor. Fertilizer should be

used only when vine deficiency symptoms and petiole deficiencies indicate a nutrient is needed. Late season nitrogen fertilization should never be practiced because of potential freeze injury.

VI. IRRIGATION/WATER

System Planning and Design

Successfully producing irrigated grapes, or any other irrigated crop, require two components of equal importance. The first is to design a good irrigation system that suitably matches your crop, your soil conditions, the field topography, the water supply, and your abilities and limitations as an irrigation manager. Some producers may be capable of undertaking a system design on their own, but most will not and should engage the assistance of a qualified professional. Even when engaging a professional designer, some homework on the part of the producer will speed and ease the process. Have information on the available water quantity and quality for irrigation, the soil hydraulic properties, and the energy sources available for water pumping. You should also have a clear idea of your objectives for your system with regard to initial capital cost limitations, labor requirements, degree of system automation, and whether you want to merely supplement normal rainfall or be able to supply all crop water needs in case of prolonged drought.

Irrigation Water Quality

The first step in planning for irrigation is to identify a water source. One of the most important features is the quality of the water. To evaluate a potential irrigation water source for salinity, take one pint of water to your local OSU County Extension Office and request an Irrigation Water Test from the OSU Soil, Water and Forage Analysis Laboratory. See www.soiltesting.okstate.edu for more information. Analysis of electrical conductivity, total soluble salts, boron, and sodium adsorption ratio are important factors to evaluate.

Grapes are very sensitive to salinity in soil water. Rainfall is very low in salt content, but most surface and ground water will have considerable salt dissolved in it. Because much of the salt in applied irrigation water is left behind as the water evaporates from the soil surface and is absorbed by the crop roots, the salt content of irrigated soils will build over time. If sufficient rainfall occurs, natural leaching will wash the built-up salts below the root zone of the crop and production will not be affected.

If the rainfall is too low to provide natural leaching, or if the irrigation water salt content is too high, salt levels can build up to toxic levels or can raise the osmotic potential of the soil so high that plants cannot survive, even at very high soil water contents. Total salinity levels are normally measured by the electrical conductivity, EC, measured in deciSiemens per meter, dS/m (or millimhos per centimeter, mmho/cm, or micromhos per centimeter, μ mho/cm) (Note: 1 dS/m = 1 mmho/cm = 1000 μ mho/cm)

The threshold soil water EC at which grape yield begins to be affected is about 1.5 dS/m. For every 1 dS/m increase in soil water electrical conductivity above that level the crop yield will decrease by 9.6%.

Note that the salinity of the soil water is the important feature. The higher the salt content of the irrigation water, the more rapidly and the higher the soil water salt content will rise. The higher the electrical conductivity of the irrigation water (EC_w) the more the electrical conductivity of the soil water extract (EC_e) will be affected. The approximate relationship to grape yield is shown in the table below. The relationship between EC_e and yield is fairly accurate. The direct relationship with EC_w is less precise because it is affected by rainfall during the growing season.

Table 2. Relationship between grape yield and electrical conductivity of soil extract and irrigation water.

Yield Reduction (%)	EC_e (dS/m)	EC_w (dS/m)
0	1.5	1.0
10	2.5	1.7
25	4.1	2.7
50	6.7	4.5
100	12	--

Grapes are also quite sensitive to boron. Boron toxicity begins to injure grape leaves at concentrations of about 0.5-0.7 mg/l in irrigation water. Boron injury is typically drying, yellowing and spotting along the tips and edges of older leaves. Yield reductions may not necessarily occur at the first sign of boron toxicity.

High chloride content in irrigation water may lead to leaf injury in grapes and a resultant reduction in plant performance. Chloride injury typically appears first as burning or drying at the extreme tip of older leaves and then progresses back along the leaf margins as the injury progresses. Excessive leaf burning can eventually lead to leaf shedding. The levels at which chloride injury will first appear are given for certain varieties and rootstocks in the table below.

Table 3. Chloride injury thresholds for some rootstock/varieties

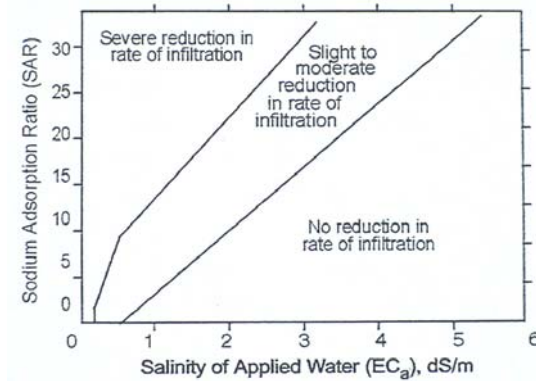
Variety or Rootstock	Soil Saturation Extract (mol/m³)	Plant Leaf Analysis (5)
Salt Creek	40	0.5
Dog Ridge	30	--
Thompson Seedless, Perlette	25	0.5
Cardinal, Black Rose	10	--

Sodium is the other major concern of irrigation water quality. It may be toxic to the plant at high enough concentrations, but generally is of concern because of its effect

on soil structure. High sodium concentrations in soil water lead to dispersion of the clay particles which seals the soil pores and prevents the ready infiltration of water. Soils with sodium problems tend to have a black, shiny appearance and are often referred to as "black alkali" soils. The effects of sodium are counteracted by the presence of calcium and magnesium. The calculated salinity term sodium adsorption ratio (SAR) takes into account the relative proportions of these three mineral salts in the soil water. The hazard from sodium depends on the soil texture. High clay content soils are at greater risk than sandy soils. Clay soils with montmorillonite (expanding clays) suffer more from sodium hazard than kaolinite or illite (non-expanding clays).

The relative risk of infiltration problems occurring are illustrated on the chart below.

Figure 3. Effect of sodium adsorption ratio and irrigation water salinity on water infiltration.



Water Quantity

Of equal importance in irrigation planning is the available quantity of irrigation water. Not only is the total amount available important, but also the rate at which it can be delivered. The water must be delivered at a rate which allows the irrigation system to replace the water depleted by evapotranspiration (ET). Evapotranspiration is the water consumed by a growing crop as transpiration through the leaves and evaporation from exposed soil. This water is used in the photosynthetic process and is withdrawn from the soil through the crop roots.

ET is driven by radiant energy from the sun, and heat from the soil and air. It is also affected by the ability of the atmosphere to carry water vapor away from the crop canopy. The higher the solar radiation, air temperature, soil temperature, and wind speed, and the lower the relative humidity of the air, the higher the ET rate will be. A crop's ET rate is also affected by its stage of growth and how much leaf area it has. ET is nearly all soil evaporation early in the growing season. ET rate increases as the crop grows until it peaks when the crop has a fully developed vegetation canopy and begins setting fruit. The rate drops off toward the end of the growing season as the plant senesces. A crop with a large, multi-layered canopy that matures in late summer may have a peak ET rate

of 0.3 to 0.4 inch per day, while a crop with a lesser leaf area harvested in early summer may have a peak ET of 0.2 inch per day.

The seasonal irrigation water requirement of grapes can vary significantly across Oklahoma. Not only does the rainfall during the growing season drop considerably as you move from east to west across the state, but the seasonal ET demand also increases from east to west. There will also be considerable variation in irrigation water requirement from season to season, depending on weather patterns. Typically the amount of water required to supplement rainfall during the growing season will be 10 to 13 inches in eastern Oklahoma and 15 to 17 inches in western Oklahoma.

The rate of water delivery an irrigation system must have in order to meet the peak ET demand of the crop is called the design capacity. This is the minimum flow rate which will allow the system to keep up with peak water use of the crop without depleting stored soil water in the root zone below the management allowed deficit. To save on cost, irrigation systems are often designed to supplement the normal rainfall that occurs during the growing season. This allows the design capacity to be smaller, permitting use of smaller components and a smaller water supply, however the irrigation system will not meet all of the crop water needs during the peak water use period unless normal amounts of rainfall occur. Design capacity is determined by the following equation:

$$Q = \frac{453 A ET}{H E_a}$$

Where:

Q = Design capacity of the irrigation system, (gpm)

A = Area the irrigation system will irrigate, (acres)

ET = Evapotranspiration rate of the crop, (inches/day)

H = Hours of irrigation system operation per day, (hours/day)

(usually limited to 22 hours/day to allow some excess system capacity)

E_a = Irrigation application efficiency, (%/100)

(E_a is usually 90% for microirrigation systems, and 70-80% for sprinkler systems)

453 = Conversion factor, (453 gpm = 1 acre-inch/hour)

While sprinkler irrigation systems will require a design capacity of 7-8 gpm/acre to meet an ET rate of 0.25 inch per day, microirrigation systems, with their increased application efficiency, typically require only 5-6 gpm/acre to irrigate the same area. Taking into account wide crop row spacing with only 50-60% of the field surface covered with vegetation, microirrigation systems may be capable of meeting the maximum ET demand of grapes with as little as 3-4 gpm/acre.

Irrigation Water Management

Irrigation water management requires an understanding of the reservoir of stored soil water the plant uses to sustain its growth, the factors that determine the rate of crop water use throughout the growing season, and ways to manage systems to supply irrigation water to the crop so that the maximum amount of yield is produced for every

unit of water used. The most profitable system for a producer will not necessarily be the one that produces the maximum yield. In grape irrigation the process is further complicated because controlled water stress at select periods of the growing season can affect the sugar, organic acid and soluble solids content as well as pH and color of the fruit. These factors can affect not only the flavor and quality of the fruit, but also the flavor and quality of wine produced.

The amount of water in the soil reservoir that the crop has available for growth is determined by the rooting depth of the crop, the available water capacity of the soil, and the amount of soil water depletion that can be tolerated by the crop at its particular growth stage. Available water capacity is bound by the upper limit of field capacity and the lower limit of permanent wilting point. Field capacity is the amount of water a unit depth of soil will hold against the pull of gravity. It is the soil water condition when there has been a rainfall or irrigation event of several inches and the soil has had 24 to 48 hours to drain. Field capacity usually occurs at a soil moisture potential (as measured by a tensiometer) of 0.1 to 0.3 atmospheres (10 to 30 centibars). It is chiefly determined by the texture of the soil. At field capacity a light sand will hold about 1.25 inches of water; a medium loam about 2.25 inches; and a heavy clay about 3.70 inches of water per foot of soil depth.

Permanent wilting point is the amount of water held by a unit depth of soil when a growing crop has extracted all the water it can before dying. The soil water potential at permanent wilting point for most crops usually occurs at a soil water potential of about 15 atmospheres. At permanent wilting point a light sand will hold about 0.25 inches of water; a medium loam about 0.55 inches; and a heavy clay about 1.3 inches of water per foot of soil depth.

Available soil water capacity is the amount of water held in a unit depth of soil that is available for plant growth. This is the amount of water stored between field capacity and permanent wilting point. For a light sand the available soil water content is about 1.0 inch of water; a medium loam about 1.70 inches; and a heavy clay about 2.40 inches of water per foot of soil depth. The approximate range of available water capacity for the soils of Oklahoma is given in each USDA County Soil Survey in the table of "Physical and Chemical Properties of Soils". Depending on the age of the survey it may be expressed in inches of water per inch of soil, or in inches of water per foot of soil.

The effective feeder root zone depth is the depth of soil that has well developed roots for irrigated crops. This depth is somewhat less than the maximum rooting depth of the crop in most soil environments, and can be affected by restricting layers in the soil. In unrestricted soils the effective feeder root depth of grapes will typically range from 3 to 6 feet with about 70% of the root mass in the upper half of the root zone. The lighter textured the soil the deeper the crop will normally root.

The allowable soil water deficit is the percentage of available soil water that the irrigation manager will allow to be removed by the crop before the soil water is replenished by irrigation or rainfall. The allowable deficit depends on the type of crop

being raised, its stage of growth, and the rate of water use. Grapes can typically tolerate depletion of about 50% of the stored soil water in the root zone before crop yield will be affected. Management allowed deficit will not be the same throughout the growing season; some growth stages (flowering and fruit set) are more susceptible to drought damage.

Readily available soil water is the depth of water that can be removed from the crop root zone without reducing the yield due to water stress. This is the water that the irrigation manager controls, and is usually the amount of water depleted between irrigations and the amount replaced with each application. The readily available water for each cropping situation is the product of the available soil water capacity, the feeder root zone depth, and the management allowed deficit. For example if grapes have a feeder root depth of 4 feet; and a management allowed deficit of 50% are grown on a loam soil (Available soil water capacity = 1.7 inches per foot), the readily available soil water is: $4 \text{ ft} \times 0.50 \times 1.7 \text{ in/ft} = 3.40$ inches of water in the crop feeder root zone.

Rainfall in sufficient quantity falling on a crop with available storage capacity in the root zone so that some of the water is stored in the soil for crop growth is effective rainfall. Some measured rainfall is lost to evaporation, some runs off sloping fields, and some soaks into the soil. Of the amount that soaks into the soil, the amount that fills available space in the crop feeder root zone and remains there for crop growth is called effective rainfall. If some soaks into the soil, but the rain occurs immediately after the crop has been irrigated, there will be little or no available storage space, so little if any of the rain will be effectively stored. Most of it will be leached out of the bottom of the root zone. If very little rain falls on a hot day, most of it will be lost to evaporation before it soaks into the ground. Very little, if any, of small summertime rain showers is effective. Normally, at least 0.25 inch of measured rain must fall before any is stored in the soil. Soil texture affects the amount of heavy rainfall that is effective. Sandy soils will absorb heavy rainfall more readily, while clays will lose most of the rain to runoff.

The percentage of the water delivered to an irrigation system that is effectively stored in the crop root zone for growth is the irrigation system application efficiency. The amount of water delivered to the irrigation system is called the gross application depth. The amount actually stored in the crop root zone is called the net application depth. The net application depth is the product of the gross application depth times the irrigation efficiency. Like rainfall, some irrigation water is lost to runoff, evaporation and deep percolation. A system with 75% application efficiency would store 0.75 inch of water in the crop root zone if 1.0 inch of water was applied. If properly designed, sprinkler systems have very little loss to deep percolation and runoff, but can have fairly large losses to evaporation in hot, dry, windy conditions. Solid-set and hand moved sprinkler systems typically have 65% to 75% application efficiencies. Traveling volume gun systems will typically have application efficiencies in the 60-70% range. Surface or gravity irrigation systems tend to lose less water to evaporation, but lose large amounts of water to runoff and deep percolation. Surface system efficiency is more dependent on the management skill of the operator and typical efficiencies for graded furrow systems can

range from 40 to 70. Microirrigation systems have application efficiencies around 90-95%.

The rate at which a soil will absorb water is permeability. Permeability is sometimes called infiltration rate. Permeability will affect irrigation efficiency and rainfall effectiveness. A highly permeable soil will absorb water readily, while a soil of low permeability will cause more water to run off the soil surface. Permeability is largely a function of soil texture, but soil structure and soil organic matter will also affect permeability. Permeability is not constant, but varies with time. When water is first applied to a dry soil it will be absorbed rapidly. As the soil is wetted, surface pores fill with water and clays swell, slowing infiltration. After a certain amount of time the soil will reach its "ultimate infiltration rate", the rate at which water can be absorbed for an extended period of time. Sprinkler irrigation systems should be designed to apply water no faster than the ultimate infiltration rate of the soil, otherwise ponding of water on the field surface and runoff will result. Permeability also affects the operation of surface irrigation systems, such as furrow systems. Highly permeable soils can be furrow irrigated only on very short fields because the furrow stream will move only a short distance down slope before being completely absorbed. Longer furrow lengths can be used on low permeability soils, but excessive runoff can be a problem. The permeability of Oklahoma soils can be found in the USDA County Soil Survey in the table of "Physical and Chemical Properties of Soils". The values listed are the ultimate infiltration rate of the soils, given in inches of water per hour.

Methods for Managing Irrigation Water

Tensiometers are a water-filled tube with a porous ceramic tip buried in the soil and a vacuum gauge at the upper end. The device wets up and dries down with the soil in which it is buried. As water is taken in or drawn out of the tube through the ceramic tip, the change in water content of the tube is indicated by the reading on the vacuum gauge. A higher vacuum reading means the tube is drier and the drier the soil. The instrument can accurately measure soil water status from field capacity up to a soil water potential of about 0.8 atmospheres. Thereafter, the water column in the tube will separate. In sandy soils, this range of measurement can account for up to 50% of the available soil water, making the instrument a very effective management tool. In heavy soils, the range of measurement will account for only about 10% of the available soil water, making it less effective as a management aid. The instruments should be used in pairs, a deep one and a shallow one, at representative locations throughout the field. The instrument can be fitted with electrical contacts to automatically control irrigation systems based on soil water potential.

Electrical resistance blocks are porous blocks of gypsum or other material with electrical contacts embedded in it. The block is buried in the soil where it absorbs water. As the soil becomes wetter, the block absorbs more water. The wetter the block, the more readily an applied electric current is carried from one contact in the block to the other. A meter connected to the block by wires measures its resistance which can be calibrated to estimate the water content of the surrounding soil. The range of operation can be from

field capacity to permanent wilting point. The accuracy of the device can be affected by temperature, salinity and fertilizer. It can give general indications of water content. They should be used in pairs, a deep block and a shallow block, and at several representative locations in larger fields.

The method of tracking soil water status by measuring inputs and outputs of water from the crop root zone is called soil water budget scheduling, or checkbook irrigation scheduling. Starting from a known soil water content, usually field capacity after a substantial rain or irrigation application, additions and withdrawals of water from the soil water reservoir are recorded. Additions are effective rainfall and net irrigation. Withdrawals are due to crop evapotranspiration. By estimating ET with pan evaporation, Mesonet information or some other method, and measuring rainfall and irrigation applications, an irrigator can tell what his field's soil water status is at any time and determine the need for irrigation. The method requires the irrigation manager to keep a water budget much like keeping the register of a checking account, hence the name of the method. The budget will tell how much water has been depleted from the crop root zone and how close the crop is to the management allowed deficit. It will also tell how much water must be applied to refill the crop root zone to field capacity at any time.

The use of a probe, a metal rod with a slightly enlarged, rounded tip, can help an experienced irrigator judge soil water content. Moist agricultural soil is generally more friable than dry soil. By monitoring the ease with which the probe can be pushed into the soil and irrigator can judge water content. This method is especially useful in helping to judge how deeply an irrigation application has penetrated the root zone. A good deal of experience is needed to use this method with reasonable accuracy. Probing must be done at representative sites in the field to be of value.

An experienced irrigator can judge soil water content by the feel and appearance of a handful of soil. Observing the texture, the way the soil holds its shape when squeezed and released, and the amount of moisture left on the palm and fingers will tell how much water is held in the soil. Moisture checking must be done at representative sites throughout the field. A coring device must be used to obtain samples from deeper than about 6 inches below the surface to judge water content throughout the depth of the root zone.

Irrigation Application Methods

Furrow irrigation is one of the earliest irrigation methods used. Ditches running between alternate rows of crop allow infiltrated water to supply the root zones of adjacent crop rows. The efficiency of this irrigation method is poor. Furrows must run down a constant slope or across slopes along the contour to promote uniform water movement. Dry vegetation is maintained, but the presence of the furrows between the rows and the saturation of the soil during irrigation interferes with movement of labor and equipment in the field.

Sprinkler irrigation sprays water uniformly over the field surface. Hand-moved systems use a relatively small number of pipes that are moved after each application to irrigate a new area of the field. These systems have a lower initial cost, but are labor intensive to operate. Since the entire field surface is wetted and the application can be distorted by wind, the application efficiency is not nearly as high as for microirrigation systems. Because the vegetation is wetted during water application foliar diseases can be aggravated.

Solid-set irrigation systems use enough equipment to cover the entire irrigated area. For perennial crops like grapes, the pipelines are normally buried below ground. Vertical riser pipes elevate the sprinkler heads above the vegetation within the crop rows. On small systems all of the field may be irrigated at one time. On larger systems only part of the field may be irrigated at one time. Irrigation is shifted to successive parts of the field by opening and closing valves, which may be manually or electrically operated. Solid-set systems are quite expensive to install but require little labor to operate, and can even be programmed to operate automatically.

Microirrigation is the term used when referring to application by trickle emitters, drippers, misters and micro-sprinklers. Microirrigation systems apply water through emission points at flow rates on the order of a few gallons per hour. The emitters may be widely spaced point sources of discharge for widely spaced plants, or very closely spaced points which effectively discharge a line source of water for closely spaced plants in rows. The emitters may be above ground or below ground. Microirrigation systems tend to be low pressure systems with minimal energy requirements. The system is best suited to crops planted in widely spaced rows, which allows only the soil near the crop roots to be watered.

Microirrigation systems in grapes will typically have one or two emitters per vine. The emitters and the lateral line which supply them may be on the soil surface at the base of the vines, buried a few inches below the soil surface at the base of the vines, or suspended in the canopy, attached to the wires that support the trailing vines. If the terrain of the field is uneven, care must be taken to ensure uniform water application. An elevation change of 2.31 feet results in a change of pressure of 1 psi inside the lateral line (an increase of 1 psi for a drop in elevation and a drop of 1 psi for a rise in elevation). Because microirrigation emitters are typically operating at pressures in the range of 8-15 psi, a 1 psi pressure change can have a significant effect on water output. If the field has a constant slope, it can be broken into zones of similar elevation with a pressure regulator controlling the system operating pressure for each zone. If the field surface undulates, pressure compensating emitters will have to be used to keep the water application rate constant for all parts of the field.

One advantage of microirrigation systems is reduced wetting of vegetation. This helps to control foliar diseases that can often be aggravated by the high humidity conditions that develop in the vegetation under sprinkler systems. It is normally preferred to operate the microirrigation system no more than 16 hours per day. Operating for extended periods of time can affect the health of the crop root system. Having several

hours of off time each day, or irrigating on alternate days gives time for drainage and promotes root aeration.

Because microirrigation systems have enough hardware to cover the entire irrigated area at one time their initial cost is quite high. However, they can be operated with very little labor and lend themselves to automation very well. Water quality is critically important for success in microirrigation. Filtration of suspended particles, control of pH to prevent buildup of mineral salts which can precipitate and clog emitters, and frequent flushing of lines are all necessary to maintain the system properly. In light textured soils gophers are frequently a problem for buried polyethylene pipelines.

VII. PLANTS AND PLANTING

Plants

Grapevines need to be ordered as early as possible. Calling for vines in January or February of the year of planting can lead to problems with plant quality. Late orders seldom deliver the variety or rootstock needed. Super jumbo rootings are never available from late orders and vineyards started with green graft vines produced in greenhouses in three or four months can be too weak. Vineyard establishment from non-rooted cuttings is a gamble and one should consider success from them a rare good fortune. Dedicate a full year prior to planting to obtain the desired variety, rootstock and rootings. Have the vines shipped as soon as they are dug at the nursery.

If vines are received before the site is ready for planting, e.g. soil preparation, irrigation set up or trellis construction, the vines should be unpacked and covered with soil (heeled in) in the shade until planting. Vines will remain healthy in the heel bed for up to four months. Do not store vines in water or a refrigerator. The heel bed should be watered periodically to keep the roots moist but not wet. Never allow the roots to dry out.

The vines should make very fast growth by May and reach a trunk diameter of one inch or more the first year.

Planting

Immediately prior to planting, trim the roots to fit the hole and cut the top back to only two buds on the strongest cane. Remove all other canes. Carry the vines to the vineyard site in a bucket of water. Dig a small hole with a hand-held post digger about 6 inches in diameter, 4 to 6 inches deep. Stand the plant in the hole and pack the same soil back into the hole around the plant. Install a stake next to the vine. Water the vine with two or three gallons of water immediately after planting. If grafted vines are used the graft union must be above the soil line. As the new shoots begin to grow, watch for insect damage, e.g. cutworm and grasshopper. Do not allow weeds to develop and keep the young vines watered once a week or more in hot, dry weather.

Green growing vines, i.e. potted plants, should be acclimated in a protected spot for a few days prior to planting. The pots should be removed before planting. If grow tubes are used, they should be installed after planting with the base lightly covered with soil. Do not bury them into the soil as root constriction may occur.

Row and Vine Spacing

Many factors, including experience with a variety on a site, determine the best row spacing and canopy system. The spacing and canopy need to match vine vigor and the factors that influence vine vigor, e.g. soils, variety, rootstock and management. Ultra high-density vineyard spacing, e.g. four by four should not be attempted as a first vineyard.

Existing tractor size frequently determines the distance between rows. Twelve foot spacing is utilized for a standard size tractor. A ten-foot spacing can be used for a small narrow tractor. Row spacing should not be closer than the height of the canopy.

Vine spacing within the row will be determined by soil vigor potential. Deep, well-drained fertile soil will produce very vigorous vines and a spacing of eight feet between vines in rows will be needed. Shallow soils will produce less vigorous vines which can be spaced six feet apart in the row. Row length should not be more than 500 feet to insure uniform drip irrigation water pressure. Row orientation is less critical than row spacing. North/South rows intercept more sunlight and may have better air movement among the vines. East/West rows may have better protection from wind. Row orientation should be paired with site constraints, e.g. topography and erosion potential.

VIII. CANOPY MANAGEMENT AND TRELLISING

Vine Vigor

Wine quality begins in the vineyard and canopy management is a major factor in producing high quality grapes. Premium wines are produced from grapes on very healthy vines that have an optimum shoot/fruit ratio. The ideal canopy system is a function of vine vigor which is influenced by the following factors:

Climate. If other factors are equal, heat increases vigor while cooler temperatures reduce grapevine vigor. The optimum growth temperature for grapevines is between seventy-five and 90 degrees Fahrenheit. High light stimulates growth, while very cloudy conditions reduce vigor. Typically, grapes require 120 days from full bloom to harvest. The climate can determine if harvest is earlier or later than 120 days. Oklahoma generally is a high vigor climate.

Soil. Soil is a major influence on vine vigor. The extent of root development determines the absorption potential for water and minerals. Soils one foot deep should

support low vigor; plants in soils two feet deep, moderate vigor, and soils three feet deep should produce very vigorous vines.

Varieties. The cluster size and natural vigor of the variety can determine the vine's growth potential. 'Sauvignon Blanc', 'Cabernet Sauvignon', 'Chenin Blanc' and 'Semillion' are very vigorous. 'Chardonnay' and 'Merlot' are moderately vigorous.

Rootstocks. Grafted vines are generally more vigorous than own rooted vines. Some rootstocks, e.g. St. George, SO-4 and Dogridge, are more vigorous than others.

Weed Competition. Poor weed management results in poor vine vigor and increases insect and disease potential. The optimum system is weed free under the vines and grass sod middles. In western Oklahoma, clean cultivation may be replaced with grass middles and chemical weed control under the vines.

Irrigation or water management. The key is to have optimum soil moisture with fifty to seventy-five percent field capacity throughout the root absorption zone for the production season. Avoid extremes of either drought or flooding.

Fertilization. Excessive nitrogen can lead to excessive vigor. Control vigor by balancing fruit load and cane growth. At harvest, the optimum shoot size is 3/8 to a 1/2 inch in diameter, forty-eight to 60 inches long with fifteen to twenty-two mature leaves. The optimum vigor for a vine is 0.5 to 0.7 pounds of pruning wood weight per foot of canopy row, regardless of the canopy system.

Canopy and Trellis System

Canopy systems can be classified into three basic types: standard, vertical and curtain. The standard system uses cane or spur pruning on one or two wires with the shoots growing up and over one or two wires in any direction with no support or positioning. Examples of the standard system are two cane, four cane Kniffen (Figure 4), Umbrella Kniffen (Figure 5) and others.

Figure 4. Standard Kniffen Training System.

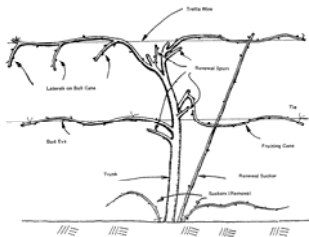
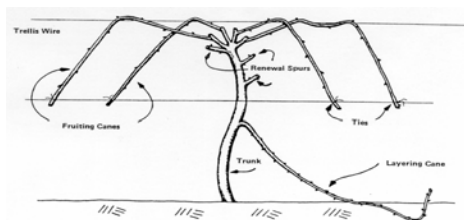
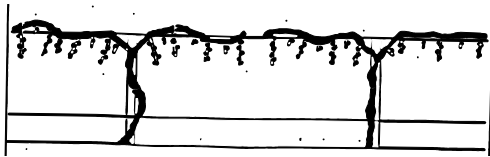


Figure 5. Umbrella Kniffen Training System for table grapes.



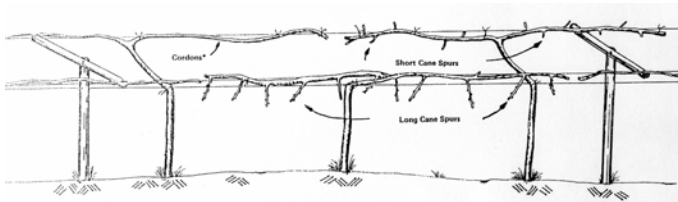
The high curtain system or Hudson River Umbrella (Figure 6) is used for vigorous vine sites. It is a high wire system where spurs are pruned in a downward position and the shoots grow outward and down without support as a curtain on extremely vigorous sites.

Figure 6. High Curtain Training System.



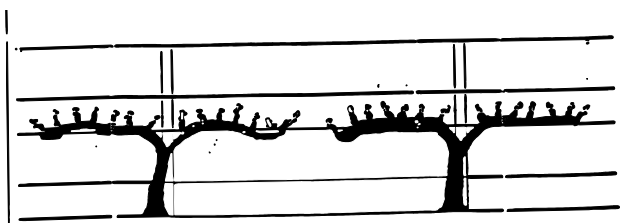
This system can be split, e.g. Geneva double curtain (Figure 7).

Figure 7. Geneva Double Curtain Training System.



The vertical shoot positioning system is opposite of the curtain system. The cordons are relatively low to the ground and shoots are positioned vertically as they grow upward (Figure 8). The shoots are positioned between two movable wires or tied to several vertical wires. In some areas older vineyards are being switched to the vertical system to achieve higher fruit quality. With vertical systems light in the fruiting zones is enhanced and air circulation is improved which reduces disease. These are positive factors which may lead to improved yield and quality. When the vertical system is used, shoots can ordinate for either spurs or canes or both.

Figure 8. Vertical Shoot Positioning Training System (bilateral cordon).



The question of hand or mechanical harvesting must be addressed prior to building the trellis. Small vineyards will usually be hand harvested. Those over 10 acres likely will be mechanically harvested. Curtain canopies are usually well suited for mechanical pruning and harvesting.

Trellis

The purpose of the trellis is to support the vines with their fruit load of up to 5 tons or more per acre. The trellis must be built sturdy enough from the outset as it is difficult and more expensive to shore up an inadequate trellis after the vines are loaded with fruit. Trellis form must be supportive of the canopy management system selected, e.g. single curtain, double curtain, vertical shoot position, etc. The trellis end posts should be installed before planting begins. Although many variations exist typical trellis material may include the following:

Wire	12 1/2-gauge, galvanized, standard or high tensile.
End Posts	8' or 10' long treated wood or steel pipe, set in concrete 2 to 3 feet deep, 6" or 8" tops; other types can be used.
Vine Stakes	Long enough to reach top trellis wire; may be T posts, bamboo or similar material.
Anchor for End Posts	trailer house anchors which screw into the ground
Drip Irrigation Line	1/2 inch black plastic that is treated for sunlight protection
Grow Tube	12 to 18" tall, various types are available.

Training System

The following discussion describes high curtain (HC) and vertical shoot position (VSP) systems. Both are suited for moderate to high vigor sites and are readily adaptable to mechanization. Both systems have an irrigation wire at 12" above ground. The drip line is attached to this wire. Both systems also have an intermediate wire at about 36". On the VSP system this serves as the cordon wire supporting fruiting shoots which reach up. The top wire on HC system is usually 60 to 66" high. It serves as the cordon wire and supports fruiting shoots which hang down. The top wire on VSP systems is usually about 60" high depending on expected vigor. With the VSP system, provision must be made to control or "position" the vertically growing shoots. This is usually done by means of two sets of catch wires which can occupy positions between the cordon and top wire at about 8" intervals, e.g. 38", 46" and 54". These catch wires are separated at each line or T post by a spacer about 4 inches long with a notch on each end which can receive and secure the wire without permanent attachment. The catch wires are attached to each end post, one on each side, by a means which allows them to be moved up as the shoots grow up during the season. This is frequently done by driving spike nails (or welding short rods to metal posts) into each side of the end post at the proper distances apart (8" in this case) and attaching short lengths of chain to the end of the wires.

At bud burst the catch wires occupy the first two positions, i.e. 8 and 16", above the cordon wire. As the shoots grow they are positioned between the first set of wires then the second. If the shoots exceed the second set of catch wires at 16" the first is moved up to the third position, 54". This allows three spaces to be occupied by 2 sets of wires. This positioning allows easy access to the plant for vineyard operations, e.g. leaf removal, cluster thinning and harvest.

From this discussion it becomes clear that the trellis “system” is truly a system. The end posts must be tall enough to accommodate the wire configuration and the wire configuration must be suited to the growth accomplished by the vines as well as future trends in mechanization. More wires and taller posts mean more money so these decisions should not be made lightly. Likewise, conversion of an inadequate trellis system in later years can be more expensive still. If vigor dictates, a high curtain system can be converted to a split canopy, e.g. Geneva double curtain, later in the life of the vineyard.

IX. TRAINING AND PRUNING

Vine Training

The objective of the vine training program is to produce the plant which will serve as the basis for fruit production throughout the life of the vineyard. For economic reasons, it is critical that this be accomplished as quickly as possible without compromising the long-term production potential of the vineyard.

Training and pruning together constitute a critical part of vineyard establishment and management. Training consists of forcing the plant's structure into a predetermined form, e.g. single or multiple trunk, single or bilateral cordon, high cordon or Geneva double curtain. The critical time for grapevine training is in the first two years of the vineyard's life. After a viable training program has established the vine shape little additional training is needed unless the vine must be reestablished following freeze damage or other cause of vine loss.

Pruning consists of judicious removal of plant parts to force the plant to retain the established structure and to control its growth to facilitate fruiting efficiency. Proper pruning is critical to obtain perfection in balancing vine health and maximum production of quality fruit.

In high vigor situations, e.g. good soils, ample water, nutrition and weed control, it may be possible to establish cordons the first growing season.

First Leaf

At planting install a plant stake (bamboo, t-post, etc.) at each plant reaching from the ground to the top wire (intermediate wire in GDC) of the trellis. After budbreak select the most vigorous cane and tie it to the stake. Since vinifera varieties are subject to freeze injury in Oklahoma many growers elect to train two trunks of vinifera varieties as a kind of “insurance” in case of freeze damage. If this is the chosen method, select and leave the two most vigorous canes. Both should be tied to the plant stake. After about three weeks subordinate canes should be removed or their tips removed at the most recent fully expanded leaf to prevent terminal growth. This allows remaining leaves on each shoot to contribute toward the plant's growth. These subordinate shoots will be removed

in mid to late summer. When the selected main trunk reaches the cordon wire it should be tied to the cordon wire and topped at the second leaf above the cordon wire. This will force lateral shoots to form from which the cordons can be selected. Cordon shoots should be selected from the strongest lateral shoots arising at or slightly above the cordon wire. If a double trunk training system is used, each main trunk can be structured into a cordon. The cordon shoot should be loosely wrapped once around the cordon wire then secured to the wire with ties and allowed to grow the remainder of the summer.

First Dormant Season

Before growth begins for the second leaf, i.e. during the first dormant season, the cordon shoot is terminated so the cordon from adjacent plants in a row meets midway between the two plants. The cordon should have well spaced leaves about six inches apart with healthy lateral buds throughout the length of the cordon. Shoots from the lateral buds on the cordon will be used to establish spurs which will be the fruiting basis for the vine in the years ahead. If the cordon has “blank” areas, e.g. areas without lateral buds, it should be cut back behind the blank section to re-grow the cordon during the second year. All shoots from the trunks during the second year should be removed.

Vigor Effects

In low vigor situations it is best to establish the plant the first year and delay construction of the trunk and cordons until the second year. In this case the vine should be allowed to grow un-pruned the first year. Then just prior to budbreak the second year, prune the vine back to two buds on the strongest cane. All other canes and buds are removed. When all of the shoots are over 18 inches long, select the strongest and very carefully tie it to the stake. Do not remove other shoots until the strongest shoot is successfully tied. These shoots break off very easily.

Prune low vigor vines to only two buds of second year's growth, eight to twelve buds prior to the third year's growth and twenty to thirty buds prior to the fourth year's growth. These buds can be on canes for cane pruned vines or two bud spurs on the cordon-pruned vines. Each bud will produce a shoot with two to three clusters of grapes.

If the pruning wood weight is less than 0.5 pounds per foot of row, leave fewer buds per vine at the next pruning season to increase vine vigor and reduce fruit loads. These small shoots on over-cropped vines are weak and ripening will be very slow and may never be complete. On the other hand, if the pruning wood weight is more than 0.7 pounds per foot of vineyard row, the vine is too vigorous. Yields will be low due to shading and the wine will have an obvious vegetative nose. In this case, leave more buds on the vine to increase fruiting and reduce vigor. However, there is a limit to how many buds that can be left without creating a shade problem. The optimum fruit to pruning wood ratio is 8:1. For each pound of pruning wood produced by the vine, eight pounds of fruit should be produced. If more fruit is produced, say 12:1 ratio, the vine is too weak and it will not make enough growth to adequately develop or ripen the fruit. If the ratio

is too low, say 4:1, the vine is too vigorous and more buds will need to be left on the vine after pruning.

In addition to optimum shoot vigor, the buds in the fruiting zone at the base of the shoots must receive sunlight in May and June. This sunlight/bud contact influences the number of clusters and number of berries per cluster for the next year. On vigorous vines, this is accomplished by removing two or three leaves in the fruit zone in early May. Sunlight does not penetrate more than two layers of leaves, so this leaf pruning by hand just after fruit set is essential. If leaf pruning is too late, the fruit can sunburn. Research has shown leaf pruning is essential for continued production. Leaf pruning also increases air circulation around the cluster.

Training Systems

Spur Pruning. Spur system is the simplest of grape pruning systems. Prune "all" canes on a vine in late February or early March so that they are only six inches long. Two weeks later, prune these short canes into spurs with only two buds each. The spurs should be about three inches long, with two buds each, and 3/8 inches in diameter. The spurs should be four to six inches apart and since grapes are produced only from buds on one year old canes they must be last year's growth.

Ideally the vine will have one spur with two buds every six inches on the vine. However, if the vine becomes weak, due to low vigor, environmental stress, or overproduction, one spur every six inches may be too many. In this case, count the number of canes, which are 3/8 inch in diameter, and leave no more than this number of buds on the vine. For example, if a vine has 16 ideal size canes before pruning, leave only 16 buds on the vine. This will be 8 spurs with two buds each, or 16 spurs with one bud each. It could also be two canes with eight buds each. Do not leave a cane with more than 10 buds. The ideal cane size is six buds each and the ideal spur size is two buds each.

Bilateral Cordon. This is the most commonly used system (Figure 8). A horizontal trunk is trained on the cordon wire left and right of the trunk. Seven spurs with two buds each are selected on each side of the trunk during the second and third growing seasons. This system is for moderate to vigorous vines, which has worked well for many varieties growing on deep soil. It is difficult to train but very easy to prune once the vines are mature. Prune the vine to fourteen spurs with one, two or three buds each. To determine how many buds to leave, count the number of 3/8 inch canes per vine at pruning and leave this number of buds. A disadvantage with the bilateral cordon is freeze and hail, which frequently develops into crown gall damage. Dead tissue on the cordon can also harbor borers. The bilateral cordon tends to have excess vigor at the bend and end of the cordon with weak shoots in the middle of the cordon.

Cane. The cane system is very different from cordon systems. To cane prune, remove all one-year-old canes except one on each side of the trunk. Select the two canes that are approximately 3/8 to 1/2 inch in diameter and four to six feet long. Arch the two

canes over the wire that is 52 inches from the ground. There should be six to twelve buds on each cane. The end of the cane should always be at least 3/8 inch in diameter. Also, leave two very short one-bud spurs on the trunk as renewal spurs. They will produce next year's production canes.

Single Curtain. The single curtain system is suited to extremely vigorous vines. This is a horizontal trunk or cordon on the top wire, going left and right from the trunk (Figure 6). Spurs are selected each winter six inches apart with one to six buds each, depending on the vigor level. If last year's growth was weak, leave fewer buds, if it was overly vigorous, leave more buds.

Sites with three feet or more of well-drained soil and where mechanical harvesting is a possibility should consider the curtain system. This year's one bud spur will be next year's short cane with the pruning rotating back and forth year after year.

Geneva Double Curtain. If the single curtain is not enough bud to reduce vine vigor to optimum size, the Geneva Double Curtain can be used. The single and double curtain systems are ideal for mechanical harvesting. They also require mechanical shoot positioning to allow sunlight to enter the fruiting zone. If over-cropping appears to be a potential problem, fruit thinning will be needed to prevent stressing the vine and producing low quality fruit.

All grape growers should weigh their pruning wood for each variety and block. With three to five years of data, the optimum pruning level can be obtained. Some vineyards have pruned from forty buds per vine to only twelve with increases in both yield and quality, plus healthier vines in a difficult climate and shallow soil.

X. ROOTSTOCKS

Rootstocks allow the opportunity to offset negative growth factors such as soil born insects (e.g. phylloxera) and diseases (e.g. cotton root rot), salt accumulation, marginal water, etc. If none of those conditions exist, the rootstock may not be needed. When no rootstock is used, the vine is called an "own root," which means the variety and the root systems are the same, say 'Cabernet Sauvignon'. Own root vines have the same genetics throughout the plant and can be reestablished from suckers after severe freeze damage. If grafted vines freeze below the graft union they require replacement or re-grafting.

Plants on rootstocks are grafted plants. With grafted plants the above ground variety, such as 'Cabernet Sauvignon' is called a **scion**. The below ground part of the plant is called the **rootstock**. The scion and rootstock are typically joined together at a workbench in January or February, using various grafting techniques such as the whip graft. The scion and rootstock graft is callused for 60 to 90 days in a high humidity environment at 78 to 80 degrees F. It is planted in a nursery row and grown for one year, then sold and transplanted as a Dormant Bench Grafted Vine.

A rapid graft propagation technique is used where the callused graft is rooted under mist for 30 days, grown in a greenhouse for 30 days, conditioned in a lath house for 30 days and planted in the vineyard in May. Vines from this system are called **Green Growing Bench Grafts**. Summer temperatures, sunlight and low humidity can make green growing bench grafts very difficult to establish. Growers need to determine which problems demand a rootstock before establishing a vineyard.

Rootstocks commonly used are either selections from hardy native species or plants resulting from crosses of various native species. Vines resulting from crosses would be expected to exhibit traits from one or both of the parents of the cross.

Note the following native species and crosses listed with some of their major verified traits. Rootstocks included in ongoing OSU trials are in bold. Summary results of their performance can be found at www.okstate.edu/ag/asnr/hortla/ftpcns/grapes.htm

Vitis riparia – Found in riparian habitats on alluvial soils, climbs trees, grows in wetter areas. It has shallow roots, lower vigor, and hastens maturity. It resists phylloxera and performs poorly on lime soils. e.g. ‘Riparia Gloire’

Vitis rupestris – Found in rocky creek beds. It is shrub-like and a low climber. It is deep rooted (little branching) and drought tolerant in moderate to deep soils. It is resistant to phylloxera with variable resistance to nematodes and variable lime tolerance. e.g. ‘**St. George**’

Vitis berlandieri – Found in Texas limestone soils. It is deep rooted and has some drought tolerance. It is good on lime soils and has variable phylloxera resistance. *V. cinerea* variety is deeper rooted, tolerant of dryer soils and good climber and has good Cl exclusion.

Vitis champinii – Found in limestone soils. It is deep rooted, induces high vigor, resists nematodes and has moderate phylloxera resistance. It is known to increase K in fruit. e.g. ‘Salt Creek (Ramsey)’ and ‘Dog Ridge’

V. champinii X (*V. solonis* X Othello) – These vines have good nematodes resistance but questionable resistance to phylloxera. They are less vigorous than their *V. champinii* parent. e.g. Harmony and **Freedom**

V. riparia x *V. rupestris* – These vines have phylloxera resistance and variable resistance to nematodes. They have a moderate root system and low to moderate vigor. They are poor on lime soils but tolerate “wet soils”. e.g. 101-14Mgt, **3309C**, Schwarzmann

V. berlandieri x *V. riparia* – These are the most common rootstocks. They have good phylloxera resistance and fair nematode resistance and lime tolerance. They have relatively shallow root systems with low to moderate vigor. e.g. **5BB**, 5C, SO4, 420A

V. berlandieri x *V. rupestris* – Vines from this cross have good phylloxera resistance and poor nematode resistance. They are deep rooted with good drought resistance. They tend toward excess vigor. e.g. **110R, 1103P, 140R**

The following rootstocks were released by University of California-Riverside in 2004. They are hybridized Ramsey (*Vitis champinii*) and Schwartzman (*V. riparia* x *V. rupestris*). They are untested in Oklahoma:

RS-3: Moderately vigorous, suitable for course to fine sandy loam soils; resistant to root knot and lesion nematodes, moderately resistant to dagger nematode; tolerant to fanleaf virus.

RS-9: Low vigor; good on coarse-textured soils; resistant to root knot, dagger and root lesion nematode.

SOURCE: UC-Davis Foundation Plant Services 530-752-3590. Available Fall, 2004

XI. VARIETIES

Variety selection is arguably the most important decision a grower must make during vineyard planning. The variety must be acceptable to the winery, it must be productive and it must be as tolerant as possible of the individual vineyard conditions, e.g. soils, temperature, water etc.

All grapes are classified botanically in the genus *Vitis* which contains several different species. In common usage grapes are separated into three general groups: 1) American grapes, *Vitis labruska* et.al.; 2) French or European grapes, *Vitis vinifera*; and 3) hybrids of those two. Each of these groups has certain characteristics associated with them. American grapes are more tolerant of environmental conditions, insects, diseases, low temperatures, etc to which they were exposed during their evolution. European grapes are generally less tolerant of diseases and adverse weather and in many cases are susceptible to them, e.g. freeze injury, phylloxera and Pierce's disease.

On the other hand, the wines with the greatest name recognition e.g. 'Chardonnay', 'Cabernet Sauvignon' and 'Merlot', are made from *vinifera* grapes. Therefore, they are in the highest demand by wineries and are the most valuable. Hybrids follow the characteristics of their parentage and are generally ranked between American and French grapes with respect to environmental factors. Yield and value of hybrid grapes are similar to American types.

In short, *vinifera* grapes are the more valuable but generally are harder and more risky to grow in Oklahoma. Grape variety performance can be affected by local conditions. This can include yield as well as fruit composition which can ultimately affect the finished wine and the winemaking process. Perspective growers should seek localized information as much as possible. Oklahoma State University conducts grape

variety evaluation trials. Summary results are available from local county extension offices or on line at www.okstate.edu/ag/asnr/hortla/ftpcns/grapes.htm

Muscadine Grapes (*V. rotundifolia*) are native to Southeastern United States. They have a unique flavor, which is frequently preferred by people in Southeast United States but not well known in other areas. In Oklahoma, muscadines are limited to the southeast counties generally south and east of Ada. Some muscadine varieties are listed below:

Variety	Description
Higgins	Bronze, female, vigorous, medium size fruit production
Regale	Purple, self fruitful, large clusters, medium size fruit, wet stem scar
Summit	White, female, large fruit very productive, very sweet
Doreen	Lt. green, self fruitful, medium berries, top producer, dry stem scar
Fry	Bronze, pistillate, large, early ripening berries, excellent taste
Jumbo	Red, pistillate, very large, vigorous, tough skin
Carlos	Bronze, self fruitful, small fruit, very productive, very vigorous
Scuppernong	White, pistillate, first named Muscadine variety
Cowart	Purple, self fruitful, good production

XII. HARVEST

Ripening

Sugar accumulation should be to the full potential for the variety. The winery contract will indicate the ideal sugar level needed for a variety. If sugar accumulation stops at 16, 18, or 20% without reaching the ideal level, the fruit is not healthy, this affects cold hardiness and next years crop. Weak vines will not mature the fruit regardless of how long it remains on the vine.

After seriously evaluating each block of vines, the vineyard manager must determine if the vine's balance of vigor and fruiting is good, marginal or poor and use that as a basis for pruning the next year, i.e. leave more or fewer buds to balance growth and fruiting.

Sampling

Since wine grapes are grown for a winery the winery, personnel routinely monitor fruit maturity and specify when to harvest. Different wineries frequently have their own criteria to determine when to harvest. The factors involved include sugar content, acid and pH. These factors are measured before the grapes are harvested based on a random fruit sample taken from the vines at regular intervals prior to harvest. It is important to collect berries for the sample in a manner such that the sample represents the total crop as closely as possible. Generally, berries are collected from both sides of the row, in shade and sun. The sample is combined and harvest indicators determined.

Varieties not recommended for the area frequently produce clusters with unevenly ripening fruit.

Birds and other animals can be a serious problem at harvest time. Netting is the only sure way to prevent fruit loss.

Table grapes are harvested when they taste good or when the sugar level is above 16%.

XIII. INTEGRATED PEST MANAGEMENT

Weed Management

Vineyard floor management is one of the most difficult cultural practices the grape grower must accomplish. The key to success in managing weeds is to be proactive. Perennial weeds in a vineyard site should be killed before the vines are planted. Once weeds become established with subsequent rain, they are very difficult to control.

In relatively low rainfall areas of western Oklahoma weed control by disking may be possible. However, do not deep disk or cultivate so close to the vines that roots are damaged.

Most commercial vineyards depend on chemicals for weed control. Several herbicides available are effective, safe, economical, and pose no danger to the applicator or the environment if used according to the label instructions. Herbicides must be used with precision, according to the label.

There are two types of herbicides; postemergence which kills weeds (and vines) on contact, and preemergence which is sprayed onto the weed free ground to kill weed seeds as they germinate.

Row middles. A good low mowed sod middle has become an accepted vineyard practice in many grape production areas. It allows somewhat better equipment passage through the vineyard during wet conditions for application of fungicides. When rains occur, fungicides are needed and driving a tractor with a sprayer through mud is very difficult. In a few instances sod middles could help reduce excessive vine vigor. Sod middles can compete with the vines for water and nutrients. Uncontrolled weeds can harbor insect pests. Weeds can be especially harmful to young vines during the establishment years. Overwintering weeds under the vines are a major problem and makes cultivation or chemical weed control in the spring very difficult or impossible.

Vine Establishment. All perennial weeds should be killed prior to planting. Application of glyphosate, e.g. Roundup®, in the fall, before spring planting is very effective. Winter plowing down the row, exposing weed roots to freezing will also help. An application of Surflan®, immediately after planting, can help keep weeds in check the first year. Postemergence herbicides, e.g. Fusilade® or Poast® can be used the first year

for killing grasses with no damage to the vines; however, they will not kill broadleaf weeds. The use of trunk guards or grow tubes the first year will allow cautious application of Roundup® or Rely®; as these herbicides should not be allowed to touch green tissue on the grape plants. Any of these methods of chemical weed control can be used through the third year.

Mature vine. In some areas cultivation or cultivation plus incorporating Treflan® can provide adequate weed control. Effective weed control begins with an early March application of preemergence herbicide to prevent weed growth for the spring and early summer. Products available for use include Surflan which is good in preventing, grasses, Solicam, which prevents grasses and broadleaf weeds, and low rates of Simazine, which prevents broadleaf weeds. These products can be used in combination for better grass and broadleaf weed control. Simazine should not be used at a rate greater than one pound per acre on high pH soils and Karmex should not be used at all on high pH soil.

It is possible to manage weeds and grass without chemicals; however, it can be very difficult. Close mowed grass in the row middles is very easy. The problems come when the areas under the vines produce weeds during rain periods. Push lawnmowers and weed eaters are sometimes used, but it is frequently very damaging to the vine trunks. Special PVC trunk guards can also be used but that requires extra labor. Further information on herbicides availability and application can be found at your county extension office.

Chemical Sucker control. In the early spring, after budbreak and before suckers are 10" long, Rely® or Gramoxone® Extra can be used on mature vines either alone or in combination with a pre-emergence herbicide without damaging the vine. This will allow a later application date of the preemergence herbicide, which will give control longer into the season. Roundup cannot be used for sucker control because it will damage the vine. Thus Roundup, or Roundup plus a preemergence herbicide need to be applied before budbreak and sucker growth.

Spot treatment. After the application of preemergence herbicides or with cultivation, Roundup®, Rely® or Gramoxone Extra® may be used for spot treatment of weeds that escape. Spot treatments should be made with a hand held nozzle. On very mature vines with thick layers of rough dead bark, without suckers or low hanging shoots, these products can be used with a fixed boom and sprayed down the row if no wind is present. If these products touch green tissue, they will kill the vine.

Combinations. Preemergence herbicides can be combined to control both grass and broadleaf weeds and combined with postemergence herbicides to control existing weeds. Grass is the main target in the pre spring applications and broadleaf weeds are the target in the fall.

The ideal system is to keep the vineyard middles mowed close. Kill the weeds under the vines down the row with a contact herbicide. The weeds in row on one acre or less can be easily controlled with a three-gallon backpack sprayer.

Grape Disease Management

Disease Management Strategy. Diseases are a limiting factor in the production of wine and table grapes worldwide. The most important disease of grapevine foliage and fruit each season in Oklahoma is black rot, which occurs every season. Although disease management necessarily focuses on black rot, a comprehensive strategy addressing other diseases is essential. In addition to black rot, there are several other diseases that can become significant under favorable weather conditions or in certain situations. These include powdery mildew, bunch rot and stem/trunk diseases, such as crown gall and stem cankers. Disease management is not just the application of fungicides, although fungicides are an important tool when used appropriately. Disease management begins with cultivar selection. Choosing cultivars that are even moderately resistant to a disease such as black rot will greatly reduce the number of fungicide applications necessary to control disease. Take care to acquire healthy nursery stock free of diseases such as crown gall. Sanitation is also an important tool in managing disease. However, for diseases like black rot, which attack expanding leaves and developing fruit, fungicides must be applied several times during these critical periods to prevent infection. It is important that the right fungicides be applied at the right time to prevent disease. Controlling disease with the fewest applications needed not only saves fungicide and application costs, it also keeps the environmental impact low. Disease management actions are needed at different growth stages.

Dormant Season. All mummies, prunings and other debris should be removed from vineyards during the dormant season, as these can serve as an important overwintering source of inoculum for diseases. An application of lime sulfur solution can be made prior to budbreak to suppress early season diseases from developing from overwintering inoculum. In vineyards where black rot has been a problem, mummy removal and early preventative fungicide spray programs are essential.

New Shoot Growth Stage. Depending on weather conditions and the history of disease in a vineyard, fungicides may need to be applied as new shoots develop. This is especially important for black rot, which gets started early in the season, to prevent the build up of inoculum on young shoots. A fungicide should be applied at the 2 to 5-inch and the 10-inch stages of shoot growth. The protectant fungicide, mancozeb, is highly effective against black rot. This fungicide is a good choice for early season applications during new shoot growth because of both its broad-spectrum effectiveness and its lower cost.

Bloom to Mid-Season. Beginning at the initiation of bloom, the picture becomes more complex. Strategies will vary depending on the susceptibility of cultivars being grown to several important diseases. Black rot is by far the most important disease of wine grapes in Oklahoma. Powdery mildew can sometimes be a problem, while downy

mildew occurs only occasionally. The most critical applications of the season for controlling black rot are 1) at the initiation of bloom (immediately pre-bloom or very early bloom), 2) at the mid-late bloom stage 10-12 days later and 3) at the post-bloom stage 10-12 days later. If disease pressure is high, if cultivars are moderately to highly susceptible, and/or if environmental conditions are favorable for disease (wet), fungicides should be applied at ten day intervals, and additional cover sprays at 10-14 day intervals will also be necessary. If powdery mildew is detected, be sure to use a fungicide that controls both powdery mildew and black rot.

The systemic sterol inhibiting fungicides, Nova and Elite, give excellent control of black rot. They are more expensive than fungicides like mancozeb, so you will probably want to wait to use them to protect the fruit crop starting at bloom. They also give moderate control of powdery mildew. If both black rot and powdery mildew are problems, one of the newer strobilurin fungicides (Abound, Flint, and Sovran) would also be a good choice. These are nearly as effective against black rot as Nova and Elite and give excellent control of powdery mildew and some control of downy mildew. Rubigan is highly effective against powdery mildew, and Ridomil is highly effective against downy mildew, but neither of these fungicides gives control of black rot, thus limiting their use on grapes in Oklahoma. Remember to rotate the type of fungicide based on mode of action (for example, rotate a sterol inhibitor with a strobilurin) in blocks of 2-3 applications to prevent fungicide resistance from developing. Whenever possible, fungicide sprays should be combined with insecticide applications to save on application costs.

Late Season. Black rot and powdery mildew can appear late in the season on moderately to highly susceptible cultivars if rain or heavy dews occur. These sometimes require fungicide applications, but if you are contemplating using a fungicide, remember to check on the post harvest interval (PHI) of that fungicide to be sure that you can use it then. Botrytis bunch rot is not usually an important problem in Oklahoma, but when it does occur, the fungicides Rovral (7 day PHI) and Elevate (0 day PHI) are effective against it.

Insect Management

Terminology. Pest management represents one of many strategies used by growers in a total crop management program. Like any other management program, it attempts to maintain the pest population in and around the crop below a specific damaging level. The population level of a pest organism that causes enough damage where the cost of controlling the pest equals the amount of loss experienced by that pest is known as the economic injury level (EIL). Unlike other management programs, pest management makes use of economic thresholds (ET), which represents the population level of a pest slightly before reaching the EIL. Using the ET as an action threshold prevents the pest population from attaining the EIL and ultimately saves the grower money and crop loss. Most insect pest populations fluctuate around a general equilibrium position (GEP) where damage is limited by certain biological, mechanical, cultural and environmental factors. Under certain environmental conditions, even in the presence of

natural controls, pest populations can increase rapidly. This sudden shift in pest numbers is what causes growers to apply pesticides.

Tactics. Several approaches to pest management in grapes exist which attempt to decrease pest populations below the ET. These include but are not limited to:

- 1) Cultivars and rootstocks that are resistant to a pathogen or insect.
- 2) Biological control (natural or released) organisms.
- 3) Cultural practices to reduce pest numbers or make the environment unfavorable.
- 4) Altering pest behavior by mass trapping, mating disruption, etc.
- 5) Trap monitoring and scouting to arrive at the optimum timing for pest control measures to be implemented.

Several of these tactics are related to the management of insect pests, and not plant pathogens. Often times, the approach in managing insects is entirely different from that used in keeping disease pressure low. Because insects are more easily seen and can be monitored, ET have been readily developed which serve as signals on when to rescue a situation from increasing insect pressure. In contrast, diseases, such as black rot of grapes, can suddenly appear overnight and, under the right conditions, quickly become epidemic in a vineyard. Mode of action of the pesticide used and efficacy of the products also explains why two different approaches to pest management for insects versus diseases exist. Insecticides are often used as rescue treatments to suppress pest populations and provide enough residual control to keep populations from quickly rebounding. Fungicides, on the other hand, are generally used as protectants, that serve to coat the plant and prevent healthy tissue from becoming infected. This is not to suggest that either pesticide, under the right circumstances, could function similarly; however, several efficacy trials go into the registrations and labeling for all of these chemistries.

Benefits of an IPM Approach. Several benefits favor a pest management approach over traditional methods of controlling pests. These benefits include:

- 1) Reducing the number of applications or amount of material needed.
- 2) Treating only susceptible blocks or varieties.
- 3) Restricting chemical applications to hot spots.
- 4) Treatment based on actual numbers not on calendar predictions that may be faulty.
- 5) Using monitoring, scouting, and degree days to select the optimum timing of pest control measures.
- 6) Conservation of natural enemies of pests.

The results of these benefits may help reduce the number of pesticide applications per season to four or six instead of eight to ten.

Grape insect pests

Grape insect pests can be divided into guilds based on where each species of insect feeds. This division results in three distinct guilds: cane and foliar feeders, fruit pests, and root pests. The fruit feeders seem to draw the most attention based on their destruction of viable product. However, managing the other two guilds is equally important, since destruction of foliage, cane and roots can quickly eliminate the fruiting capability of the plants.

Cane and Bud Pests

Grape Scale. When growers are pruning they should check the canes for evidence of scale insects on the old canes. The scale-like bumps that appear on the cane are evidence of last year's problem and of those things yet to come. During the pruning operation, growers should flag or mark scale-infested canes and even prune out heavily infested areas. Grape scales overwinter on the cane and under loose bark. Crawlers from the first generation become evident in May. These insects can be monitored using double-sticky tape on infested canes. In addition, if old scale is evident, growers can monitor the old scale for activity by the young or crawler stage. Simply use a sewing pin to gently lift the old scale up and glance underneath. This should be conducted about twice per week until nymphs are seen. If crawler activity has begun then apply a delayed dormant spray of superior oil to the canes. Just before the buds begin to show green is when treatment for this pest and European red mite can take place.

Grape Flea Beetle. Another pest of grapes during the early growing season is the grape flea beetle. This insect is a metallic blue green color and is only about ¼ of an inch in length. The adults eat holes in buds during the daylight hours while the larvae will feed on the foliage and flower clusters. Generally, the larvae are not the greatest concern because of management of grape berry moth after post bloom, but tender buds cannot sustain much damage from the adult stage of this insect.

Climbing Cutworms. Several species of cutworms are common in Oklahoma and most of them are not significant pests of grapes; however, some damage on early bud development can occur if a large population of cutworms is present. Climbing cutworms are a primary problem in the early season (through May) and generally subside when other primary pests are managed well. Cutworms can become very large caterpillars (up to 1½ - 2 inches in length) and are sometimes difficult to control once they obtain a larger size.

Control of Flea Beetles and Cutworms. Problems with these insects early in the season can often coincide. Simple inspection during bud swell can help identify such a problem. If bud damage has been evident in the past in certain areas of the vineyard inspect those areas first. Check 100 vines for any evidence of insects or bud damage and record the number of hits. Insecticide treatment should be limited to those sites where more than 1% of the new buds are damaged. Sevin® insecticide is a common treatment for both of these problems.

Foliar Pests

Grape Leafhopper. Grape leafhoppers overwinter as adults in wooded or littered areas and emerge in May to begin feeding on the undersides of leaves. Adult leafhoppers are highly mobile and are often overlooked, even by the trained eye. In addition, several other leafhopper species can be found in Oklahoma grapes. The grape leafhopper adult is a mottled tan and white color and only about 1/8 of an inch long. The nymphal stage is much smaller and nearly a transparent green in color. By mid-May adults will begin inserting eggs under the leaf epidermis, and by late May first generation nymphs will be present for a 20-30 day period. Three to four generations of grape leafhopper can be found in Oklahoma and these populations may overlap. In addition, certain cultivars of grapes may prove to be more susceptible to damage from this pest than others.

Control of grape leafhoppers is best achieved when the insects are in the immature stages. Therefore, scouting should begin on May 1, particularly if leaf stippling is already present. Scouting should involve checking a minimum of three leaves from each of 15 vines and calculating the percentage of leaves with nymphs present. If more than 60% of the leaves are infested with more than 5 nymphs per leaf, before August 1 then treatment is justified. After August 1, 80% of the leaves with more than 10 nymphs per leaf should be used as an economic threshold.

Grape leafhopper is a pest that lends itself well to biological or mechanical control methods. Green lacewing (predatory) nymphs can be used in managing this insect pest. Place 3,000 to 8,000 lacewing eggs per acre in the vineyard to control leafhoppers. Some control can also be attained by pulling off the basal leaves after egg laying activity but before nymphs reach the fifth instar (near berry set). In addition to these methods, several organic alternatives are available for controlling this pest. These methods include the use of diatomaceous earth laced with Pyrethins, or a 1-2% solution of M-pede with 1 quart of natural oil, or the application of Surround® WP throughout the critical period to deter feeding. Among the insecticides available, Sevin® and Provado® appear to be the better choices.

Grape Phylloxera (foliar or aerial). Leaf galling by grape phylloxera causes distortion, necrosis, and premature defoliation of French/American vines. The premature defoliation can, in turn, delay ripening, reduce crop quality, and predispose vines to winter injury. Generally, cultivars with smaller leaf widths are the most susceptible to aerial phylloxera, while cultivars with larger leaves are less susceptible (Table 5).

Table 5. Cultivar susceptibility (number of galls/leaf) to Aerial Grape Phylloxera.

High (leaf width < 5.3")	Medium (leaf width 5.3"-5.7")	Low (leaf width 5.5"-6.3")
Villard Noir (83.8)	Saturn (26.9)	Campbells Early (8.6)
Himrod (80.2)	Verdelet (13.6)	Concord (8.5)
Reliance (70.5)	Fredonia (12.2)	Venus (8.0)
Lakemont (68.5)		Mars (3.6)
		Cimarron (3.5)

Grape phylloxera overwinter in the egg stage on the cane and hatch about the time of expansion of the fifth leaf. They quickly move toward the expanding leaf material where the stem mother of the subsequent crawlers begins to feed and elicits formation of the gall. About the tenth leaf stage, the crawlers are released from the gall and begin to feed and form galls on expanding leaf material. There may be as many as 6-7 generations of aerial phylloxera per year in Oklahoma. Thus far, it has not proven to be a particularly devastating pest and has occurred primarily in late season in relatively low numbers.

Grasshoppers. When the majority of the population of grasshoppers is reaching the adult stage, people begin to panic about how to manage the onslaught. Adult grasshoppers are difficult to control. They are somewhat more tolerant of the insecticides, but more importantly they are highly mobile and harder to hit. This is why we stress the importance of controlling nymphal populations. As the roadside grasses and weeds begin to dry up over the summer, hoppers will look for other succulent food sources, usually in the form of some plant or crop that growers wish to salvage. In some crops, like grapes there are still some good insecticides available for use.

Growers should read the label before making these applications and be aware that the treatment will not control the problem for the entire season. Migrating grasshoppers from adjacent fields and other grassy areas will move in and begin to feed on the crop after the effectiveness of the application has passed. In grapes, Dimethoate is likely the best choice. Use ½ to 1 pint of dimethoate per 100 gallons (not to exceed 400 gallons/acre). There is a 28 day pre-harvest interval when using this material in grapes. Once again, it should be noted that this application may provide some residual control; however, the majority of effectiveness will be on those hoppers hit directly by the application. During the early part of the season, if grasshoppers are seen when still very young (not fully winged) this is an excellent time to control them with formulations containing Sevin® insecticide. These treatments can be directed to areas surrounding the vineyard, not directly in the crop, where the young hoppers are likely feeding on adjacent grasses and other hosts. This treatment into the adjacent foliage helps control the hoppers while they are still young and also serves to preserve beneficial organisms that can help throughout the vineyard.

Fruit Pests

The Degree Day Concept. Any further discussion of grape pests must include the degree day concept. Insect development is linked directly to external temperatures. Essentially, the warmer the temperature, the more rapidly the insect develops. In contrast, cooler temperatures, i.e. those below the insect's developmental threshold, suppress development and activity. This latter statement doesn't mean that the insect is damaged when experiencing brief episodes of cold, since most insects have their own built-in antifreeze in the form of glycerol. It means that development is slowed or ceases during these brief cold snaps. Insects may possess several different developmental thresholds and using temperature information to follow or anticipate specific life stages can be extremely useful in timing scouting and treatment decisions. In the case of the Grape berry moth (GBM) the developmental threshold is 50°F; therefore, insect development occurs anytime temperatures exceed this level. Calculating the degree days needed to attain a specific life stage requires an inexpensive thermometer that measures maximum and minimum temperatures for each day. Daily degree days are then accumulated over a period of time. To calculate degree days use the following formula:

$$\text{Daily Degree Days} = \frac{\text{Maximum temperature } ^\circ\text{F} + \text{Minimum temperature } ^\circ\text{F}}{2} - 50^\circ \text{F}$$

$$\text{Example} = \frac{80^\circ + 55^\circ}{2} - 50 = 65 - 50 = 15 \text{ degree days for that day only.}$$

Degree days for each day are added to accumulate total degree days which can be used as a tool in helping anticipate certain events associated with this insect pest, its life stages, and the damage it creates.

Grape Berry Moth (GBM). Early in the season (April) is the time to begin monitoring for grape berry moth activity. High risk areas (vineyards with woodlots around more than 25% of the perimeter) should be the first sites targeted. Three pheromone traps can be used at those sites to indicate the arrival of the first moths. Traps should be placed in the adjacent wooded area, particularly where native grapes are present. First generation larvae will create webbing on the fruit in May and June and 2nd through 4th generation larvae can tunnel in several berries. When one moth is captured in traps, then growers can start accumulating degree days (base 50°F). After 400 degree days, check 100 clusters in the edge row for larval activity. By mid-May the three traps can be moved inside the vineyard on the top wire. From 1200 degree days on check 50 clusters along the edge and 50 clusters about 10 rows in from the edge. If more than 1% of the clusters are infested spray the perimeter from 400-700 degree days. Applications to control 2nd and 3rd generation GBM can be made across the entire vineyard at 1200-1600 degree days and 2400-2700 degree days, respectively. While much of the degree day information gathered thus far is from other states (e.g. - Arkansas) the validation of these data for Oklahoma is ongoing and results obtained in 2002 suggest that this concept of using degree days to follow GBM phenology is fairly accurate.

Synthetic insecticides such as Guthion®, Imidan® and Sevin® may be used to control GBM; however, safer, biological choices are available that do an effective job. These latter materials include formulations of *Bacillus thuringiensis* sold under the trade names of Agree®, Dipel® or Javelin®. Mating disruption of GBM using Isomate-GBM pheromone has resulted in successful suppression of this insect for up to 90 days in some warm, southern states; however, this technology has not been thoroughly tested in Oklahoma. In addition, this latter strategy is likely very costly and may not fit in an area that has a relatively new industry and probably very little pressure from insect pests. Only time will tell how useful this strategy may turn out to be for Oklahoma grape growers.

Stink Bugs. Stink bug populations in many vineyards across the state can literally explode over night. In 2002, observations across some of the established orchards in Northeast Oklahoma revealed damage approaching severe levels. We also witnessed a prolonged oviposition and hatching period for stink bugs, which simply means all nymphal stages, can be found at any single time.

Many growers have seen egg masses and/or small nymphs of these insects. The eggs are somewhat barrel-shaped. After hatching, the young nymphs are hard to distinguish from other tiny insects without the aid of a hand lens. These insects have piercing, sucking mouthparts and can cause extensive damage in some crops if the populations are great enough. Dimpling or deformity of the fruit is a symptom of stink bug feeding. Although a number of insecticides will kill stink bugs on contact, providing residual control of new migrants is difficult. Treatments may have to be repeated as adults continue to be found. Management of these and other pests is a real challenge for many growers, in particular, those that are trying to avoid the use of more toxic insecticide choices, and those that have a thick canopy of leaves.

Green June Beetle (GJB) and Japanese Beetle (JB). These two species are both Scarab beetles that overwinter as larvae either in pastures (GJB) or in grasses (JB). They pupate in the soil sometime in late May and emerge as adults in late June. In July and August, they lay eggs and the cycle repeats itself. In Oklahoma, the JB was first found in 1996 in and around nursery stock in Oklahoma City and Tulsa. In 1997, it was found under similar circumstances in the Ponca City area. Populations of this insect have not proliferated in Oklahoma for some unknown reason and numbers still remain low. As the grape industry expands it may experience more pronounced problems with this insect. The GJB is a common pest of fruits in Oklahoma, feeding on sweet sap as any of these fruits begin to ripen.

Adults of both species can be effectively trapped using either a specialized trap and pheromone source for the JB or a ripe, cut fruit trap for GJB. Traps for JB should be deployed a minimum of 200 feet away from grapes, in order to avoid attracting the pests into the vineyard. GJB traps may be set out adjacent to vineyards and monitored regularly for activity; however, if harvest of grapes is not delayed and fruit does not become overly ripe before being picked, then problems with this insect are minimal.

Insecticide considerations

Associated with the problem of insecticide use, comes many issues. First, biological insecticides like *B.t.* (e.g.- Agree® or Dipel®) are virtually ineffective on stink bugs, therefore, an application to combat grape berry moth will not control the stink bug population. Second, organophosphates, such as Imidan® or Guthion®, are effective on all of these insects but are more toxic to the user and beneficial organisms. Third, many of the organophosphates, such as Imidan®, work effectively when mixed with an acidifying agent, but may provide only partial control, with little residual, when used without something to modify the pH of the solution. As always it pays to read the label in its entirety. The label suggests that the pH of the solution be below 6.0 for the chemical to be optimally effective. This will also prolong the residual capacity of the chemical. For grape growers this is often an easy solution, since many have food grade citric acid available. Modify the solution pH down to about 5.0. This is often critical with many organophosphates, but in particular with Imidan®. Finally, in a thick canopy and with a good to excellent crop, stink bug nymphs will often hide in the heat of the day wherever they can find protection. This may be under leaf tissue or inside the grape clusters. This suggests that good coverage is a must; therefore, if the canopy is very leafy, use as much liquid as possible. Remember, rates of insecticides are expressed in the amount of active ingredient or amount of formulated product per acre. This means that, regardless of the amount of water applied over a given area, the same amount of pesticide will always be applied. The increased volume of liquid will insure that the entire canopy is adequately covered.

Spider Mites

Feeding from spider mites may cause early season leaf bronzing and reduce the amount of photosynthesis; thereby altering fruit ripening. Two-spotted spider mites overwinter in ground weeds and migrate into grapes if heavy weed populations are destroyed during the growing season. European red mites overwinter as tiny red eggs around cane nodes and in the spring move to the foliage where several generations can occur. Populations are generally highest in late July and August when warm, dry conditions are persistent and help in concentrating their food source, i.e. the plant's juices. 'Concord' and 'Riesling' are two cultivars that are relatively susceptible.

To combat problems with spider mites, use a 2% solution of Superior oil applied at bud swell to kill eggs and scale adults. If this early season approach is not used, foliar miticides may be applied once 70% of the leaves become infested. In addition to these approaches, IPM Laboratories, Inc. has three species of spider mite predators that have proven very useful against these pests.

Sharpshooters and Pierce's Disease

The question concerning the potential impact of Pierce's disease to the Oklahoma grape industry is still unanswered. Some of this information may help you in deciding about the potential impact on the Oklahoma industry. Outbreaks of the disease have been

reported in Texas, Arkansas, Florida and California. The latter state has probably been the one most heavily infected, with nearly the entire lower third of the state reporting infestations of the disease's major vector, the glassy-winged sharpshooter, *Homalodisca coagulata*. It is also reported to be present in some California vineyards every year, with the most dramatic losses occurring in the Napa Valley and in parts of the San Joaquin Valley. Currently, Pierce's disease (PD) seems to be restricted to portions of North America with mild winters. It has been found in all southern states that raise grapes commercially; from Florida to California, and in Mexico and Central America. In the southeastern states, from Florida through Texas, PD is the single most formidable obstacle to the growing of European-type (*Vinifera*) grapes.

The causal organism, *Xylella fastidiosa* is a bacterium that has a wide host range including many woody perennials such as American elm, maple, mulberry, plum, peach and alfalfa, just to name a few. The bacterium blocks the xylem, the water and nutrient-conducting vessels of plants. The typical symptom is for leaves on the plant to begin to dry or to scorch. The subsequent marginal necrosis spreads inward. On red fruited varieties, a dark red to purple band is formed between the necrotic margin and the green interior of the leaf. On white fruited varieties the band is yellow. Eventually, the leaf blade sheds, leaving the petiole attached to the stem. The stem will remain green at the base of the leaf petiole, while the remainder of the stem turns brown as it matures. The fruit on affected vines dries but remains attached to the stem. Infected vines can die in as little as one to two years. The potential exists for all sucking insects that feed on xylem sap to serve as vectors of Pierce's disease. Vectors acquire the bacterium by feeding on infected plants.

Presently, all known vectors of the bacterium belong to the insect order Homoptera (some entomologists consider this a suborder). The main vector groups are leafhoppers, froghoppers and spittlebugs. There are several different species of spittlebugs in the U.S. and even in Oklahoma. Based on specimens located in the OSU Insect Museum, the glassy-winged sharpshooter has not been found in Oklahoma. This does not mean it could never occur, but according to the literature, the insect is unable to survive winter temperatures of less than 20°F. In Oklahoma, of course, temperatures do occasionally get lower than this, so the range of the potential vector may be limited to southern portions of the state, similar to what is seen with the disease range in Arkansas. The next obvious question is, "are there other similar insects which may serve as vectors of Pierce's disease?" The answer is, yes. One common species of Cercopidae that occurs in Oklahoma is the twolined spittlebug. This insect is commonly found on alfalfa, pecan and many other plants. It is not reported to have the voracious appetite of the glassy-winged sharpshooter, but certainly would be able to acquire the disease from an infected plant and transmit it to healthy plants while feeding. This suggests the need to be careful where you acquire your plants.

Root Feeders

Grape Root Phylloxera. This tiny insect at one time devastated the wine grape industry of France. Its management and control represent one of the classic cornerstones

of modern applied entomology and host plant resistance. On American vines the insect's life is passed in galls both above and below ground and sexual and asexual reproduction both occur. On European vines, *Vitis vinifera*, the cycle takes place almost exclusively underground and only asexual reproduction occurs. On American vines the root galls and deformities simply stop growth and increase in root diameter. In contrast, on *vinifera* grapes continuous infestations kill the root. When this happens, the aphids abandon the desiccating food source and move to the surface of the soil through available fissures and cracks. Once at the surface, they seek another vine and, if they find one, descend to its roots and again begin feeding, thus spreading the problem. The solution to this devastating insect problem was to graft the European vines, with their highly desirable fruits, onto resistant American rootstocks. Table 6 lists some rootstocks that have shown resistance to grape root phylloxera.

Table 6. Rootstocks with resistance to grape root phylloxera.

3309 Coudrec	So4
110 Richter	5C
St. George	Dog Ridge
140R	Harmony
1103P	Salt Creek

Grape Root Borer. Many “look-a-like” moths resemble grape root borers and make it a difficult pest to monitor. These similar species include dogwood borers, oak borers and lilac borers. The former two species have relatively clear wings (both fore and hind wings) and many yellow stripes or patches along the top of the abdomen. The lilac borer possesses darker wings, but lacks any yellow patches on the abdomen. The grape root borer male is characterized by the unique presence of four pencil-like tufts on the tip of the abdomen; however, these are probably not retained in sticky trap specimens. The grape root borer also possesses one single yellow stripe across the back, near the base of one of the first abdominal segments. In addition, the grape root borer has a dark forewing and clear hind wing.

Flights of this species generally begin in earnest sometime in the middle of July. Once pheromone traps have been set out for this insect, be certain to change the pheromone source once a month. Female borers lay 300 to 400 eggs on foliage, stems or the ground. These eggs hatch in about two weeks, with the larvae subsequently tunneling into the soil to feed on the roots for the next 1 ½ years. Larvae mature in the early summer of the second year and pupate near the soil surface. This pupation characteristic allows for scouting and control without the use of chemicals. If regular examination of the soil around the base of the vines reveals any pupal skins, then pupae can be covered with 6 inches of soil which effectively aborts emergence.

For growers that insist on chemical control, then two weeks after first moth capture, treat with Lorsban® 4E at the base of each vine. Do not treat the foliage or fruit. This chemical requires a 35 day pre-harvest interval. This is likely a major issue for Oklahoma growers who may generally be in the heart of harvest by mid August.

By using the available tools for scouting, monitoring and controlling insect populations in grapes, growers can experience a minimum of headaches related to insect pest problems. This is particularly true for Oklahoma grape growers, who are exploring a relatively new industry that many of the more stubborn arthropods have not yet discovered. As the industry begins to expand and find its niche within our state, growers that have been diligent in their pest management tasks, and those who have kept good records should be at an advantage in confronting the problems that may arise.

XIV. ECONOMICS

Commercial grape production can be financially rewarding, but it can also be very costly in investments, time and labor. No one should venture into commercial grape growing without carefully considering the investments and risks involved.

Markets

Wineries are the number one market for grapes in Oklahoma. *Vitis vinifera* varieties are preferred by wineries because of superior wine quality and consumer name recognition, but they are more disease susceptible than either American or hybrid grapes. Consult prospective winery outlets for their variety preferences before selecting varieties for a vineyard. One ton of grapes will produce 140-170 gallons of wine.

Education

Viticulture requires a great deal of expertise which can come only from experience. Potential grape growers should plan on a small planting for three years in order to learn all the complicated cultural practices necessary for the successful production of quality fruit. Owners should participate "hands on" in all the vineyard practices in order to make informed decisions later in the life of the vineyard.

Investment

You will need sufficient capital and time to live for three years without any return from your vineyard while you still devote time to the enterprise. Pre-productive expenditures can vary greatly, but expect over the first three years to exceed \$5000 per acre exclusive of land costs with annual expenses over \$2000 per acre. Part-time grape farming rarely succeeds especially with an operation over one acre.

Budget

Preliminary budget estimates for vinifera grapes in Oklahoma suggest the following figures exclusive of land and irrigation source costs (Tables 4 and 5).

Table 4. Preliminary budget estimate summary for producing Cabernet Sauvignon grapes in Oklahoma.

Year	Operating Costs (\$/a)	Fixed Costs (\$/a)	Total Cost (\$/a)	Production (Tons/a)	Value (\$/ton)	Net All Spec. Costs (\$/a)
0	\$ 112	\$ 7	\$ 119	0.00	-	\$ (119)
1	\$ 3,415	\$ 1,024	\$ 4,439	0.00	-	\$ (4,439)
2	\$ 1,405	\$ 995	\$ 2,400	0.00	-	\$ (2,400)
3	\$ 1,675	\$ 1,427	\$ 3,102	1.30	\$ 954	\$ (1,862)
4	\$ 2,297	\$ 1,427	\$ 3,724	4.05	\$ 954	\$ 140
5 & Up	\$ 2,607	\$ 1,427	\$ 4,034	5.40	\$ 954	\$ 1,118

Table 5. Preliminary budget estimate summary for producing Chardonnay grapes in Oklahoma.

Year	Operating Costs (\$/a)	Fixed Costs (\$/a)	Total Cost (\$/a)	Production (Tons/a)	Value (\$/ton)	Net All Spec. Costs (\$/a)
0	\$ 112	\$ 7	\$ 119	0.00	-	\$ (119)
1	\$ 3,415	\$ 1,024	\$ 4,439	0.00	-	\$ (4,439)
2	\$ 1,405	\$ 995	\$ 2,400	0.00	-	\$ (2,400)
3	\$ 1,675	\$ 1,427	\$ 3,102	1.30	\$ 1,040	\$ (1,750)
4	\$ 2,297	\$ 1,427	\$ 3,724	4.05	\$ 1,040	\$ 488
5 & Up	\$ 2,607	\$ 1,427	\$ 4,034	5.40	\$ 1,040	\$ 1,582

A major variable in addition to yield and value is crop loss due to freeze damage or other weather related events. Note the above figures are for vinifera only. Budget projection for Hybrid and American varieties are under development. Those varieties will have lower value and yield but are expected to have lower pest control costs and be more dependable producers. That may lead to greater value in the long run. Yield, fruit value and cropping history over time will define long term profit potential.

Budgets are supplied for planning purposes only. Specific cost analysis must be performed for each vineyard as site variation can exert significant effect on potential value.