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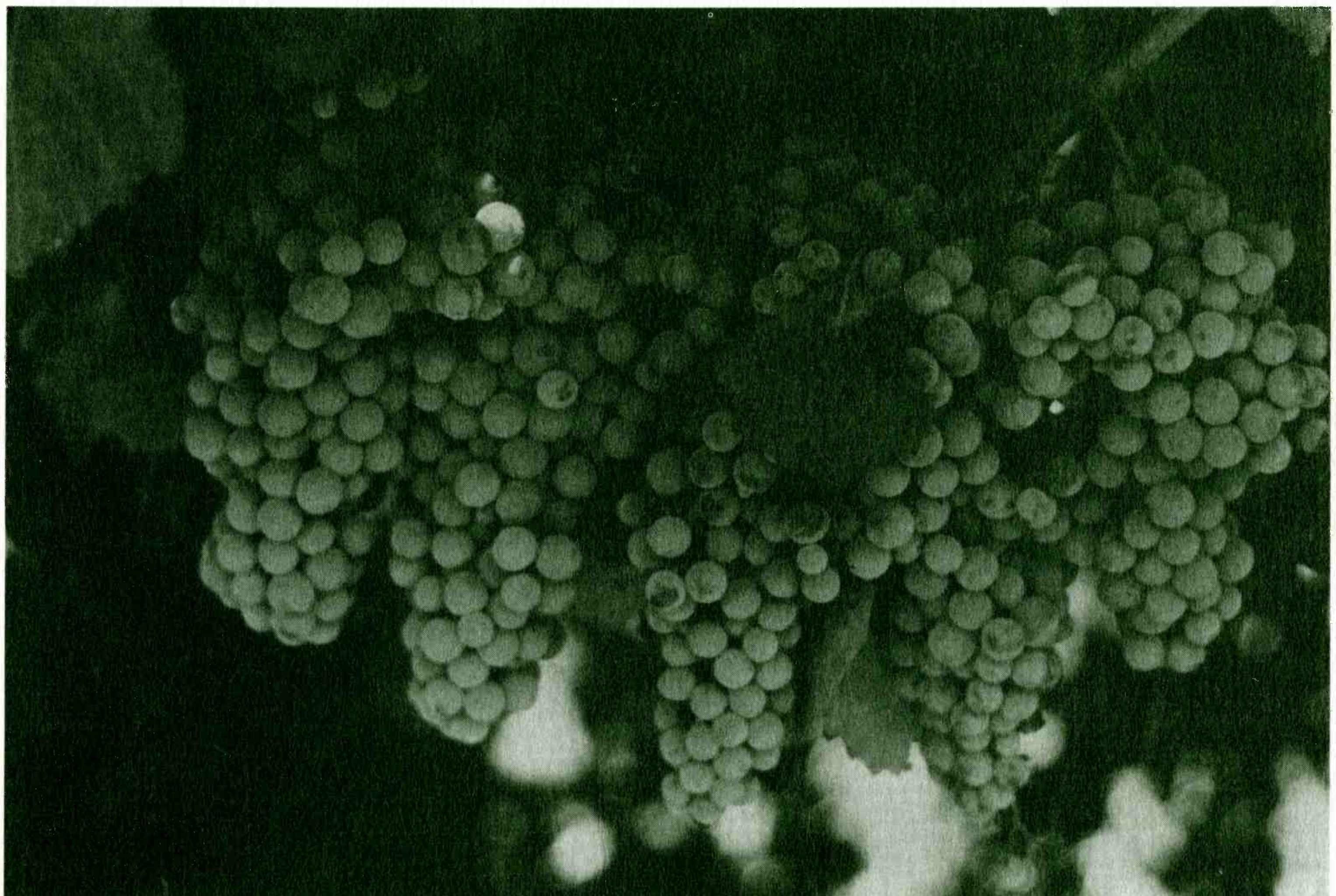
Grape and Wine Production in the Four Corners Region

This is a report of research performed with financial assistance from the Four Corners Regional Commission



Grape and Wine Production in the Four Corners Region

UNIVERSITY OF ARIZONA
TECHNICAL BULLETIN 239

REGIONAL PUBLICATION

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INTRODUCTION

The states of the Four Corner Region, Arizona, Colorado, New Mexico and Utah, have been experiencing great change as the 21st century approaches. With population increases and industrial expansion, the natural resources of the states are becoming strained. It seems clear that better ways must be found to utilize our resources so as to provide a better life for our citizens. In agriculture it would seem that the development of crops which utilize less water, provide greater employment and provide a higher economic return need to be found. Studies have indicated that grapes are such a crop.

With the above in mind, this study was undertaken to:

1. evaluate the adaptability of grape varieties at research and home vineyard locations throughout the region,
2. evaluate wine produced from the above grapes, and
3. utilize the findings to establish viticultural regions based on soil and climate which could be used for making varietal recommendations.

In addition, research was undertaken on the known problems of disease and winter damage.

It has been found that there are adaptable varieties to most locations in our states, and that these grape varieties can produce wines of commercial quality. Attempts to adapt previously developed procedures for establishing viticultural regions failed; however, a new system dependent on soil properties and altitude has been developed and is used to describe five different viticulture regions, see page 28.

Grape varieties that are adapted to and produce grapes whose wines are found to be of a commercially acceptable quality in the viticulture regions (denoted as HT, T_l, T_m, T_h, and M) are given on page 100.

Results of research conducted on winter injury problems indicate three ways of minimizing the problem: 1) choose a site where there is good cold air drainage, 2) choose varieties which can withstand the temperatures found in the region, and 3) use cultural practices which increase cold hardiness of the vine.

The most destructive disease problem within the states of Arizona and New Mexico is Texas Root Rot. Our work indicates that the disease may be controlled on non-calcarious soils by acidifying the soil with sulfur. At elevations below 5,000 ft. areas having calcarious soil, that are known to be effected by the disease, should be avoided.

It is recommended to those interested in establishing vineyards that they proceed at a modest level with incremental plantings of 1 to 5 acres. In this way the grower will become proficient with viticultural practices and give him the opportunity to evaluate the market.

This publication is meant to give potential growers, vinters and technical personnel the necessary information for establishing a grape industry within our states.

Concord Vineyard in Utah

CLIMATE

Climatic Regions

Different grape varieties have been found quite adaptable to a number of different locations and various environments. Only in areas with temperature extremes, poor soil drainage and unfavorable water conditions will grape vine growing be difficult. One method developed in California, to aid in determining varietal suitability for a given location, is to calculate the heat summation units of an area. The total units are the sum of the mean daily temperature above 50 degrees F, from April 1 to October 31. The temperature base of 50 degrees F is used because this is approximately the temperature at which growth begins. When the total growing degree days (GDD) in an area are calculated, the area can be placed into a specified climatic region using the GDD method. The climatic regions are:

Region	Growing Degree Days
I	less than 2500
II	2,501 to 3,000
III	3,001 to 3,500
IV	3,501 to 4,000
V	over 4,001

Simply stated, Region I represents some of the very cool districts of the North Coast, while Region V characterizes the very warm areas of the San Joaquin Valley of California. Varietal suitability matches a given variety to a given area based upon the variety's past performance in one or more climatic regions. Past performance may relate to optimal vine growth, fruit productivity or wine quality.

Some examples of varieties which do well in given areas are:

Variety	Recommended Region
Cabernet Sauvignon	I, II, III
Pinot Noir	I, II
Chardonnay	I, II
French Colombard	III, IV, V

There are a few weaknesses to the system. The system assumes that higher temperatures mean a greater number of growing degree days. This would allow accumulation of heat units even though the temperature was greater than the maximum at which a plant could survive. It also assumes that all heat units are the same. That is one day with a mean temperature of 100 degrees F, therefore 50 GDD, would make as much growth as the same plant grown during 50 days with a mean temperature of 51 degrees F. The model also does not allow for the inclusion of such factors of climate as fog, wind, humidity and radiation, which may have an important influence.

WEATHER INJURY

Low Temperatures

Temperatures below freezing during bud break in the spring may endanger shoot growth. At temperatures around 28 degrees F there are two serious factors the grower must consider. One is the duration of the low temperature, and the other is the degree of relative humidity or dew point. Buds are living organisms and are made of about 50% water. They transpire water to the environment, and through evaporative cooling can become colder than the surroundings. They may also act as black bodies and radiate heat to deep space. In either case they become colder than the surrounding air at night.

The buds are able to loose moisture because of vapor pressure deficit. The vapor pressure in the bud with approximately 100% relative humidity is very high. If the relative humidity of the atmosphere is low, the vapor pressure is low, and water vapor will move from an area of high to low humidity, therefore, out of the bud. The lower the relative humidity in the atmosphere, the faster the moisture will evaporate, and the lower the bud temperature will become. It is possible for the tissue to be 6 to 10 degrees colder than the surrounding atmosphere.

Warm temperatures promote dehardening. Possibly the worst situation for the grower is a sudden frost after a warm period which had promoted the buds' growth. This condition can destroy most of the primary buds and a great deal of the vine's fruitfulness. It would take a week or more before the secondary buds would begin to grow.

There are three levels of frost severity. A first-degree frost is not serious, as it results in only burning of the shoot tip. A second-degree frost injures the clusters as well as the shoot tip, but most of the shoot remain intact. Secondary buds do not develop. A third-degree or killing frost destroys the entire shoot. From a production standpoint, the worst situation which could occur would be for a second-degree frost which would destroy the fruit on the primary bud shoots but not encourage development of the partially fruitful secondary buds.

Each area has its own history of frost occurrence. More prevalent cold areas are low-lying (i.e. river bottoms) without good drainage, and surrounded by hills that restrict air flow. The condition of the ground is important, as a bare, firm, moist soil will provide more protection against frost than a dry, high-cover crop which may restrict air drainage and have a lower capacity to absorb heat.

Autumn freezes are a more serious problem for table fruit than wine grapes, because the frost often damages the cluster stems and renders the fruit unsuitable for eating. The freezing point for the fruit is partially determined by the sugar content of the berry.

Extreme low temperatures occurring during the winter may cause severe damage to buds, canes or in some cases the trunk. In the West, *V. vinifera* vines when fully hardened can withstand a temperature of 10 degrees F with no damage, while severe damage may not occur until −10 degrees F. American varieties (*V. labrusca*) are rather tolerant and may survive temperatures down to −20 degrees F. The French hybrids are somewhat intermediate in their hardiness, but are more like the American grapes.

Low-temperature tolerance is based upon the condition of the vine, the physical protection to sensitive areas of the vine, and the relative date when the initial cold temperature occurs. Vines will be better able to withstand cold conditions when there is a gradual temperature decline. Although it is labor intensive, partially covering the trunk with soil or a straw mulch may protect the more sensitive portions. The relative date of the low temperature is important. If it occurs early in the fall, injury may be more pronounced than if the same temperature occurs later in the winter when the vine is well hardened.

MAXIMUM TEMPERATURE

High temperatures play a role in color development and maturity of the fruit. Varieties such as Cardinal, Tokay and Emperor do not color well at very high temperatures. If these varieties were grown in a cool region, they would develop adequate coloring. Night temperatures are more important than daytime temperatures. The differential of the two temperatures is also important. A large temperature differential can partially overcome the effects of high temperature. Exotic and Ribier have been shown to be more tolerant of high temperatures. The greater complexity of the color compounds, which are composed of anthocyanins, the more tolerant to higher temperatures is the variety.

A sudden rise in temperature during maturation may cause sunburn to the fruit. This can be recognized by browning, shriveling and eventually a drying of the affected grapes or the entire cluster. Overcropped vines appear to be more sensitive to sunburning. Vines which are receiving adequate irrigation and are properly trellised for needed shade will withstand damage due to a sudden temperature change better than those which are water stressed, exposed to direct sunlight or both.

To maintain the developing vine and its fruit, the water level in the soil must not reach the permanent wilting point (the limit at which the plant is not able to absorb more water). Vines which remain at this stress point for any length of time may show signs of damage. The first sign is a change in color of the leaf from green to yellow, followed by a stoppage of growth. Fruit under minor stress will become dull in color and begin to sunburn. In warm regions with early harvest periods, vines should be irrigated following harvest to prevent any water stress until the plants are ready to enter rest.

Major grape acids are malic and tartaric, which compose about 90% of the total. In the developing berries there is an increase in malic and tartaric acids from fruit set to verasion (color change). Both decline in concentration from verasion to harvest as the sugar level increases. Malic acid is more easily respired and often decreases at a more rapid rate than tartaric acid. Temperature plays a major role in the respiration of acids. As the temperature increases, the rate at which the acid is respired increases. For each 10-degree rise in temperature, the rate of respiration doubles.

A variety will be higher in acid (at the same sugar level) when grown in a cool region versus a warm one. Varieties with high acid content can be grown successfully in warm areas.

PRECIPITATION

Late spring rains may cause a delay in grape maturity by diluting the stigmatic fluid and bursting pollen grains. Rain may also force a condition known as "persistent calayptra" where the calayptera (flower cap) or the corolla remains attached to the base of the flower, preventing or delaying proper pollination and fertilization. Additionally, rain often means cooler temperatures, and bloom is promoted by temperatures slightly over 60 degrees F.

Areas or seasons with little or no rain may have only slight or no rot or mold problems, but may experience a reduction of fruit set with lack of water. Presence of mold can also be attributed to vine vigor, canopy influence and cluster tightness. In a fairly wet year, the amount of mold or rot damage will be much greater and will depend upon the variety. Higher humidity, cooler weather and lack of wind promote common problems such as powdery mildew and botrytis. Tight-clustered and late-maturing varieties are more susceptible to disease.

Winter desiccation is a major concern for vines. Dehydration occurs in the winter the same as it does in the summer when there is insufficient moisture in the soil. Also, winter stress may be more severe on poorly-matured vines. The vine continues to respire, but at a slower rate. Without sufficient moisture, physiological processes cease to function. Although desiccation may aid in the initial acclimation during State I of the hardening cycle (i.e. stoppage of growth), a prerequisite for deep hardening in Stage II, it will hinder the completion of Stage II.

MICROCLIMATE

A microclimate is an area with a specific set of conditions, within a larger area. A specific microclimate is made of many complex interactions. These include: the soil, light, moisture, temperature, exposure and slope. Although many conditions may be similar between two sites, no two microclimates are identical.

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Climatic Characterization of the Region

Most of the data presented here are not new. It is available through a variety of sources. The purpose of this chapter is to bring all the available data together and to provide a broad overview to the climate in the Four Corners Region. The charts and diagrams will present a generalized picture of what occurs. Sufficient data may not be, and probably is not, available from these figures to determine suitability of a given location; but the data can provide information on where to look, or what area to avoid. As with all attempts to produce a crop in a new, as yet untried area, caution must be used. It is much easier and cheaper, to place individual recording stations in a potential site and collect data for 1 or 2 years, than to plant a crop or invest a large sum in developing a planting only to find the crop will not do well.

The data will be presented first as an overview of the region. Later more specific data, where it exists, will be presented for each state. Finally data will be presented from western grape-producing states outside the region. Since a detailed description of each state, or region within the state, would require a great deal of discussion, and as the reader shall later see, would not be warranted, the descriptions and discussions will be brief.

REGIONAL TRENDS

Figure 1 presents the mean minimum temperatures for the month of January. Temperatures in the southern part of the Region are similar to the grape growing regions of California and Washington. The northern portions of the Region are 10 to 20 degrees F colder. Figure 2 shows the all-time recorded minimum temperatures. It should be noted that very little of the Region is similar to California in minimums. They do, however, fall within the range reported for the state of Washington. The normal January surface temperatures are shown in Figure 3. As with the mean minimum temperatures (Figure 2) the surface temperatures experienced within the region fall within the range reported for California and Washington.

The mean maximum July temperatures shown in Figure 4 are fairly similar throughout the majority of the Region, and resemble those temperatures found in the central grape producing valleys of California and Washington. Likewise, the absolute maximum temperatures recorded for the lower portion of the Region (Figure 5) are similar to the central areas of California, while the more northern portions of the Region are similar to Washington. Mean surface temperatures in the southern portion of the Region (Figure 6) are hotter than those found in California. The central to northern portions of the Region have maximum surface temperatures more similar to the northern wine growing regions of California and Washington.

The yearly mean surface temperature is shown in Figure 7. With the exception of the southwestern portion of Arizona, the mean surface temperatures found in the Region are similar to those in the wine growing regions of Washington and California.

Mean annual precipitation (Figure 8) varies widely within the Region and with locations within a state. In general, the rainfall occurring in the Region is equal to or slightly higher than the main grape producing areas of Washington and California, with the exception of the North Coast region of California. Total precipitation is important, but the distribution is even more so. In the Washington and California production regions, rainfall occurs mostly in the winter and spring. In the Four Corners Region as much as half of the precipitation occurs in thundershowers during the later summer and fall. The frequency of thunderstorms is shown in Figure 9. The Region experiences an average of 15 to 30 thunderstorms per year, while the producing areas of California and Washington average less than 5. The increased frequency of summer thunderstorms may increase the chance of disease problems and result in greater amounts of vegetative growth due to a greater amount of nitrogen washed into the soil.

Average annual evaporation from open surfaces is shown in Figure 10. Evaporation in the region is generally higher than regions of similar temperatures in California and Washington. The higher evaporation is due, in part, to slightly higher maximum temperatures and the higher incidence of solar radiation, particularly in the winter. Percent of normal winter sunshine is shown in Figure 11. The Region experiences 50 to 85% of the possible available sunshine. This is higher than California which varies from 50 to 75% and Washington which varies from 20 to 40%. This higher percentage of available radiation in the Region increases evaporation, particularly in the winter.

ARIZONA

The climate of Arizona can be broken into six separate regions (Figure 12), which range from the low deserts of the southwest to the high mountains of the northeast. These areas are delineated by differences in temperature, moisture, soil type and elevation.

Average January and July temperatures are shown in Figures 13 and 14. Distribution of the summer and winter temperatures are similar, with the warmest conditions in both cases found in the southwestern region and the coolest in the north-central plateau. Annual mean temperatures decline as elevation increases (Figure 15). The relationship is not a linear one, however.

As the average temperatures (Figure 15) decrease with increasing elevation, the number of frost-free days, or the length of the growing season shortens. This relationship is shown in Figure 16. Unlike the relationship between temperature and elevation, the relationship between altitude and the length of the growing season is linear. It should be noted, however, that at any one elevation there can be a 50 to 100 day variation in the length of the growing season. The average length of the frost-free season is shown in Figure 17.

Shorter growing seasons are defined by earlier fall and later spring frosts. Arizona has a highly variable climate. The frequency and dates (average) of first and last frosts occurring in Tucson, Arizona are shown in Figure 18. In general, spring frosts are more variable than fall frosts.

The average annual precipitation for the state is shown in Figure 19. Rainfall is greatest in central and plateau areas (Table 1), and lowest in the southwest and northwest. The distribution by month for each region is shown in Figure 20. As can be seen in Figure 21, little correlation can be made between precipitation and elevation.

Table 1. Average annual precipitation and percentage of annual precipitation that falls between May and October in each of the major sections of Arizona. (Smith, 1956.)

section	average annual precipitation (inches)	percentage falling between May and October
Northwest	12.40	51
Northeast	9.26	62
Plateau	19.36	55
Central	18.87	48
Southwest	7.83	48
Southeast	14.44	65

Temperature and humidity combine to create conditions which are either pleasant or unbearable. This is an important consideration where labor is involved. Figure 22 presents the comfort index for July. The normal comfort range is considered to be 72 to 78.

COLORADO

Colorado can be divided into three areas. The state is divided by the Continental Divide and Rocky Mountains which run from the northwest corner to the southcentral part of the state. The average January and July temperatures are shown in Figures 23 and 24. In both cases the average temperatures are lower in the intermountain region. The southwestern part of the state is slightly cooler than the eastern slope of the mountains.

Length of the frost-free season is shown in Figure 25. It ranges from 80 days in the northwestern mountains to 160 days in the southwestern and eastern parts of the state. The average annual precipitation (Figure 26) is the greatest in the high mountains. Lesser amounts occur on the eastern slope with slightly lower amounts occurring in the southwest.

NEW MEXICO

Mean January and July temperatures are shown in Figures 27 and 28. Temperatures generally become cooler as one moves north and west. Mean minimum January and July temperatures vary with elevations and are shown in Figures 29 and 30. Like the relationship between altitude and mean temperatures in Arizona (Figure 15), the relationship between New Mexico's mean temperatures and elevation is not linear. All-time record low temperatures are shown in Figure 31. While a trend might be suggested, no statistical correlation can be made between the minimum temperature and elevation.

Heat units between April 1 and October 31, based on California's growing degree day model, are shown in Figure 32. The majority of the state is either Region I, IV or V. Varieties which will grow in these parts of the state do not correspond with those which grow in similarly designated regions of California. The heat within an area does correspond quite nicely with the elevation (Figure 33).

The length of the growing season (Figure 34) is shorter than one might suspect from the mean and maximum summer temperatures and the number of heat units accumulated. The growing season ranges from less than 150 to more than 180 days, much less than Regions III, IV or V; of California and Arizona. Length of the growing season correlates quite closely with elevation (Figure 35).

The average annual precipitation is shown in Figure 36. It ranges from 8 to 20 inches with the greatest amount occurring in the higher mountains. Although numerous thunderstorms may occur, the probability of accumulating 1 inch of rain during the month of August is about 10%. Little effect is expected on ripening. Rainfall is not great enough to produce the crop without irrigation. Evaporation and evapotranspiration are not as great in New Mexico as in Arizona. Figure 10 depicted the average evaporation from an open surface of water. The data presented in Figure 37 depicts the average annual evaportranspiration from plants based on the Thornthwaite formula. It should be noted that the values presented for evapotranspiration are about 90% of evaporation from an open surface.

UTAH

The mean January and July temperatures are shown in Figures 38 and 39. In each case the warmest temperatures are found in the southwestern part of the state and the coolest in the northeastern portion. Although the warmest mean temperatures occur in the southwestern portion of the state, the longest frost-free season (Figure 40) is found in the southeastern part of the state. The shortest growing season is found in the northeastern part of the state. Average annual precipitation ranges from 6 to 20 inches (Figure 41). The greatest amount occurs in a north-south line running through the middle of the state.

AREAS OUTSIDE THE REGION

The following information is presented to describe the climate where grapes are grown outside the Region. Figure 42 shows the principal wine growing regions in California. It should be noted that major production is found in the large central valleys. Other production occurs in the cooler coastal valleys.

Mean minimum January and mean maximum July temperatures are shown in Figures 43 and 44 respectively. Minimum January temperatures below freezing do occur, but not to the same degree as those in the Four Corners Region. As have been previously noted, the mean maximum temperatures for the state of California are slightly lower than those found in the southern portion of the Four Corners Region, but similar to those found in the northern portions of the Region.

The average frost-free growing season is shown in Figure 45. By comparison with Figure 42 it may be observed that the majority of grapes grown in California are grown in areas with an excess of 240 frost-free days. This is greater than the Four Corners Region, with the exception of southern Arizona.

The five climatic regions, based on growing degree days, are shown in Figure 46. Again, by comparison with Figure 42, it may be found that although plantings do exist in the cooler regions, the majority of the grapes are grown in Regions IV and V. The average annual precipitation is shown in Figure 47. The majority of the grapes are grown in areas where the average rainfall is 5 to 20 inches. The rainfall which does occur is during the winter period.

The absolute minimum temperatures in Washington are shown in Figure 48. The absolute minimum temperatures in the south-central portion of the state where grapes are grown, are much lower than those in California; however, they are similar to those in the central and northern portions of the Four Corners Region. The average length of the growing season is shown in Figure 49. While the state ranges from less than 90 to over 200 frost-free days, the average in the viticultural regions ranges from about 120 to over 200. Even though the growing season exceeds 200 days, the amount of heat accumulated is not greater than 3500 GDD (Figure 50). The majority of the state is Region I with a small amount of Region II. There is only one, small, limited area where the total growing degree days approaches 3500 (Region III).

SUMMARY

In most cases, climatic conditions within the Four Corners Region, or a specific area of the Region, are similar in one aspect or another (i.e. mean minimum temperature, all-time recorded maximum temperature, rainfall, growing season length, growing degree days) to an area where grapes are presently being produced in California or Washington; however, while such correlations may exist, their use has not proven satisfactory for predicting what variety or varieties will do well in a given area.

This lack of correlation of the major parameters of climate, between currently producing areas and the newer, experimental areas, has led to the development of other criterion for making initial recommendations. This does not mean that climate should be forgotten when selecting a site. Climatic factors can serve as indicators to determine what varieties can or cannot survive in an area, but not how well they will do.

Absolute minimum temperatures can indicate whether or not *vinifera* vines would survive, or if a grower must plant the more hardy French hybrid or American varieties. Presence of high humidity or summer rainfall (excessive) may limit the production of tight clustered varieties or those which fail to ripen with excessive soil moisture.

The concept to be presented in the following section allows for the use of climate in determining what varieties can do well in a given area. The model takes the major selection criteria away from the heat unit or growing degree day concept and places it on soil characteristics.

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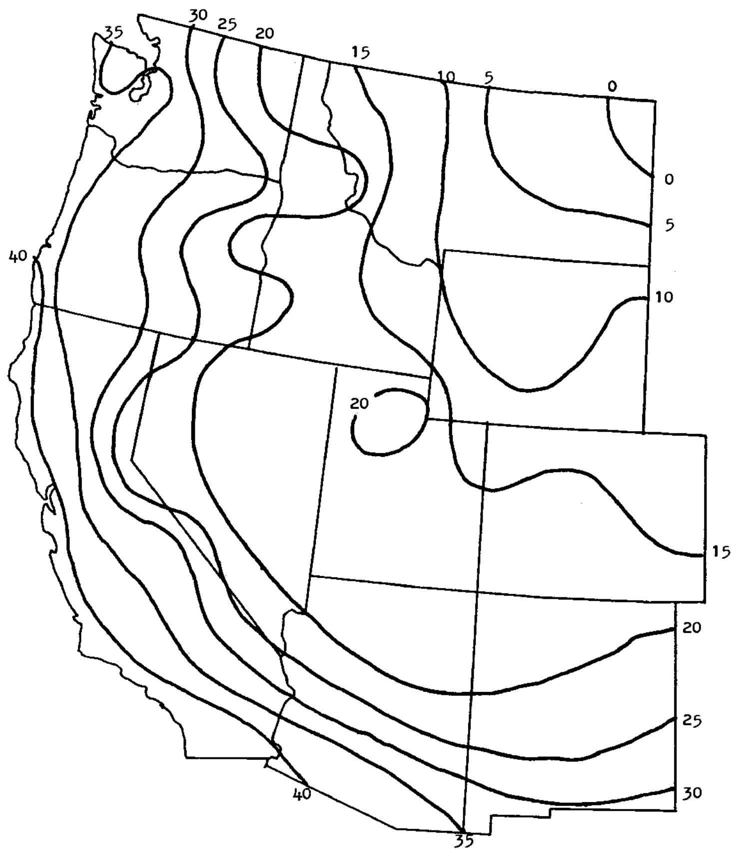


Figure 1. Mean minimum January temperatures (F). (Adapted from Henry, 1906.)

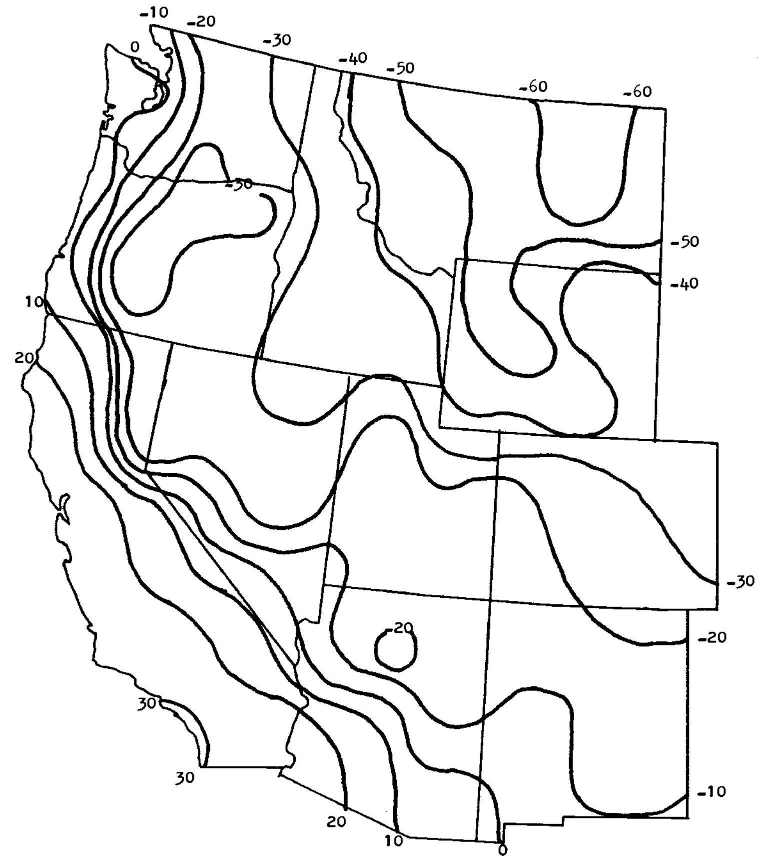


Figure 2. All time minimum temperatures (F). (Adapted from Henry, 1906.)

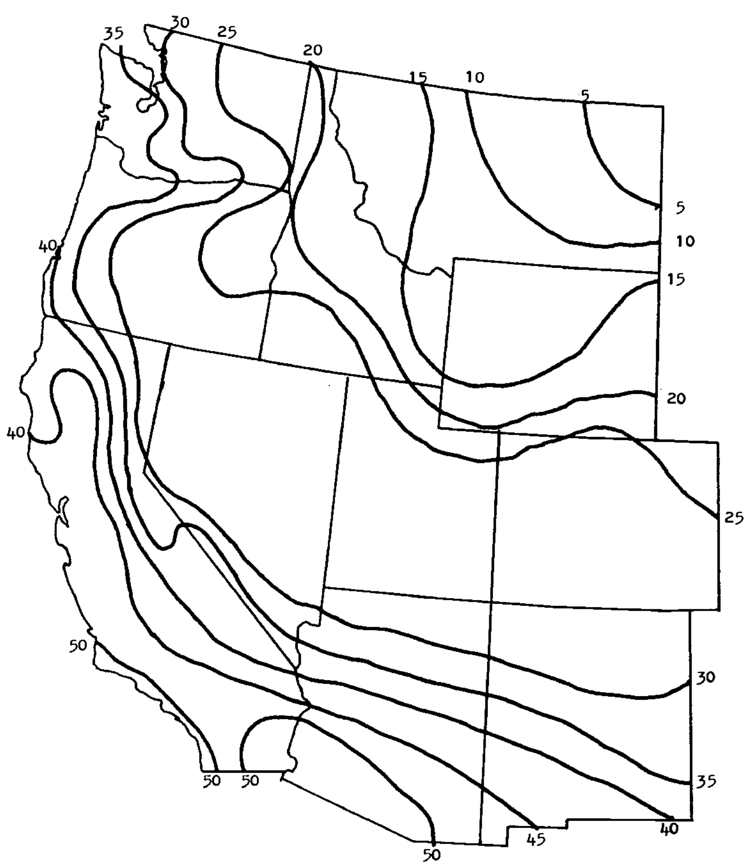


Figure 3. Mean average January surface temperatures (F). (Adapted from Henry, 1906.)

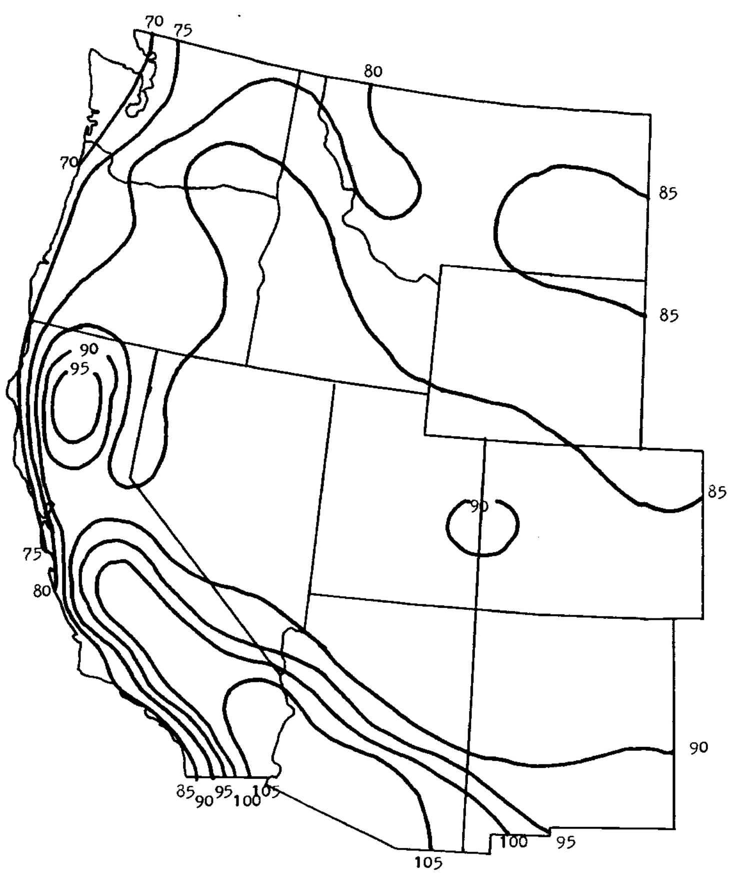


Figure 4. Mean maximum July temperatures (F). (Adapted from Henry, 1906.)

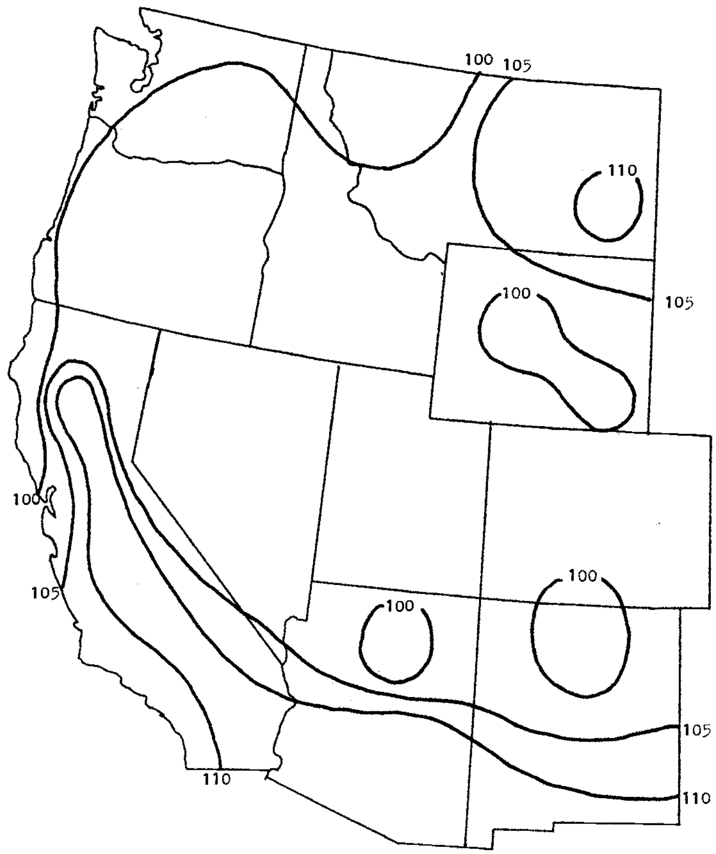


Figure 5. Maximum recorded temperatures (F). (Adapted from Henry, 1906.)

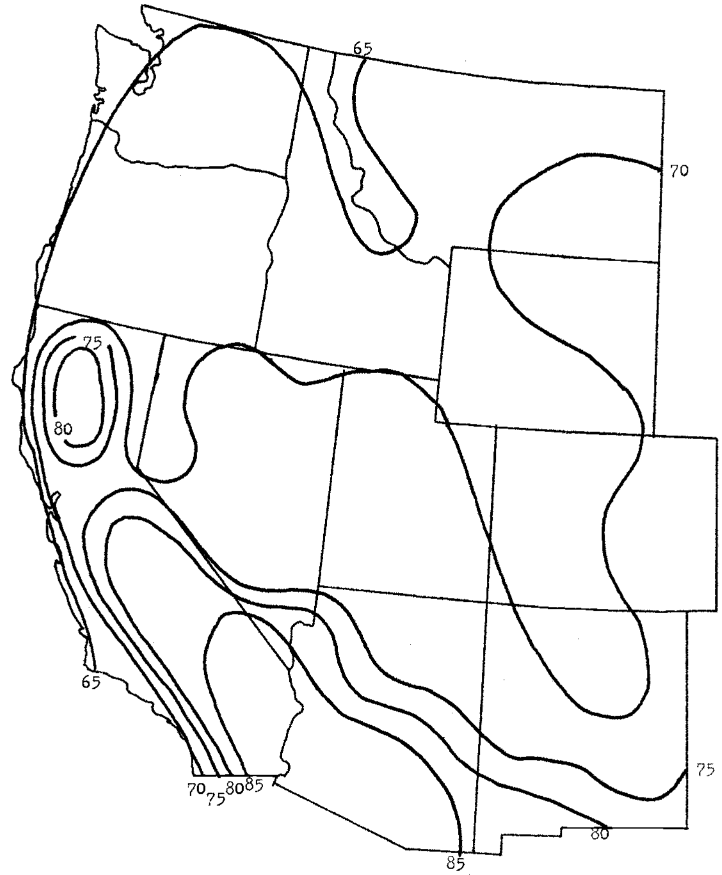


Figure 6. Mean July surface temperatures (F). (Adapted from Henry, 1906.)

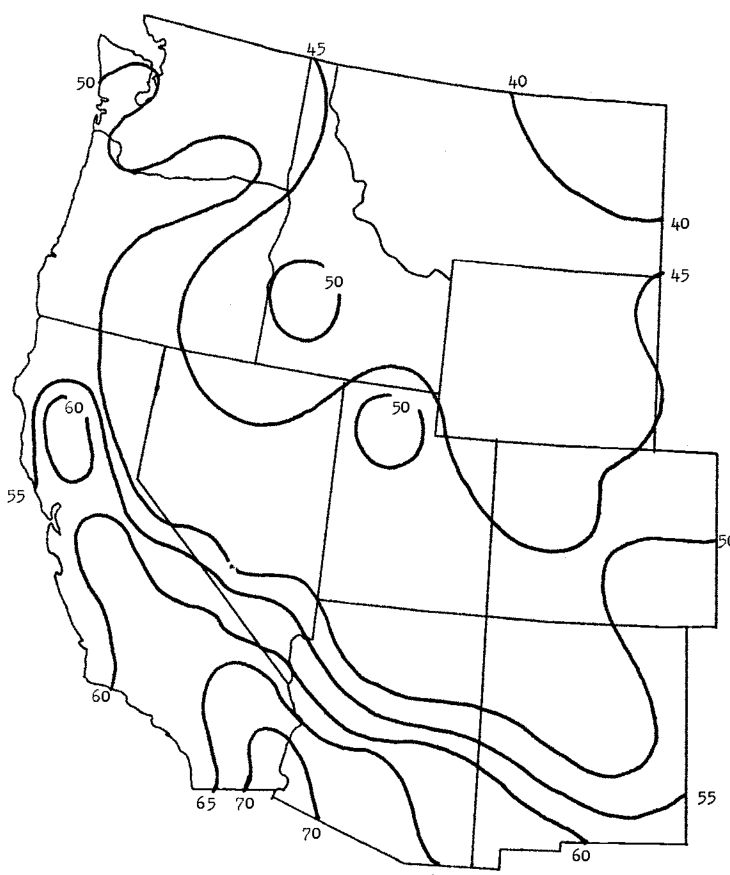


Figure 7. Mean annual surface temperature (F). (Adapted from Henry, 1906.)

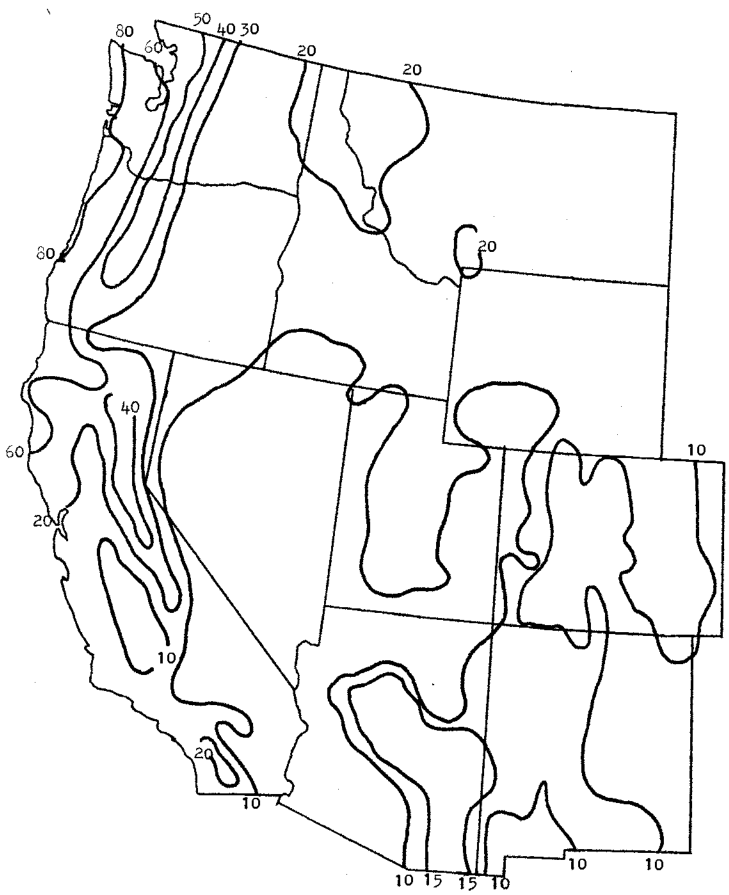


Figure 8. Average annual precipitation (inches). (Adapted from Henry, 1906.)

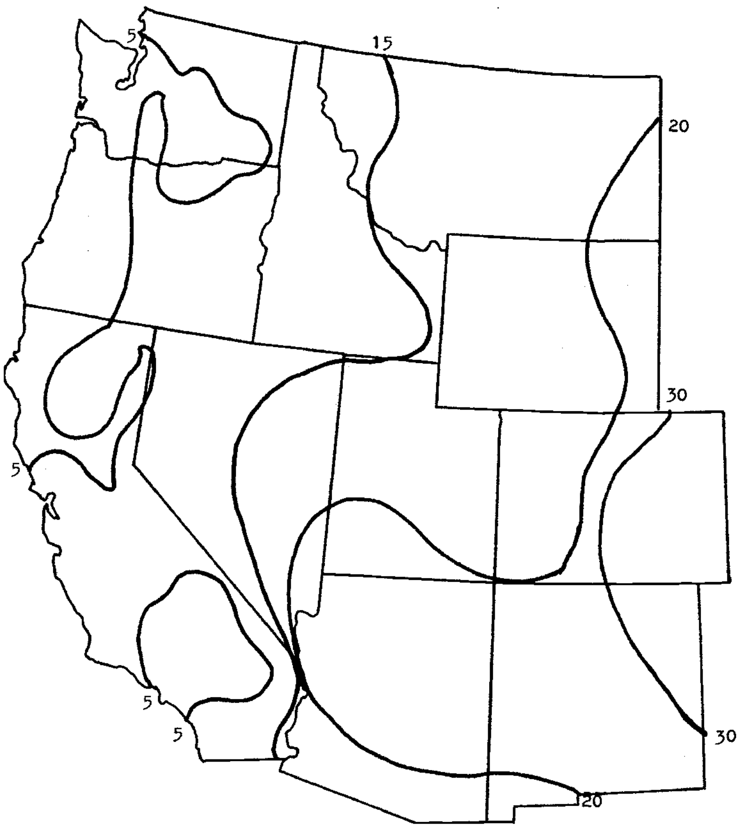


Figure 9. Average annual number of thunderstorms. (Adapted from Henry, 1906.)

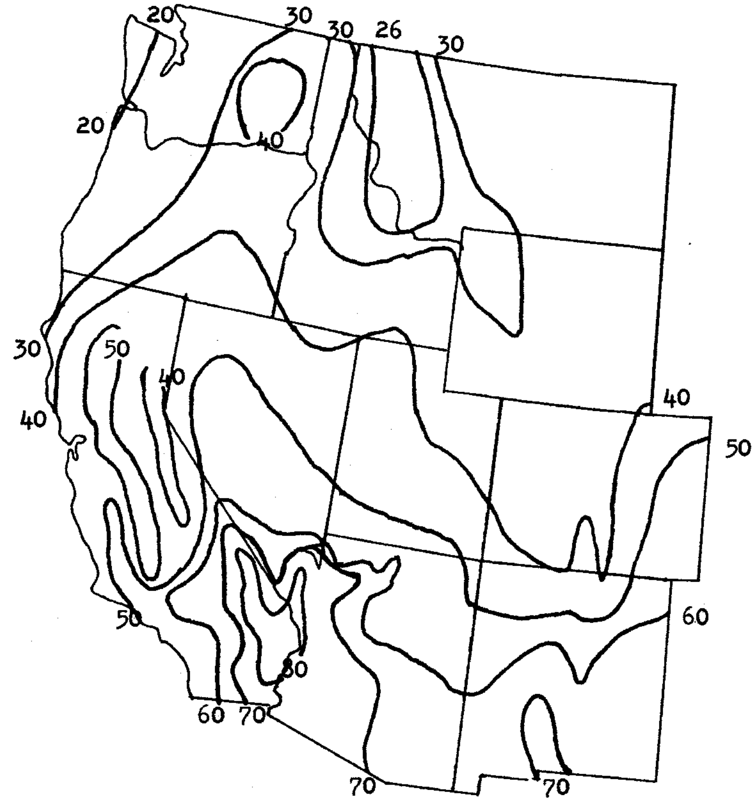


Figure 10. Average annual evaporation from open water surfaces. (Adapted from Lilley, 1978.)

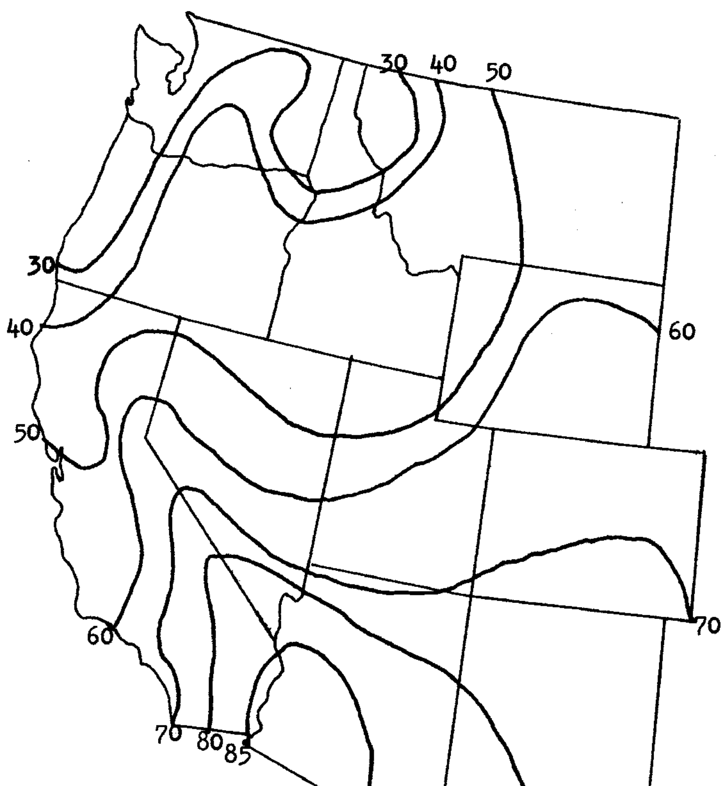


Figure 11. Percent of normal winter sunshine. (Adapted from Anonymous, 1941.)

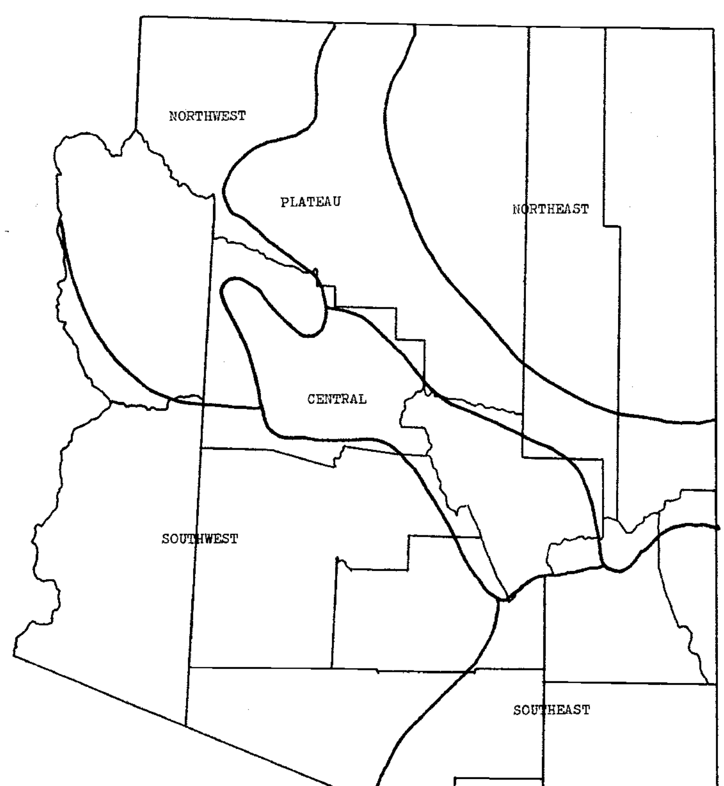


Figure 12. Regional division of Arizona. (Adapted from Sellers, 1974.)

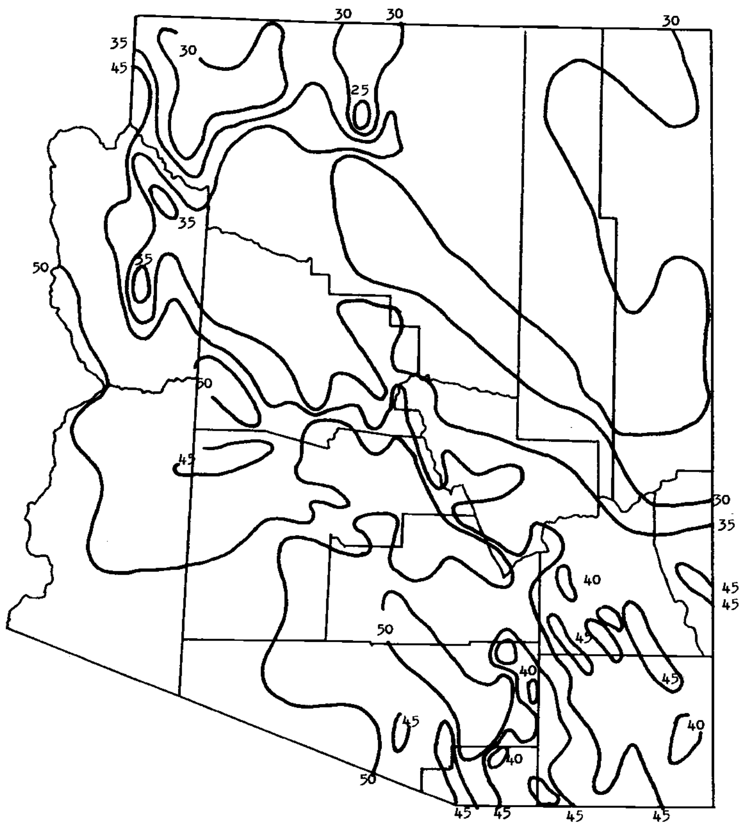


Figure 13. Average January temperature (F) in Arizona. (Adapted from Sellers, 1974.)

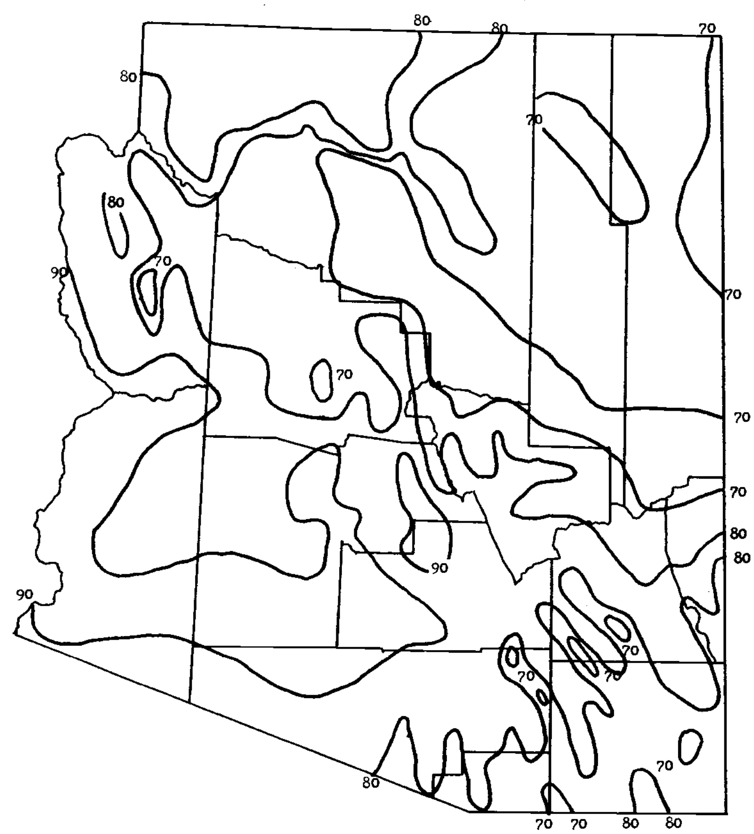


Figure 14. Average July temperature (F) in Arizona. (Adapted from Sellers, 1974.)

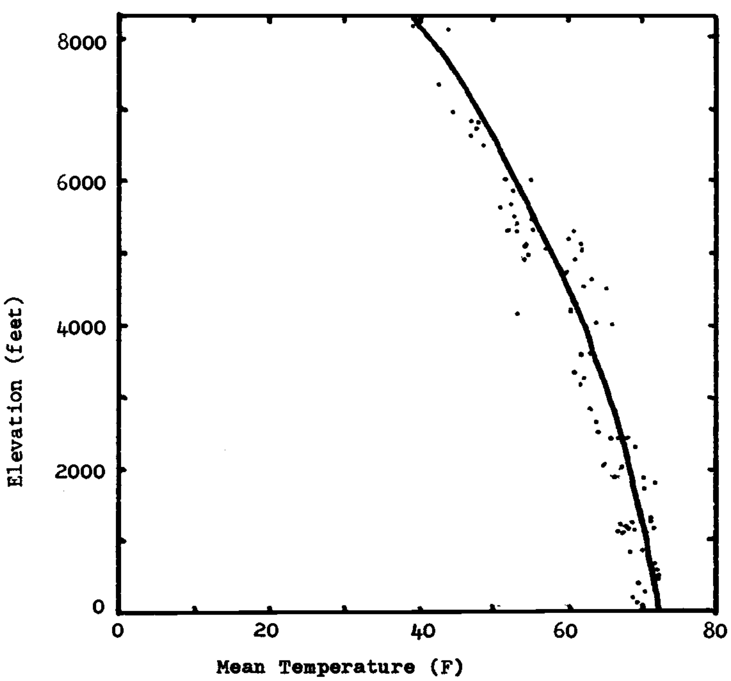


Figure 15. The relationship between annual mean temperature and altitude in Arizona. (Adapted from Smith, 1956.)

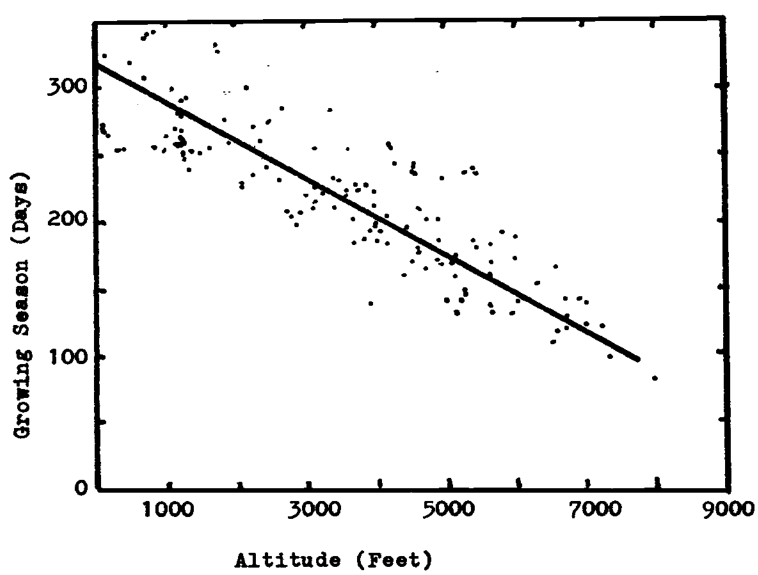


Figure 16. The relationship between altitude and the length of the growing season in Arizona. (Adapted from Smith, 1956.)

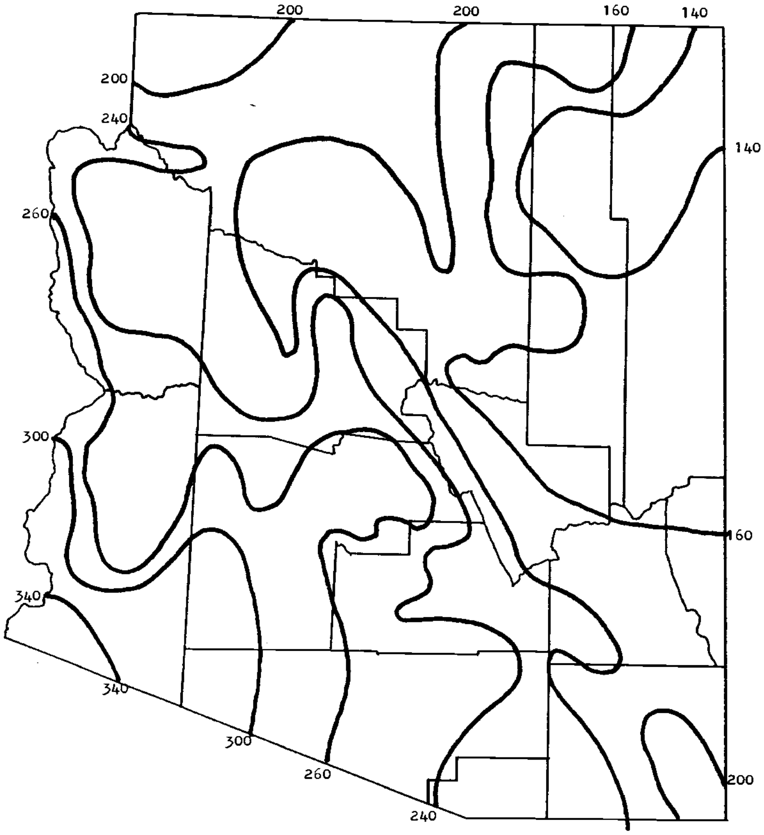


Figure 17. Length of growing season (average frost-free days) in Arizona. (Adapted from Anonymous, 1941.)

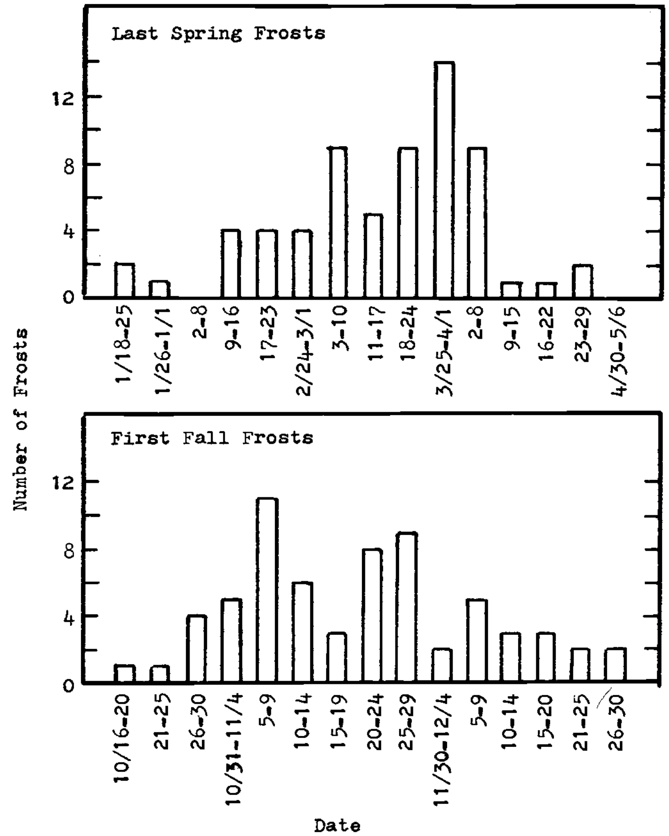


Figure 18. Frequency and date of occurrence of first fall frost and last spring frost. University of Arizona, Tucson. (Smith, 1956.)

Figure 19. Average annual inches of precipitation in Arizona. (Adapted from Sellers, 1974.)

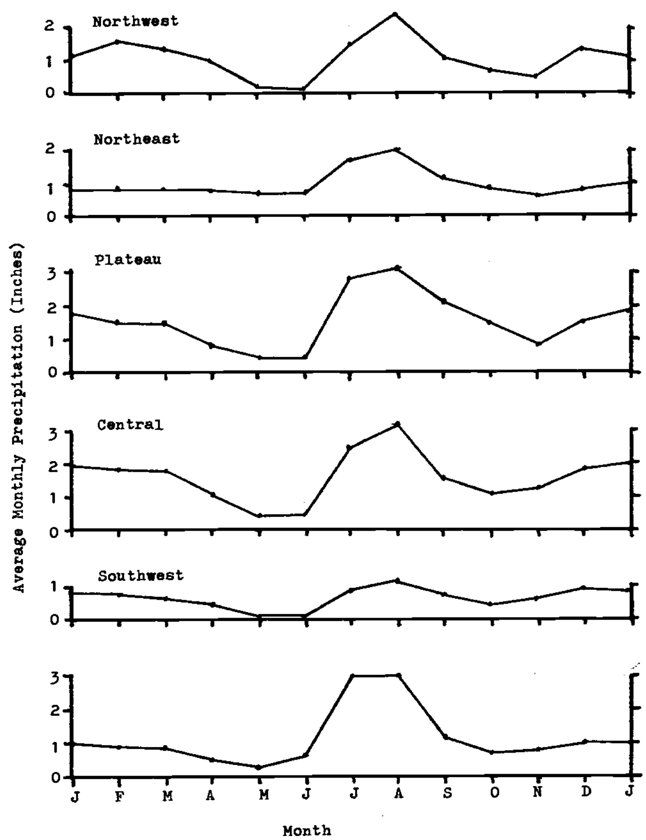


Figure 20. Average monthly precipitation for the six regions of Arizona. (Smith, 1956.)

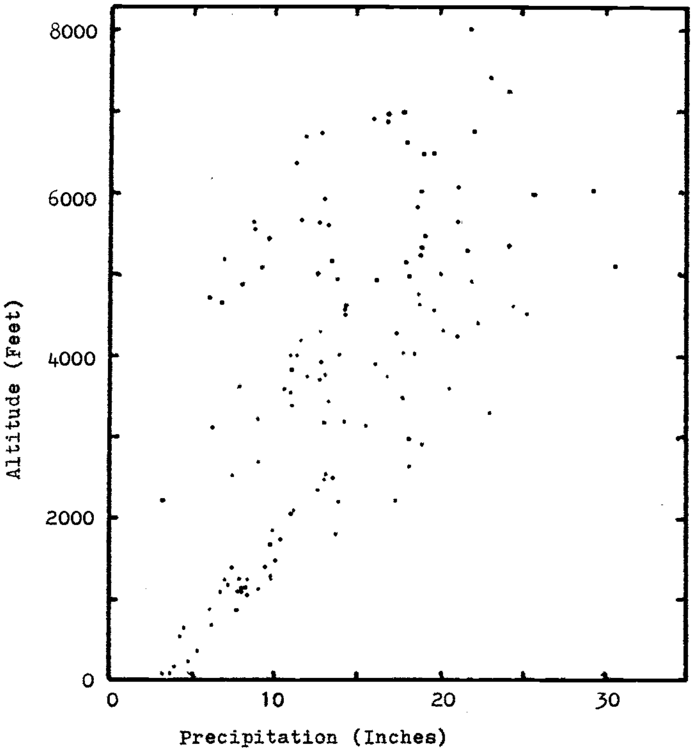


Figure 21. The correlation between rainfall and altitude in Arizona. (Smith, 1957.)

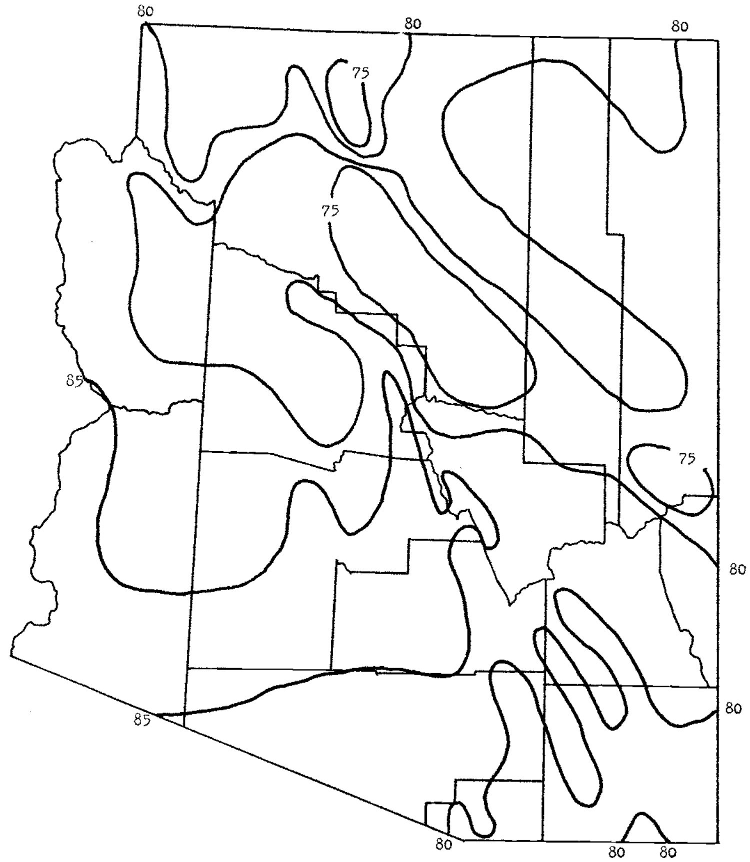


Figure 22. The average daily maximum temperature-humidity (comfort) index for Arizona in July. (Adapted from Sellers, 1974.)

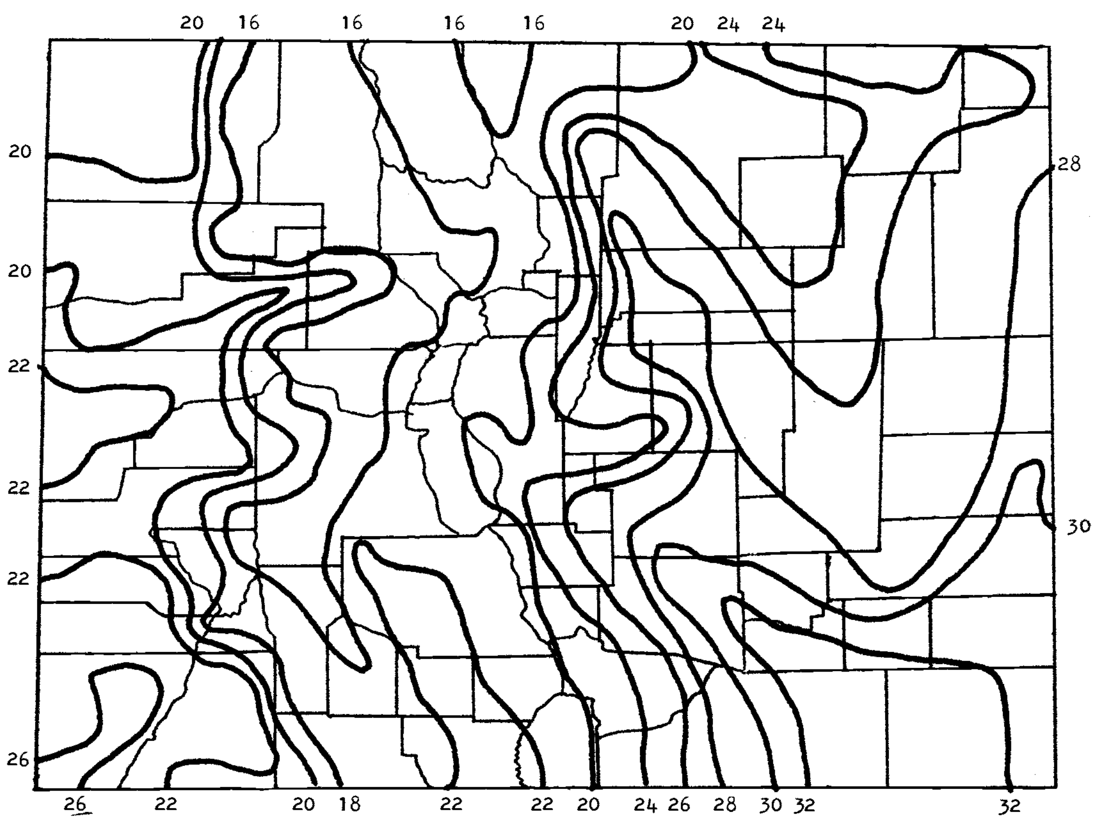


Figure 23. Average January temperatures (F) in Colorado. (Adapted from Anonymous, 1941.)

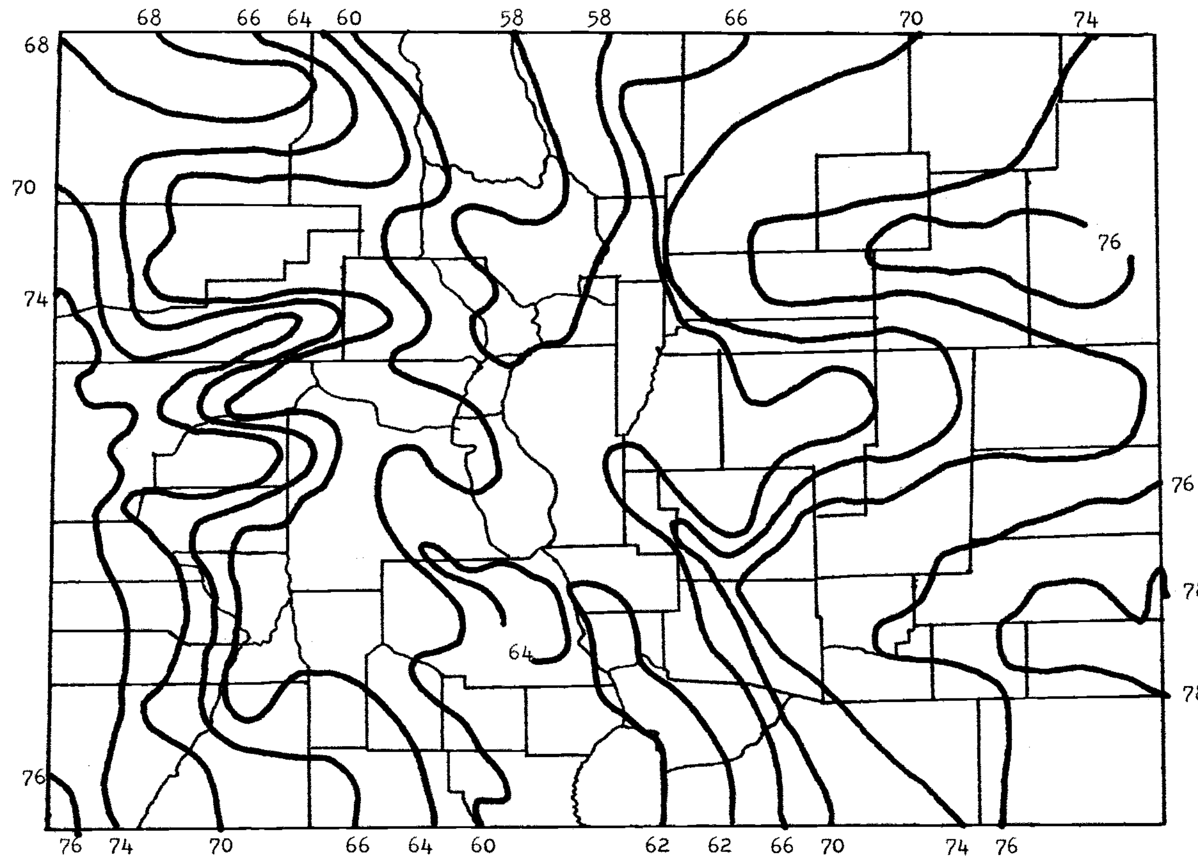


Figure 24. Average July temperatures (F) in Colorado. (Adapted from Anonymous, 1941.)

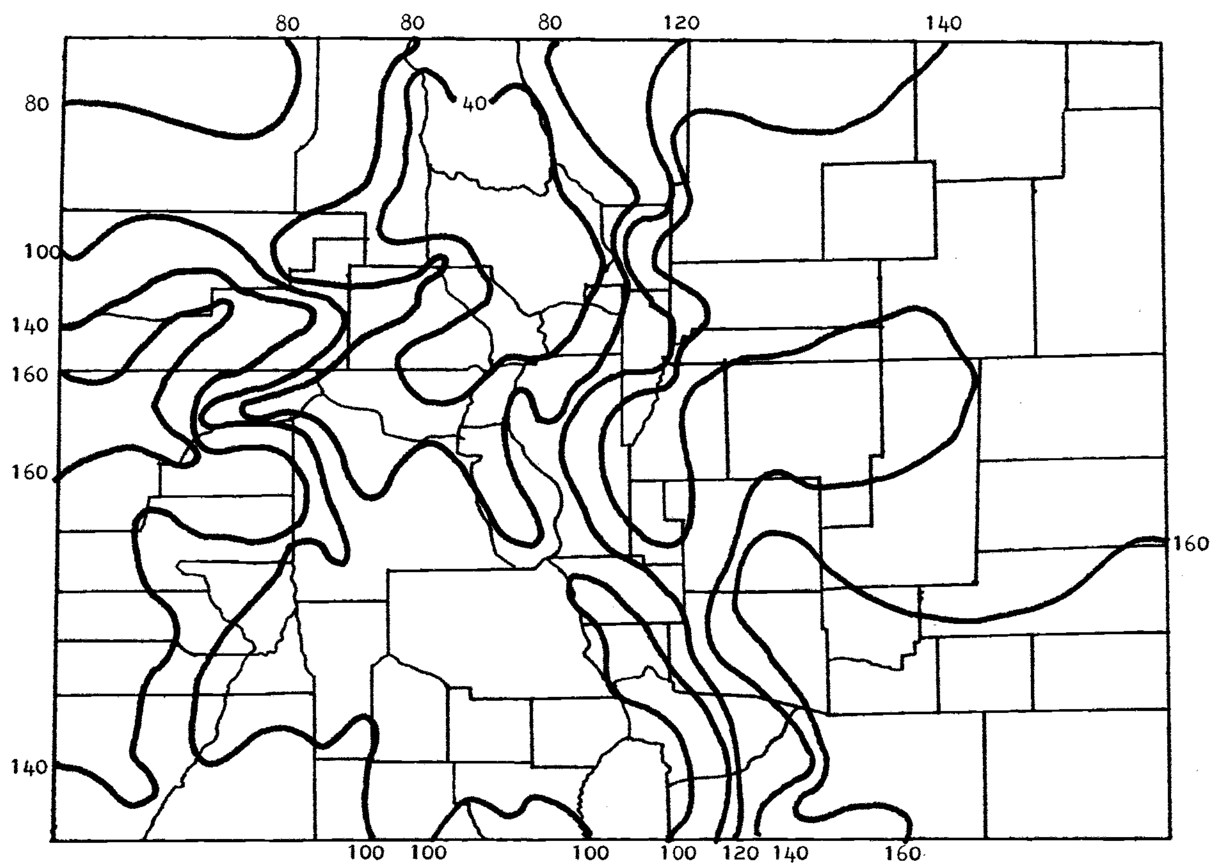


Figure 25. Length of growing season (frost-free days) in Colorado. (Adapted from Anonymous, 1941.)

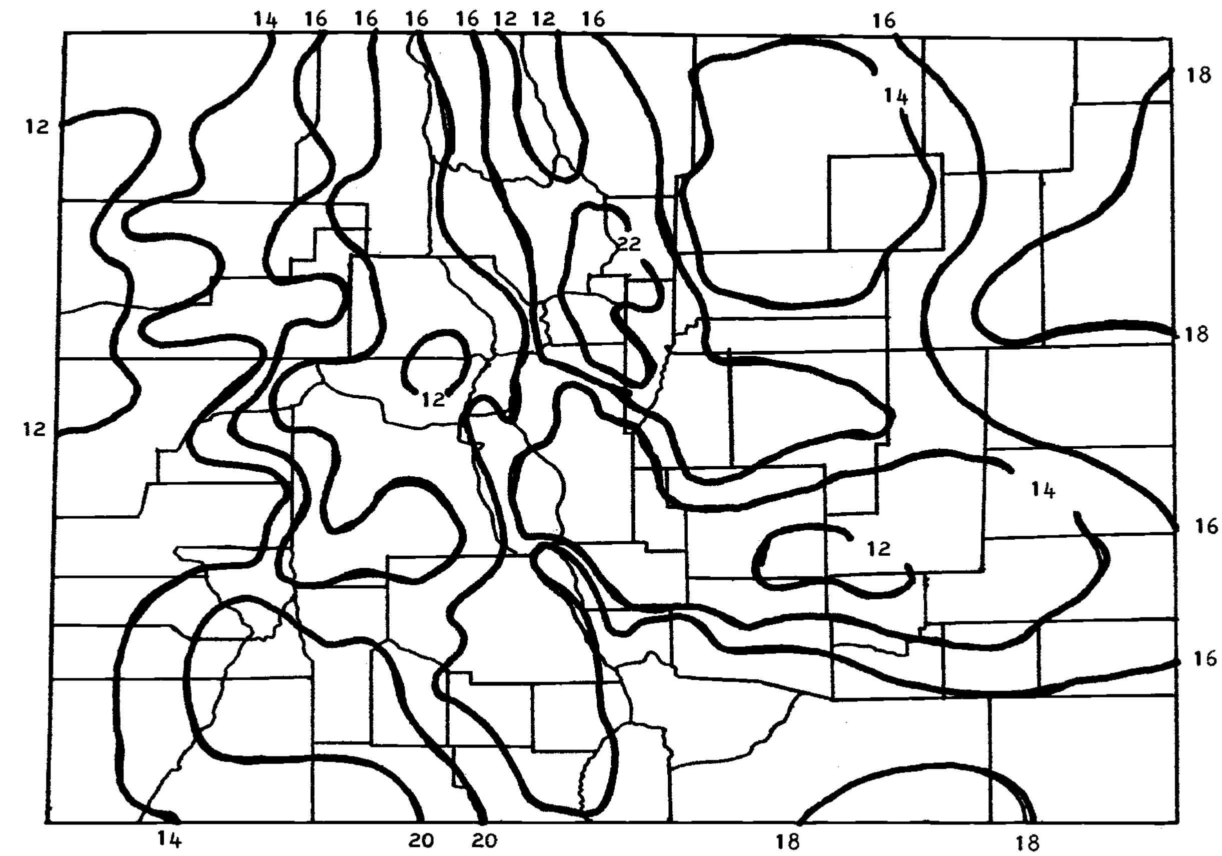


Figure 26. Average annual precipitation (inches) in Colorado. (Anonymous, 1941.)

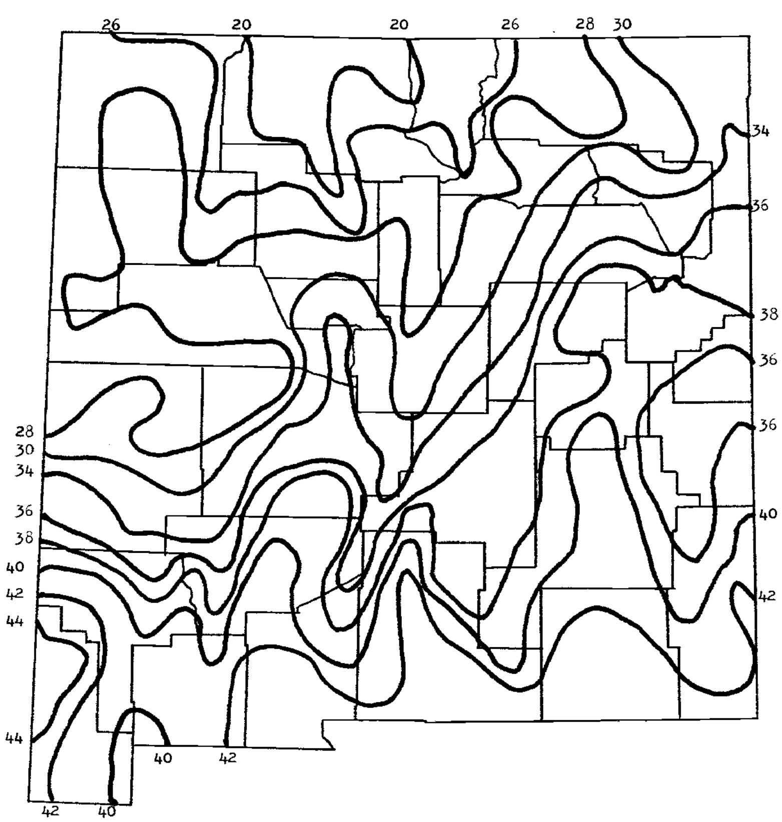


Figure 27. Mean January temperatures (F) for New Mexico. (Adapted from Anonymous, 1941.)

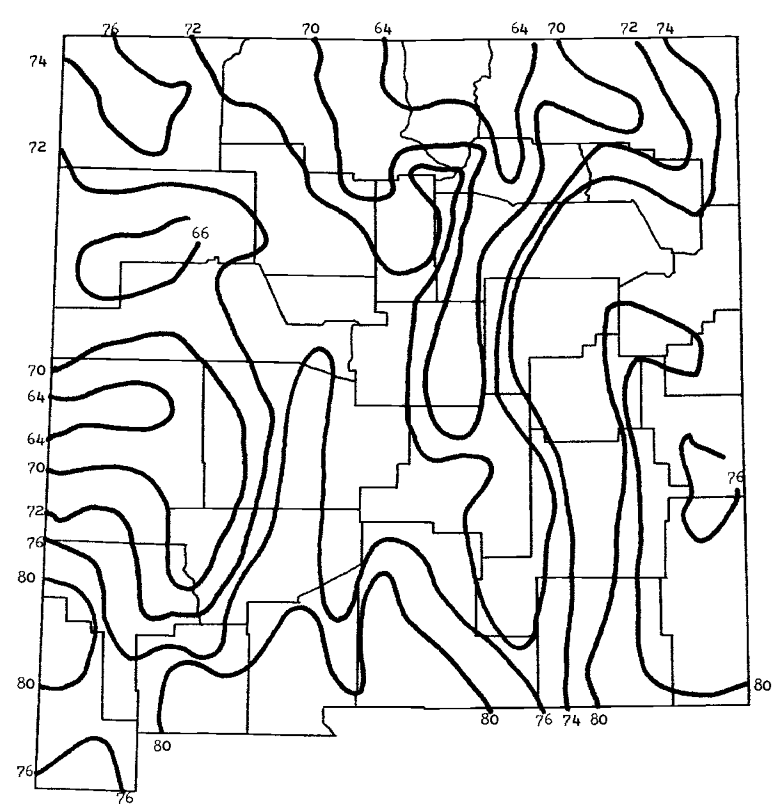


Figure 28. Mean July temperatures (F) for New Mexico. (Adapted from Anonymous, 1941.)

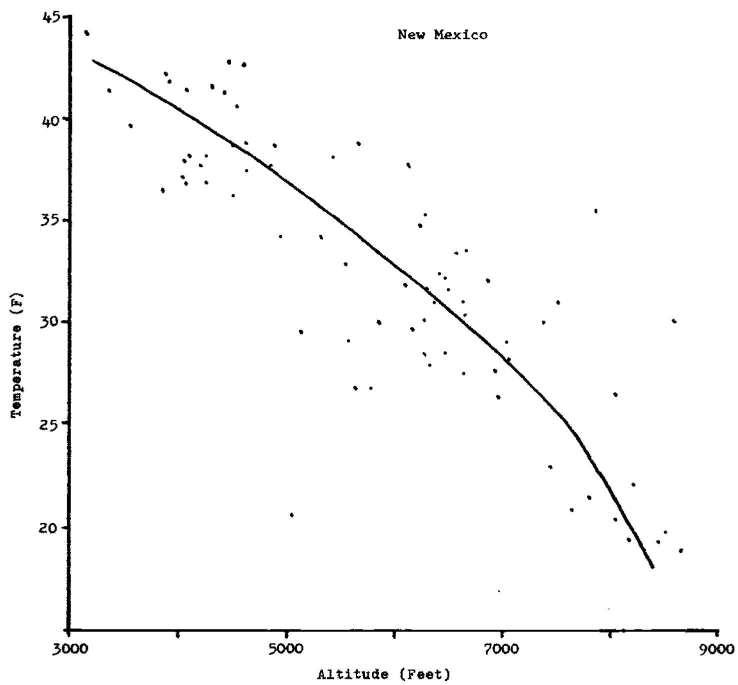


Figure 29. The correlation between mean January temperature and elevation. (Lilley, 1978.)

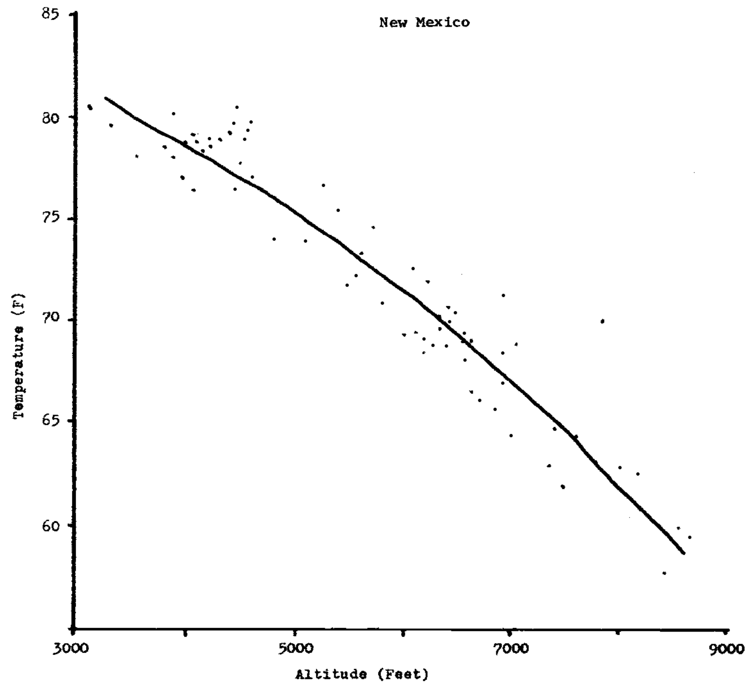


Figure 30. The correlation between mean July temperature and elevation. (Lilley, 1978.)

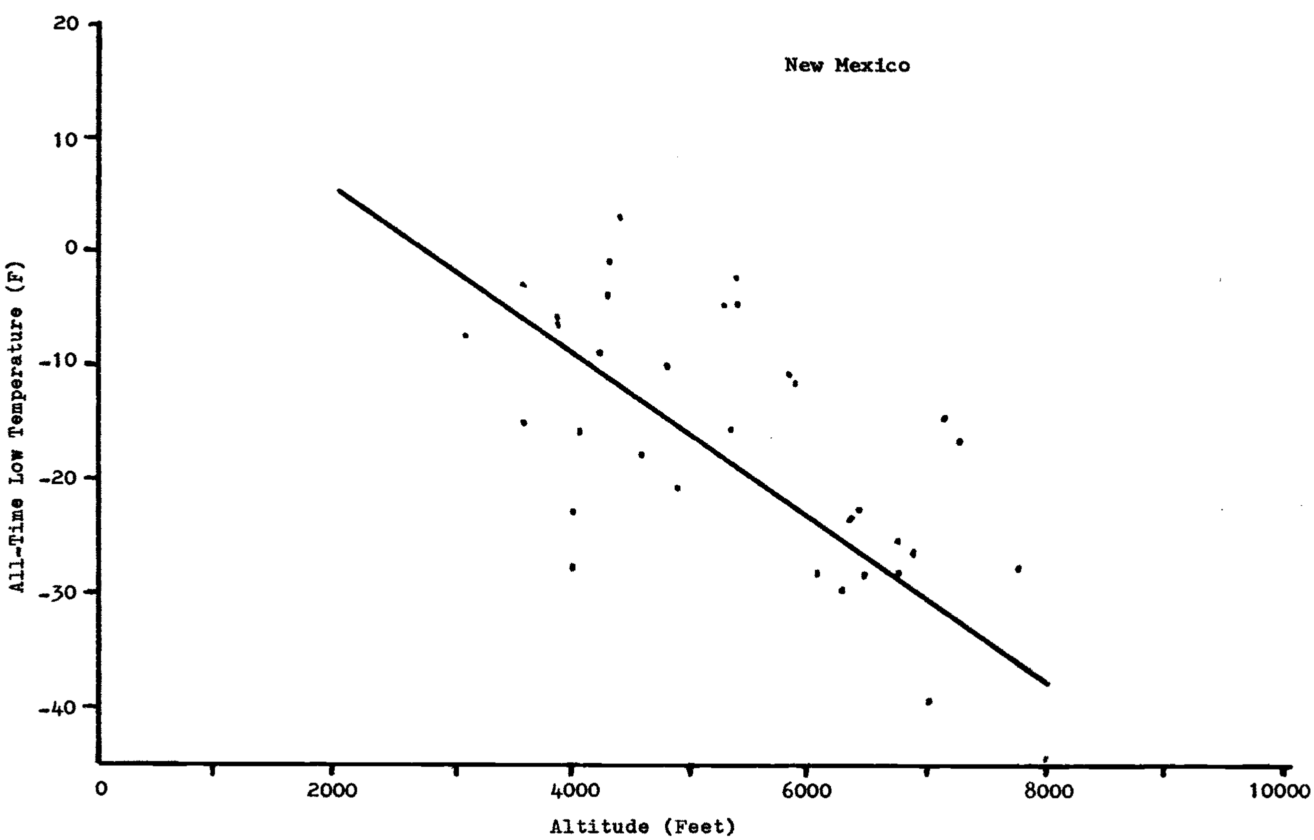


Figure 31. The correlation between all-time low temperatures and elevation. (Lilley, 1978.)

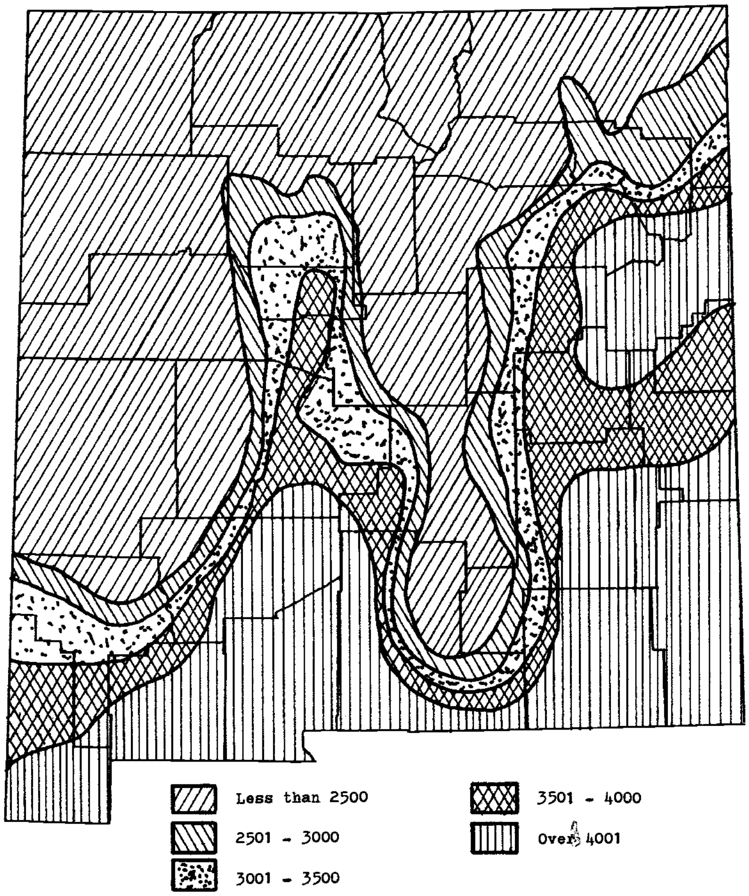


Figure 32. Growing degree day accumulation for New Mexico. (Adapted from Lilley, 1978.)

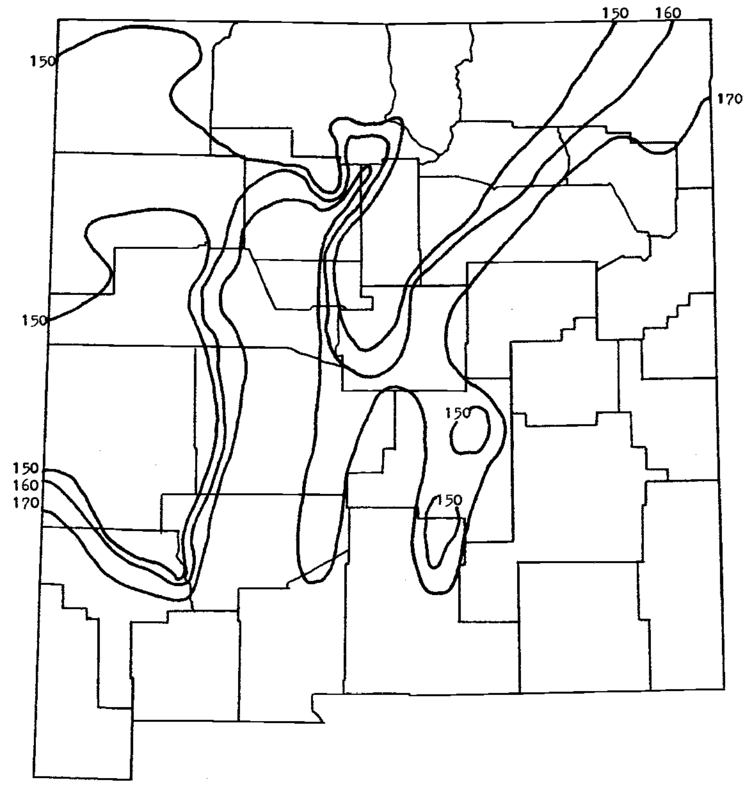


Figure 34. Length of growing season (frost-free days) in New Mexico. (Adapted from Lilley, 1978.)

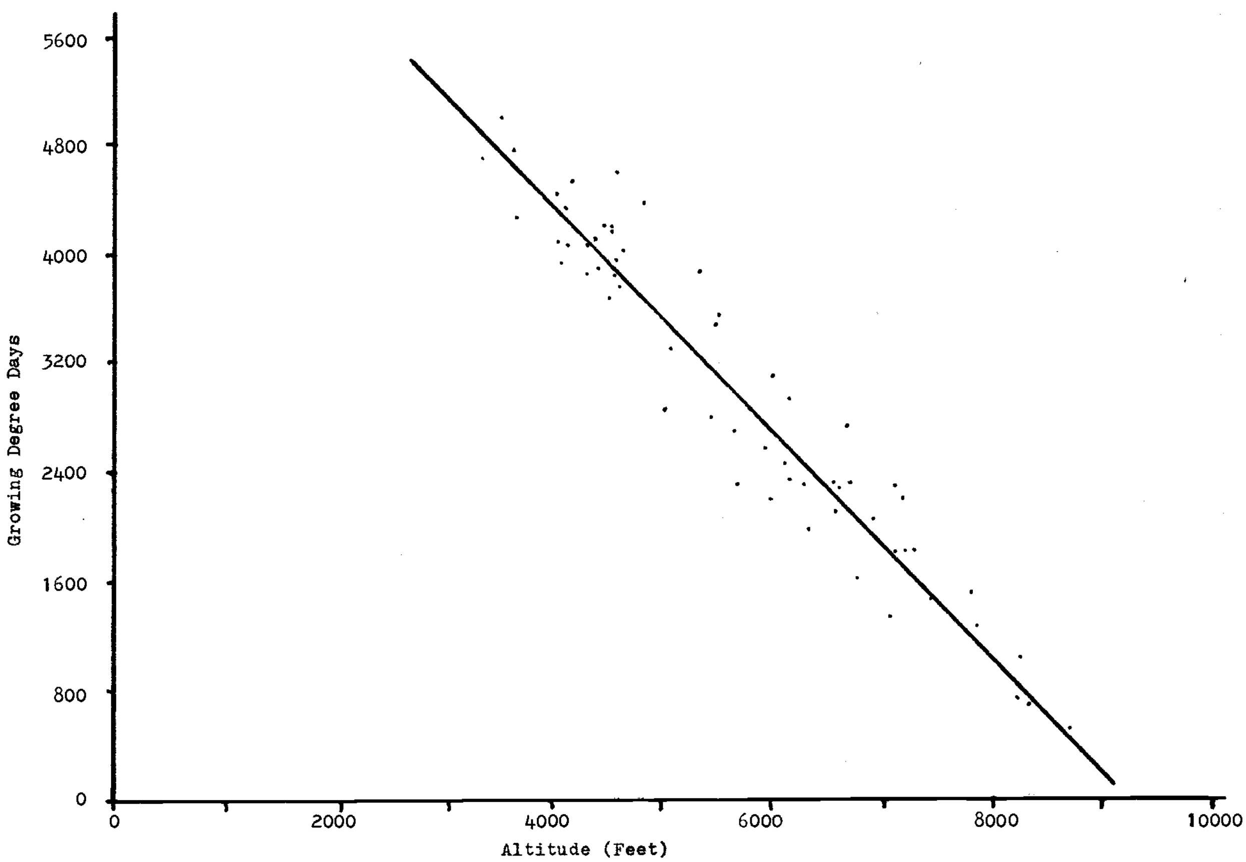


Figure 33. The correlation between growing degree days (base 50 F) and elevation in New Mexico. (Lilley, 1958.)

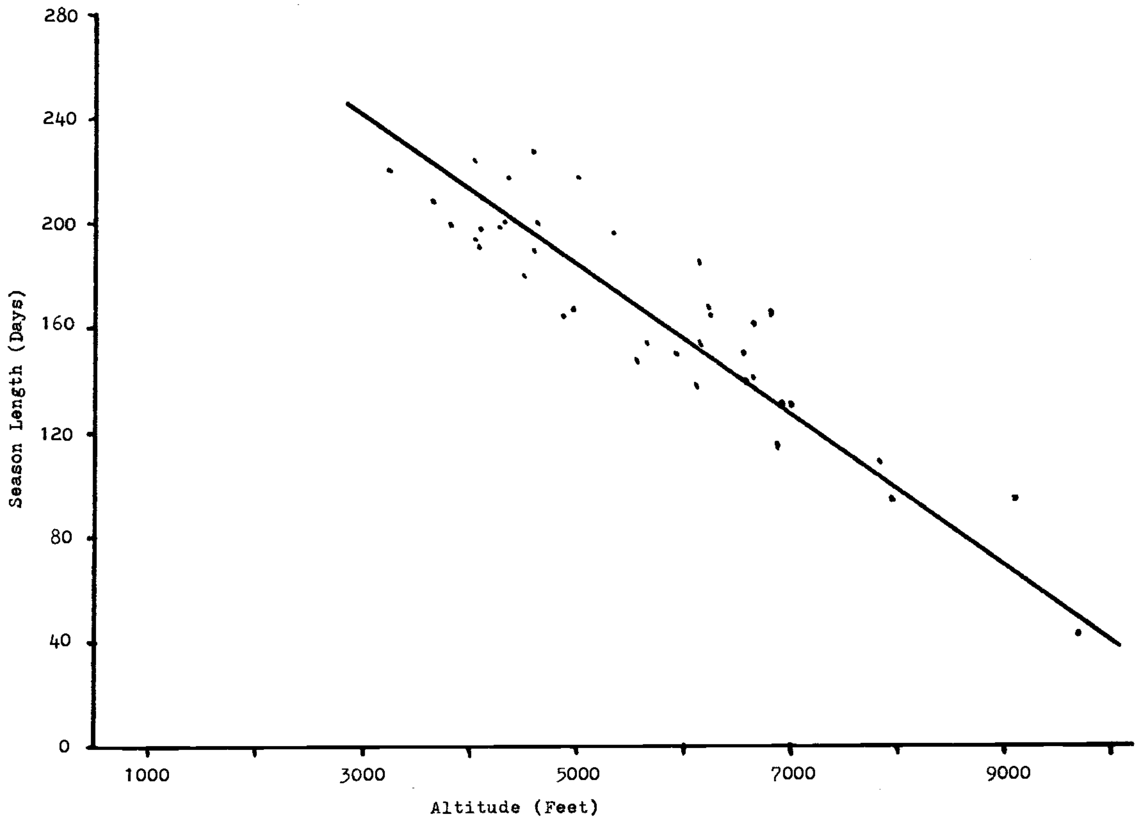


Figure 35. The correlation between season length and altitude in New Mexico. (Lilley, 1978.)

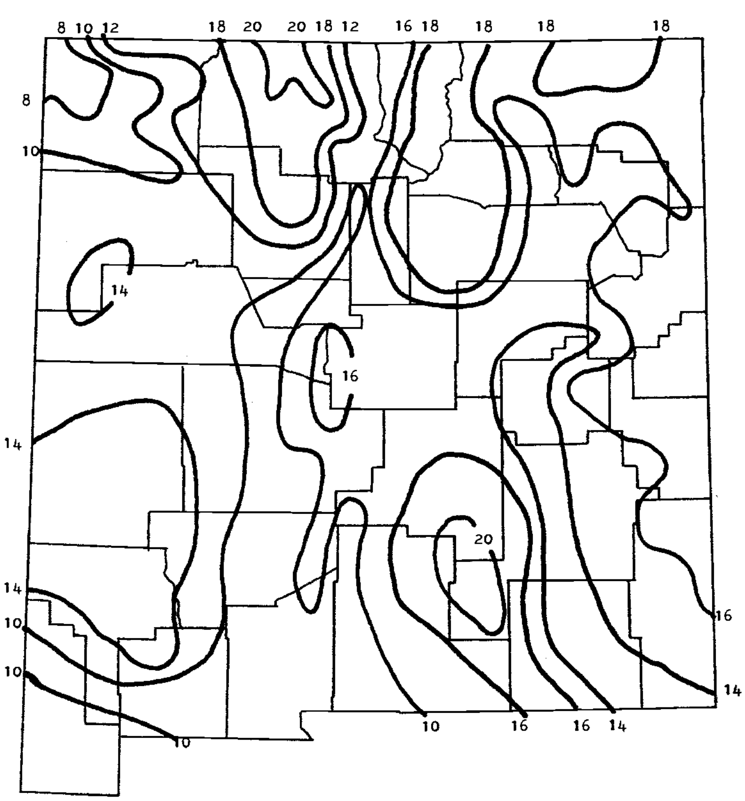


Figure 36. Average annual precipitation (inches) in New Mexico. (Adapted from Anonymous, 1941.)

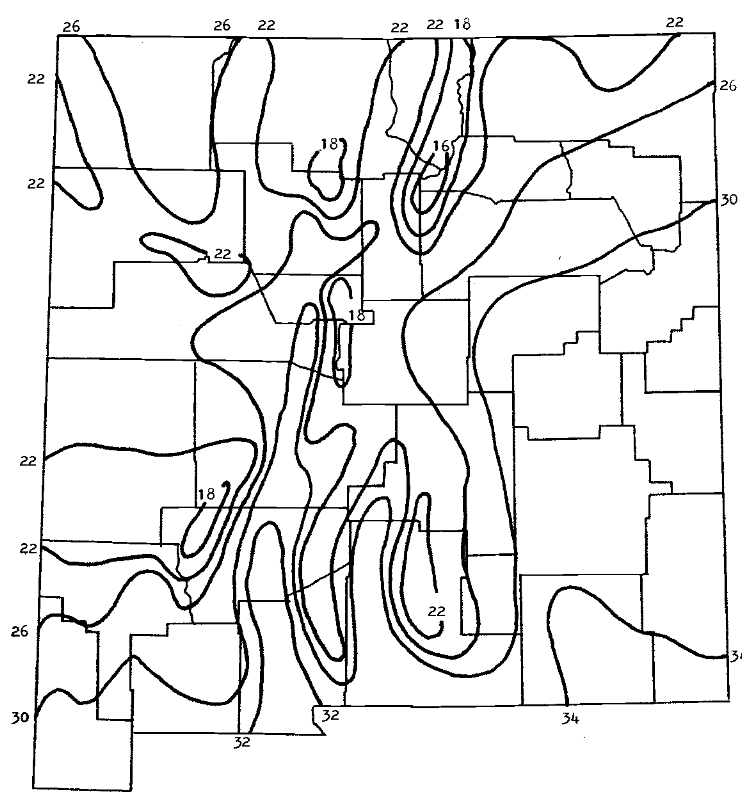


Figure 37. Average annual evapotranspiration (inches) in New Mexico between 1931 to 1955 by the Thornthwaite formula. (Lilley, 1978.)

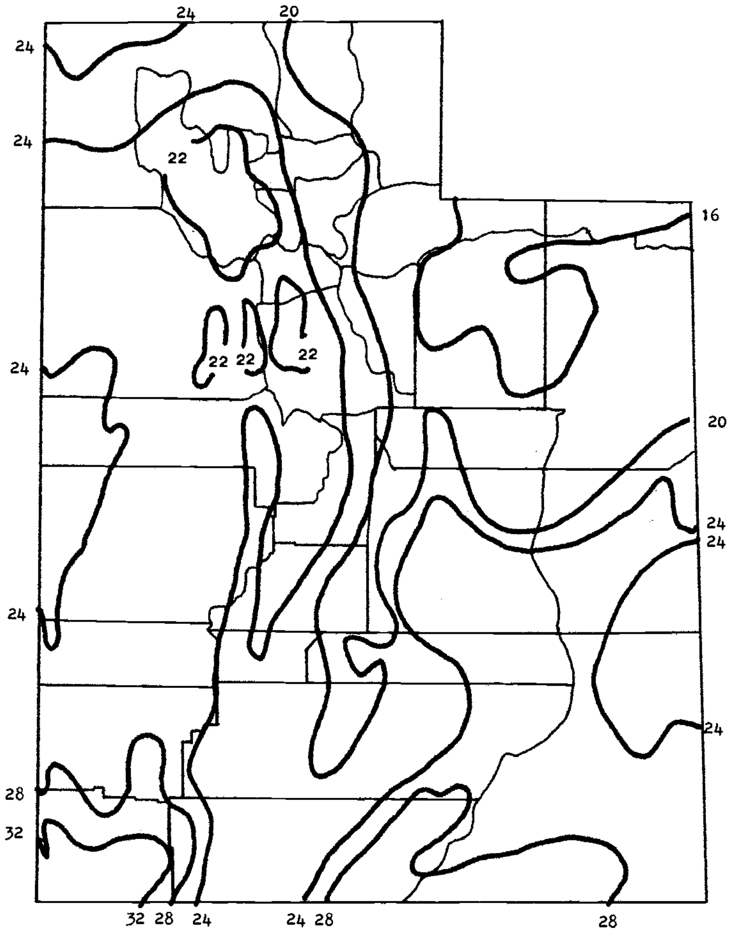


Figure 38. Mean January temperatures (F) in Utah. (Adapted from Anonymous, 1941.)

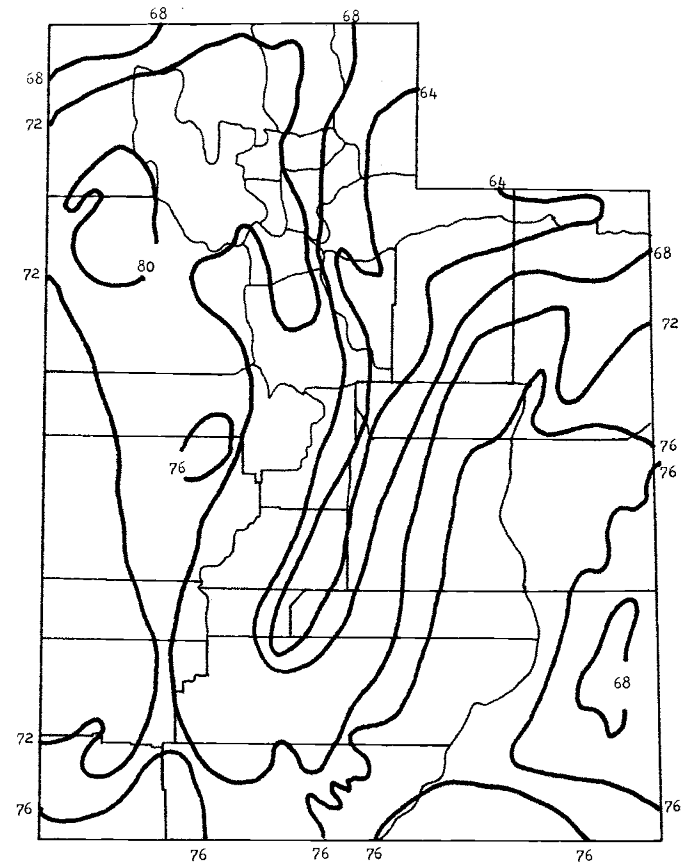


Figure 39. Mean Jul temperatures (F) in Utah. (Adapted from Anonymous, 1941.)

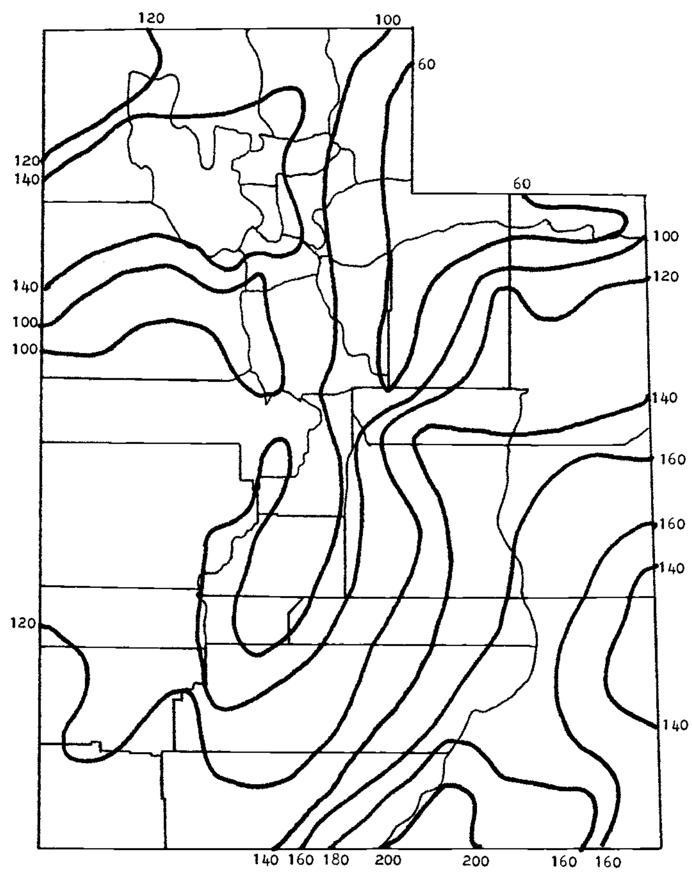


Figure 40. Length of growing season (frost-free days) in Utah. (Adapted from Anonymous, 1941.)

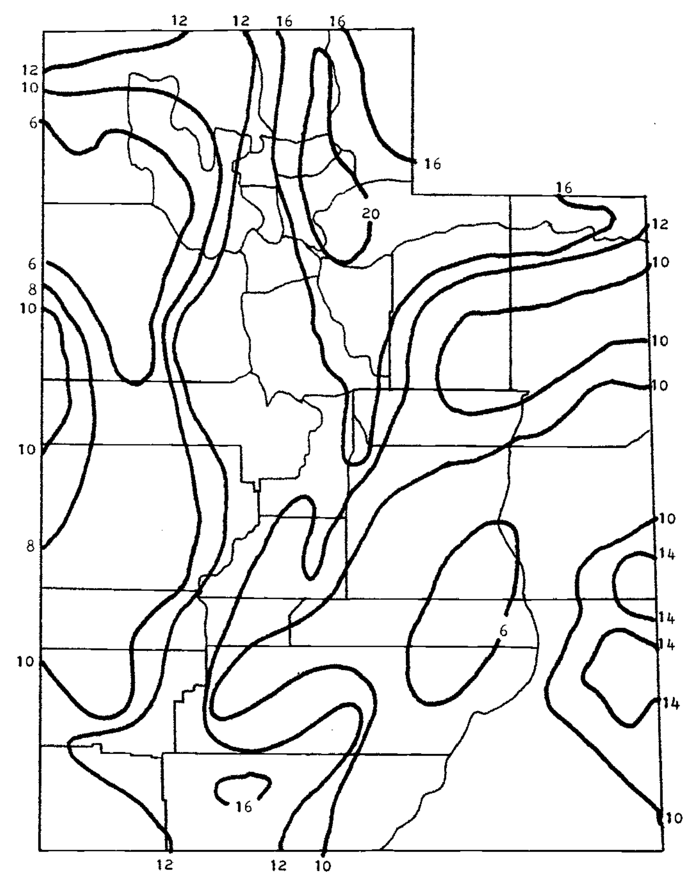


Figure 41. Average annual precipitation (inches) in Utah. (Adapted from Anonymous 1941.)

Figure 42. Wine grape producing areas in California. (Adapted from Holtgrieve and Trevors, 1978.)

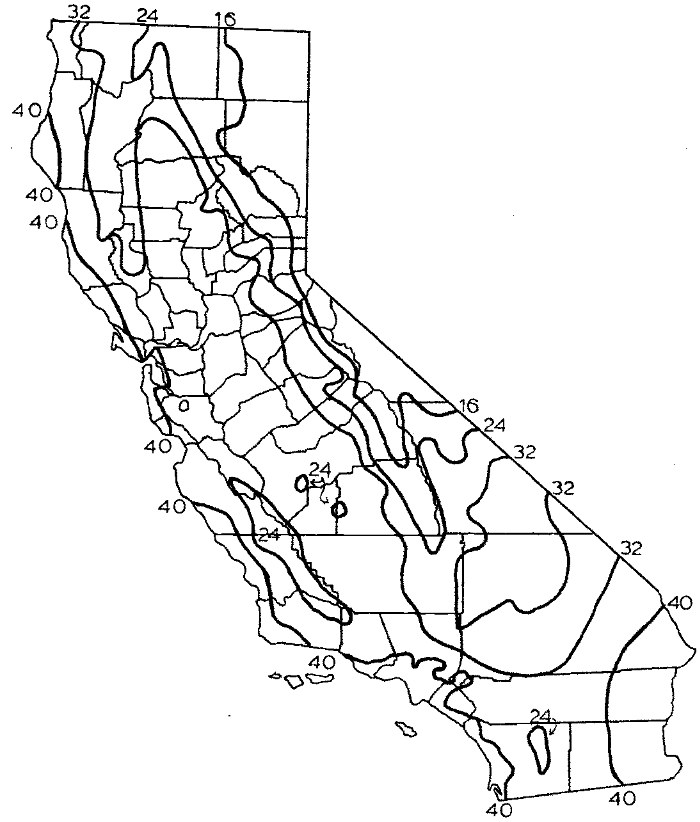


Figure 43. Mean minimum January temperature in California. (Adapted from Holtgrieve and Trevors, 1978.)

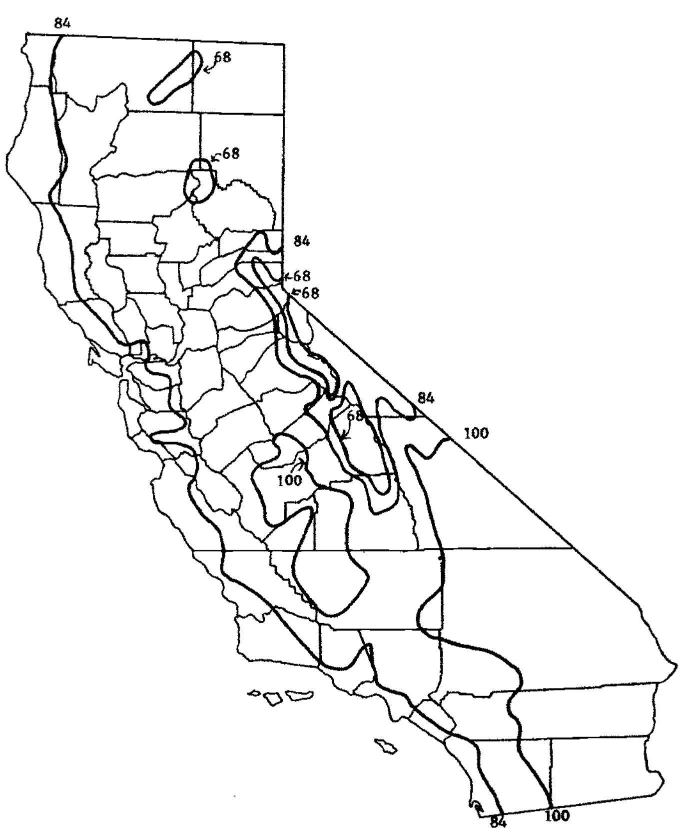


Figure 44. Mean maximum July temperature in California. (Adapted from Holtgrieve and Trevors, 1978.)

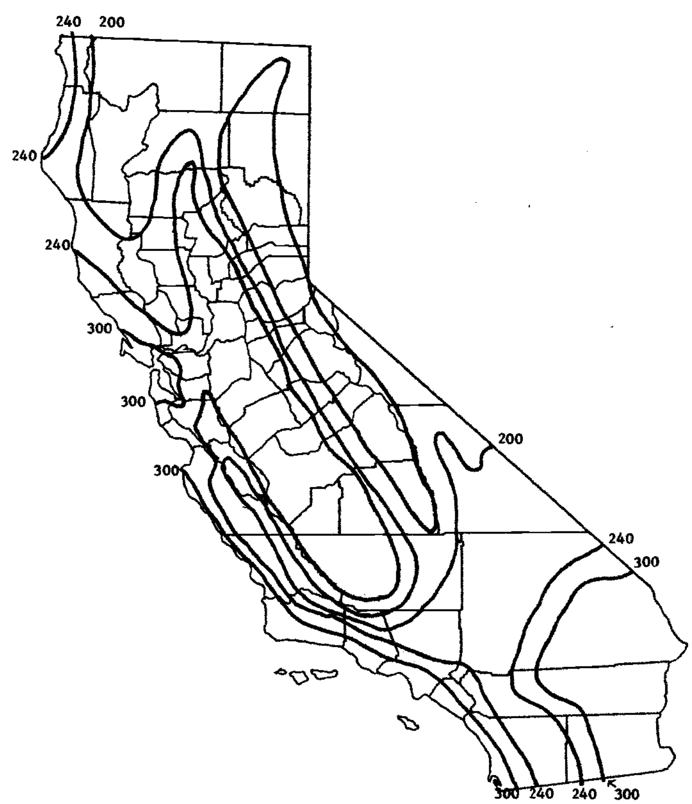


Figure 45. Length of growing season (frost-free days) in California. (Adapted from Holtgrieve and Trevors, 1978.)

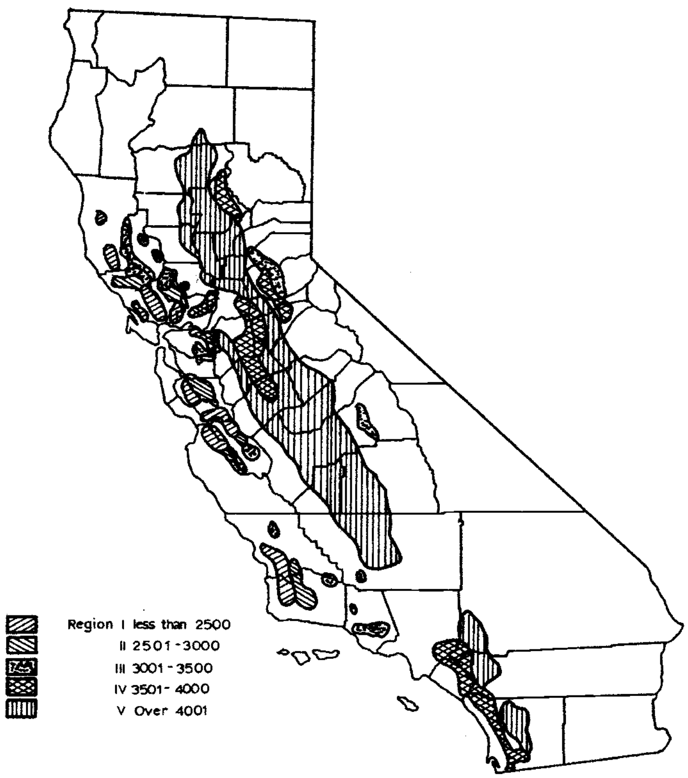


Figure 46. Climatic regions of California based on growing degree days base 50 F. (Adapted from Holtgrieve and Trevors, 1978.)

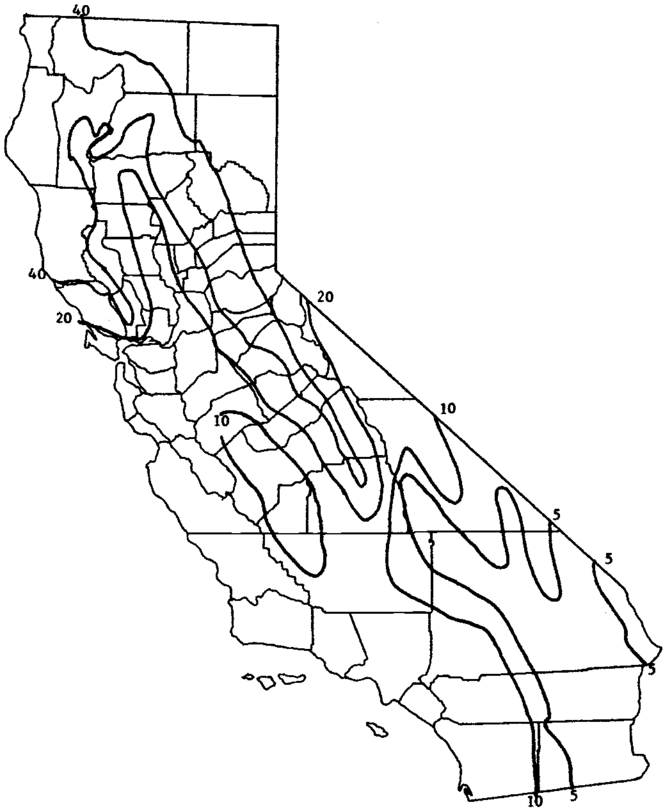


Figure 47. Average annual precipitation (inches) in California. (Adapted from Holtgrieve and Trevors, 1978.)

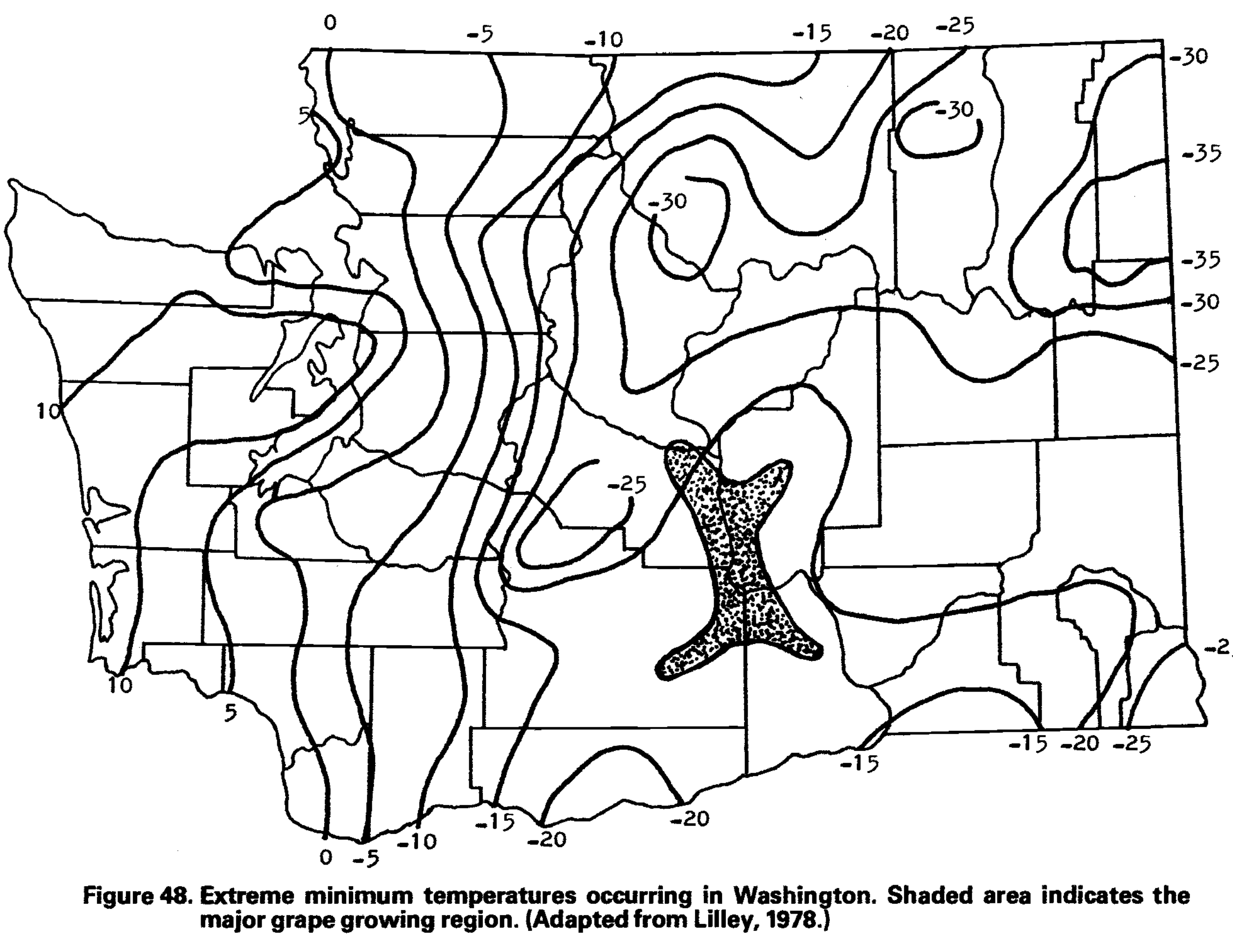


Figure 48. Extreme minimum temperatures occurring in Washington. Shaded area indicates the major grape growing region. (Adapted from Lilley, 1978.)

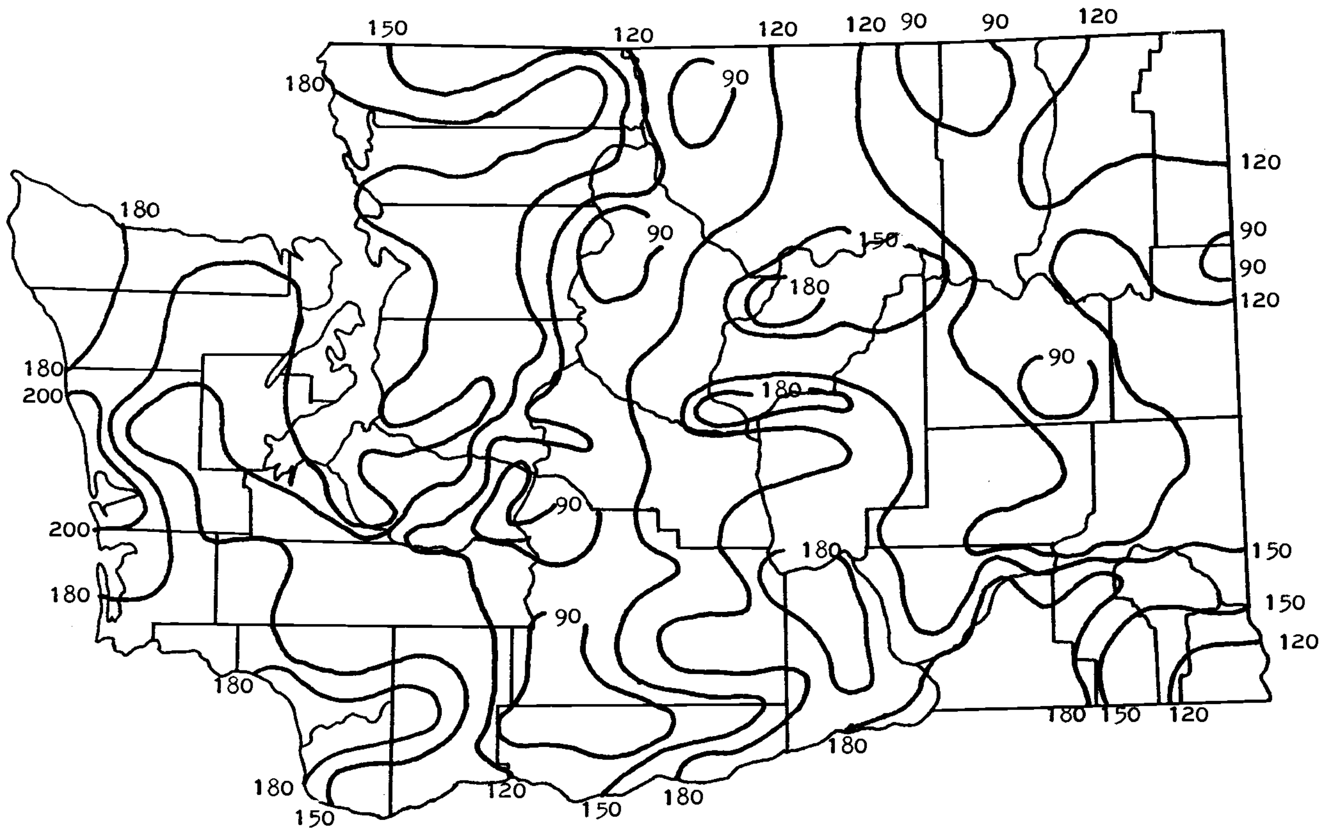


Figure 49. Length of growing season (days between 32 F occurrences) in Washington. (Adapted from Lilley, 1978.)

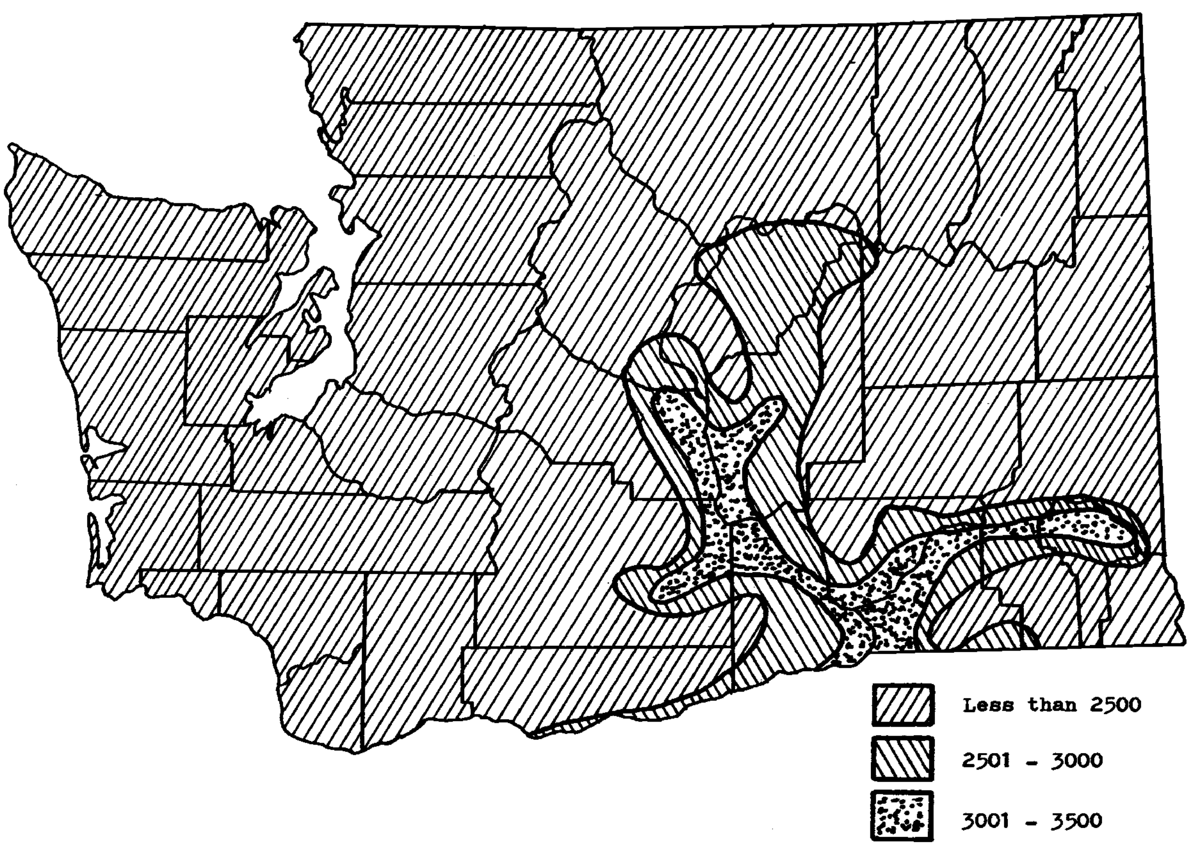


Figure 50. Average growing degree days (base 50 F) for Washington. (Adapted from Lilley, 1978.)

Table Grape Vineyard in Dateland, Arizona

SOILS

Much has been said about the effects of soils on grapes. Some writers have attributed much of the distinctive differences in wine quality to soils, while others have considered the soil as simply anchoring media which stores nutrients and water. This latter group tend to attribute the distinctiveness of wines to climate. It may be pointed out, however, soils are in themselves a product of climate. Indeed, soils developed from the same parent material under differing climates are in themselves as distinctively different as the wines which may be produced upon them. It is generally agreed that many soil properties are of importance to the production of grapes; therefore, any discussion of site selection at a vineyard would be incomplete without a discussion of soils.

Factors Affecting Soil Formation

Soils, like plants and animals, have distinctive characteristics which may be recognized by visual and chemical means. These soil characteristics are used to distinguish individual soil series, just as similar criteria are used to identify individual plant varieties. In soils differing characteristics are due to five soil forming factors: 1) Parent material, e.g., sandstone, basic igneous rock, marine sediments, 2) Climate, 3) Topography, 4) Living organisms, plant and microbiological, and 5) Time.

Parent Material

The starting point of any soil is the geologic material from which it was formed. The primary minerals of quartz, mica ... secondary minerals, clay, calcite ... and organic residues in these deposits are to a degree responsible for the soil's texture and chemical composition.

Climate

The climatic factors of rainfall, temperature, wind and seasonal patterns have influence upon soil properties. Rainfall affects the moisture content in soils. This in turn affects the chemical and biological activity responsible for weathering of the parent material. The transport of minerals by leaching is also dependent on soil moisture. Temperature, wind and seasonal pattern affect the above processes and, hence, weathering.

Living Organisms

Soils developed under differing plant covers have distinctively differing properties. Plants are continuously cycling nutrients. Nutrients present in the soil are taken up by plant life in the root zone. Retaining organic residue later decomposes on the surface. Since the uptake of nutrient differs, soils developed under grass are different in organic matter content and chemical and physical properties than those developed under forests. Microorganisms also are responsible for many chemical reactions occurring in soil, such as the conversion of sulfides to sulfates and the fixing of nitrogen gas into forms which may be utilized by plants.

Topography

The amount of surface fluid flow is determined by the relief of an area. This in turn influences other processes such as erosion and cold air drainage. Soils on steep slopes are usually thin and low in natural fertility, whereas the soils on the valley floors are deep and fertile. Plant cover is markedly affected by not only the slope, but also the direction the slope faces. A south facing slope will be warmer and drier than an east or north facing hill.

Time

The older a soil, the greater will be the effect of the soil forming forces on its development. Old soils tend to be highly leached of nutrient and tend to increase in acidity. Thus, the young valley soils again are more fertile than the older soils surrounding them.

SOIL CLASSIFICATION

Soils are an integration of the soil forming factors. These manifest themselves into visual and chemical properties which can be seen or determined. These soil properties are in turn used to classify soils. The classification system currently used in the United States has six categories or classification levels referred to as:

order—suborder—great group—
subgroup—family—series

The *order* is the most general classification and the *series* the most specific.

The details of the classification are beyond the scope of this publication. Thus, the discussion here will be limited to those names which are of importance to grape growing.

ORDER

Of the 10 different orders found around the world, only a few are used extensively for the production of grapes.

Entisols

This order of soils includes all soils which show no profile development. They are most frequently found on valley floors. They are commonly formed in recent deposits of alluvium or wind blown materials. These soils are frequently deep and fertile and capable of high production. Entisols are usually low in organic matter but high in base saturation. Slopes are usually 0–2%. These soils are usually irrigated in the Four Corners Region if water is available. When planted to grapes, high production occurs. Indeed, overproduction is frequently encountered, but can be controlled by pruning, as discussed elsewhere. Where there are perennial streams, high water tables may be encountered. Air drainage is usually poor, thus at locations about 2,000 ft. spring frost damage is prevalent, about 4,000 ft. both late spring frost and winterkill are encountered.

In California Entisols are utilized for wine grape production in most wine producing areas of that state.

These soils are known more for their high production rather than quality grape production. Frost protection from spring frosts is frequently provided in the northern regions of that state. In Washington Entisols are usually avoided because of winterkill problems. Formative elements are used in the nomenclature for orders. The formation element is *ent*.

Aridisols

These soils are light in color and low in organic matter. A few of these soils have been used for production of table grapes in Arizona and California and wine grapes in Washington. There are extensive areas of these soils present in New Mexico and Arizona. They usually occur on the sloping planes near the mountains and are low in natural fertility. The extent of weathering varies, but in general they are more weathered than Entisols. Irrigation is normally required for the production of grapes, but water harvesting has been utiized to provide the required moisture demand in the semi-arid regions where these soils occur. Cropping levels can be easily controlled on the soils because of their low fertility. These soils may be shallow and contain high sodium, soluble salts, gypsum and excessive lime. Any of these latter conditions would cause problems with vineyards. The formative element is *id.*

Alfisols

California's wine grape areas occur to a large extent on soils classified as belonging to this order. These soils are in higher rainfall areas than the Aridisols and consequently are more highly weathered. Like many of the Aridisols, they contain an argillic horizon, a clay layer just below the surface soils. However, the Alfisols are more highly weathered and leached of basic minerals. As with Aridisols, these soils frequently occur on good air drainage sites and are of low fertility. Whereas the Aridisols are usually basic in reaction, Alfisols are commonly acid. Due to their low fertility, cropping levels may be easily controlled, and consequently the quality of wines produced from these grapes is high. These soils usually occur at high elevations and relatively high rainfall areas in the Four Corners Regions. The formative element is *alf.*

Mollisols

A few soil series used for the production of wine grapes in California fall in the Mollisol order. These soils formed under grass cover and are usually high in organic matter and basic constituents in the surface soil. This surface layer is referred to as a *mollic epipedon*. Most soils of this order are found in climates adverse to grape production. However, at the fringe areas where these soils are found, adjacent to Aridisols or Alfisols, they can be used for production of quality wine grapes. At these fringe areas the organic matter would be at the low end for Mollisols. The formative element is *oll*.

Ultisols

These soils are more highly leached than the Alfisols. They commonly have a red subsoil and are more acid in reaction than the Alfisols. A few bordering on Alfisol, or the ones developed under somewhat dry conditions are used to produce wine grapes in California. They are important in the Four Corners Region in that some soils borderline in properties close to them. The formative element is *ult.*

SUBORDER AND GREAT GROUP As mentioned above, the different soil orders are further subdivided. Only a few of these subdivisions seem to be important to grape production. Some of the important suborder and great group formative elements and their significance follow:

Fluv: This suborder designates that the soil is a floodplain soil. Being in the lowest part of the drainage, it may be susceptible to flooding and winterkill. Vines usually are very productive.

Arg: Soil contains an argillic horizon (under the surface soil, an accumulation of clay occurs which was leached from the overlying material).

Torr: Soil formed under a dry climate. Since *vinifera* grapes are susceptible to many plant diseases under humid conditions, designation of dry conditions for a soil is important for order other than Aridisol, (desert soils).

Xer: This element indicating suborders shows that the soil has a climate which includes an annual dry period. This form is important for plant disease considerations.

Calc: This indicates the soil has a calcic horizon (a layer of >15% calcium carbonate or lime). The presence of high lime concentrations are often responsible for micronutrient deficiencies.

Dur: Soil contains a duripan which may significantly restrict root growth.

Hapl: Weakly developed horizon. Restriction of root penetration or waterflow would not be adverse.

Ust: Dry climate usually hot in summer. This element indicates a rainfall higher than Torr for at least a portion of the grape growing season. Also important for plant disease considerations.

Subgroups

Indicates whether a soil tends toward or is borderline to other soil orders, suborders or great groups. The formative elements of the above are utilized along with the suf fix *ic* in these borderline cases. If the soil is central to the name subdivision, the formative element Typ*ic* is used.

Family

Probably the most useful part of the soil name from a grape grower's point of view is the *family name*. This portion of the name gives information on the soil texture, clay minerals and temperature. Grapes are grown successfully on most textural classes and most soils tend to be of a mixed clay mineralogy. The temperature

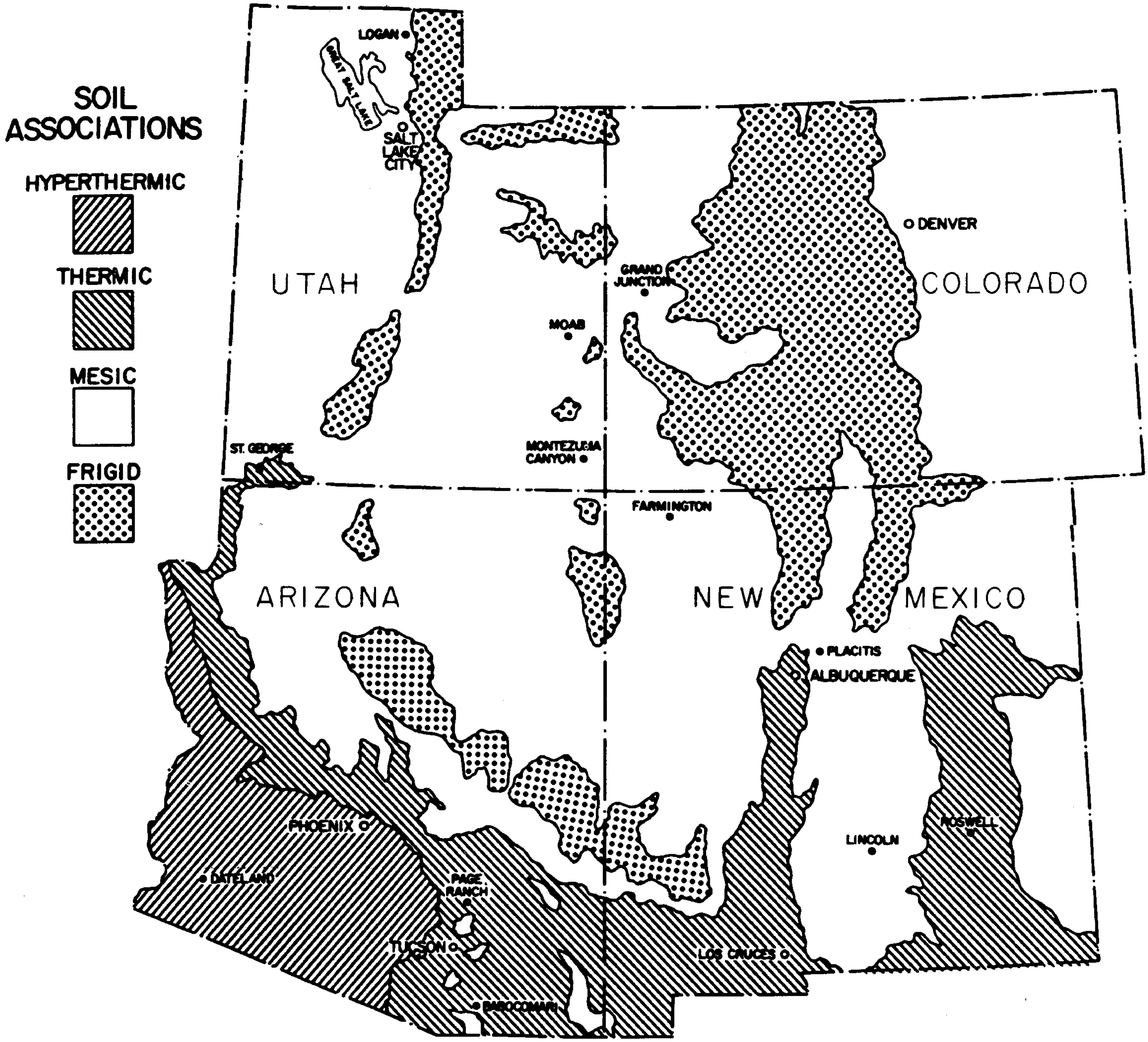


Figure 51. Soil associations map of the Four Corners Region.

consideration, however, seems to be one of the more important factors. The system used in evaluating the temperature regime of a soil is dependent on the mean annual temperature at a 50 cm depth. The formative element and their temperature ranges are:

Frigid	<8 degrees C or <47 degrees F
Mesic	8 degrees – 15 degrees C or 47 degrees – 59 degrees F
Thermic	>15 degrees – 22 degrees C or >59 degrees – 72 degrees F
Hyperthermic	>22 degrees C or >72 degrees F

Hyperthermic

Hyperthermic soils occur in California where grapes are grown principally in the Imperial and Coachella Valley. In these regions grape production is usually limited to the production of table grapes for early marketing. In the Four Corners Region, hyperthermic soils occur in southwestern Arizona. As in California, production of grapes is now limited to table varieties.

Thermic

Thermic soils are the most important soils for the production of wine grapes in California. These soils may be found from Riverside to Napa and Sonoma counties. It is within this soil grouping that the University of California grape zone classification system is principally used. It is of interest that the interface area between thermic and mesic, the next coldest region, is located in Napa and Sonoma counties. In the Four Corners Region wine grapes were successfully produced on thermic soils at different locations in Arizona, New Mexico and Utah.

Except in the low lying alluvial valleys, at elevations above 4,000 ft, few problems are encountered.

Mesic

Grapes are successfully produced on warmer locations that are found on mesic soils. As indicated above, some of the best wine grapes in California are produced on these soils. As one proceeds away from the thermic mesic interface, problems of spring frost and winterkill increase. Washington wine grape industry, for example, is located principally on mesic soils. Mesic soils were utilized in this study at sites in Utah, Colorado and New Mexico. The same problems with winterkill have also been found in these Four Corner vineyards but as in Washington high-quality wine can be produced.

U.S. COMPREHENSIVE SOIL NAME

As mentioned earlier, soil names give the:

order—suborder—great group—subgroup

The name is made up of the formative elements added ahead of the formative element of the order. Consider the White House soil series: It has a light-colored epipedon or surface so that it qualifies as Aridisol.

Order—Ar*id*isol: Formative element, id

Further: It has subsurface clay layer that has been formed by migration of clay downward (an *arg*illic horizon, formative element, arg).

Suborder—Argid

Further: The clay layer contains only enough clay to qualify as an argillic horizon (a minimum horizon, formative element, hapl).

Great Group—Haplargid

Further: It has dry climate but with some summer rain; formative element, ust. The soil borderlines belonging to the order Mollisol, hence has properties similar to the order Mollisol, formative element, oll.

Subgroup—Ustollic Haplargid

Further: The family name precedes the subgroup name and consists of three parts: 1) the texture of the control horizon, 2) the clay mineral present, and 3) the mean soil temperature as outlined previously. Thus, for our White House soil, the texture of the argillic or control section is fairly high or high in clay, hence it is called fine. The clay consists of a mixture of minerals and the temperature of the soil falls closest to the thermic group, thus the full name:

Family—White House—fine, mixed, thermic, Ustollic Haplargid

SIMILARITIES BETWEEN SOILS USED FOR GRAPE PRODUCTION

The names of soils which are taken from modern soil surveys of various counties in California, from Washington and from locations in the Four Corners Regions are shown in Table 2, 3, and 4. At first appearance the soil names seem divergent. However, there are several similarities among the soils. The formative elements for the orders Alfisol, alf; and Ultisol, ult; and the formative element arg are all soils containing an argillic horizon. Also, the order Mollisol (oll) and soils bordering on Mollisols (ollic or mollic), are frequently found. In fact, these are all soils with a minimal organic matter content in the mollic horizon. Aridisol, id, all contain a light surface layer that is low in organic matter. It will be noted that almost every soil name contains at least one of the following informative elements ust, (climate more moist than torric with rain concentrated in growing season, usually hot in summer); xer, winter ppt with long dry summer; toor (usually dry). Another common term found in the name of good grape soils is hapl or hapla. This term signified that the horizons are not extreme (should not cause a perched water table to form). One last term which keeps reappearing is ent indicating the order Entisol. These are soils with undeveloped profiles. Those used for grape production usually occur along the river bottom and have been discussed under Entisol above.

In conclusion, it may be said that soil considered for wine grape production should be low in organic matter, have an argillic and/or mollic horizon that is not strongly developed, hence permeable and with good drainage, have a dry climate, and have soil temperatures placing them in hyperthermic, thermic or lower mesic range. As will be seen later, the varieties suited to these various temperatures vary drastically and that the University of California climatic zones are principally limited to the thermic soils.

DELINEATION OF GRAPE-GROWING AREAS

As mentioned in the discussion of soils, grapes can be grown on soils belonging to the hyperthermic, thermic and mesic families. Of particular importance is what varieties may be grown on these soils to produce grapes in sufficient quantities to produce quality wines. To aid in these selections, the establishment of viticultural areas within the Four Corners Region seems advisable.

Five districts are proposed: **HT, T_l, T_m, T_h, M.**

HT: These viticultural areas are found in the low valleys of southern Arizona. They are areas where table grape production for early markets has been found to be profitable. Wine grapes can be grown for the production of mainly white table and desert wines. The site in this area, studied over the past years was Dateland, Ariz; analysis of wine grapes from our study are shown in the appendix. Recommended varieties are given later.

T_l: Viticulture areas so designated are found on thermic soil at lower elevations. The characteristics of grapes grown on thermic soil varies so widely that they must be subdivided for making varietal recommendations. Since altitude is closely related to soil temperature and the

Table 2. Soils used for grape production in California.

SERIES	FAMILY	SUB-GROUP	COUNTY
Bale	fine-loamy, mixed, thermic	Cumulic Ultic Haploxerolls	Napa
Cole	fine, mixed, thermic	Pachic Argixerolls	Napa, Sonoma
Coombs	fine-loamy, mixed, thermic	Ultic Haploxeralfs	Napa
Cortina	loamy-skeletal, mixed, non-acedic, thermic	Typic Xerofluvents	Napa, Sonoma
Hair	clayed, mixed, thermic	Typic Haploxeralts	Napa, Sonoma
Perkins	fine-loamy, mixed, thermic	Mollic Haploxeralfs	Napa
Pleasanton	fine-loamy, mixed, thermic	Mollic Haploxeralfs	Napa, Sonoma
Tehame	fine-silty, mixed thermic	Typic Haploxeralfs	Napa
Yolo	fine-silty, mixed, non-acedic, thermic	Typic Xerothents	Napa, Sonoma
Arbuckle	fine-loamy, mixed, thermic	Typic Haploxeralfs	Sonoma
Clough	clayed-skeletal, kaolinitic, thermic	Abruptic Durixeralfs	Sonoma
Goldridge	fine-loamy, mixed, mesic	Typic Haploxerults	Sonoma
Huichica	fine-loamy, mixed, thermic	Abruptic Haplic Durixeralfs	Sonoma
Sebastopol	clayed, mixed, mesic	Typic Haploxerults	Sonoma
Wright	fine, mixed, mesic	Mollic Albaqualfs	Sonoma
Red Hill	fine-loamy, mixed, mesic	Aridic Calcic Agrixerolls	Sonoma
Atwater	coarse-loamy, mixed, thermic	Typic Haploxeralfs	Fresno
Borden	fine-loamy, mixed, thermic	Typic Haploxeralfs	Fresno
Delh	mixed, thermic	Typic Xeropsamments	Fresno
Exeter	fine-loamy, mixed, thermic	Typic Durixeralfs	Fresno
Graingeville	coarse-loamy, mixed, thermic	Fluvaquentic Haploxerolls	Fresno
Hanford	coarse-loamy, mixed, non-acid, thermic	Typic Xerothents	Fresno
Hesperia	coarse-loamy, mixed, non-acid, thermic	Exeric Torriothents	Fresno
Madera	fine, montmorillonite, thermic	Typic Durixeralfs	Fresno
Pachoppa	coarse-loamy, mixed, thermic	Mollic Haploxeralfs	Fresno
Delhi	mixed, thermic	Typic Xeropsamments	Riverside
Hanford	coarse-loamy, mixed, non-acid, thermic	Typic Xerothents	Riverside
Hilmar	sandy over loam, mixed (calcareous), thermic	Aeric Halaquents	Riverside
Tujunga	mixed, thermic	Typic Xeropsamments	Riverside

Table 3. Soils used for grape production in Washington.

SERIES	FAMILY	SUB-GROUP	LOCATION
Burke	coarse-silty, mixed, mesic	Xerollic Durothids	
Hezel	sandy over loam, mixed, non-acid, mesic	Xeric Torriorthents	
Koehler	sandy, mixed, mesic	Xerollic Durothids	
Quincy	mixed, mesic	Xeric Torripsamments	
Sagemoore	coarse-silty, mixed, mesic	Xerollic Camborthids	
Shano	coarse-silty, mixed, mesic	Xerollic Camborthids	
Warden	coarse-silty, mixed, mesic	Xerollic Camborthids	
Prosser	coarse-loamy, mixed, mesic	Xerollic Camborthids	
Sagehill	coarse-loamy, mixed, mesic	Xerollic Camborthids	

delineation between hyperthermic, thermic and mesic soils is soil temperature, altitude is a convenient parameter to further separate thermic soils. The T_l areas are thermic soils below 3,000 ft. The sites where wines and grapes were evaluated include St. George, Utah and Tucson, Ariz. The analyses of musts and wine are in the appendix. Table grapes for later markets, and white and some red wines, can be produced.

T_m: These areas are found in mid-altitude, thermic soils. The altitude range is 3,000–4,000 ft. These areas are capable of producing red and some white table wines. Most of the popular wine grapes may be grown. Wine grapes grown in this area have good acidity and color. It would be expected that Entisols in the low-lying valleys would have moderate to severe problems with late spring frosts. Frost protection would seem advisable

Table 4. Soils used for experimental plots in the Four Corners Region.

SERIES	FAMILY	SUB-GROUP	LOCATION
Gila	coarse-loamy, mixed (calcareous), thermic	Typic Torrifluvent	Albuquerque, NM Tucson, AZ
Tremont	fine-loamy, mixed, hyperthermic	Typic Haplargids	Dateland, AZ
Whitehouse	fine, mixed, thermic	Ustollic Haplargids	Babocomari, AZ Page Ranch, AZ
St. George	coarse-silty, mixed (calcareous), thermic	Typic Torrifluvents	St. George, UT
Leeds	fine-loamy, mixed (calcareous), thermic	Typic Torrifluvents	St. George, UT
Ackmen	fine-silty, mixed, mesic	Cumlic Haplustolls	Montezuma Canyon, UT
Mesa	fine-loamy, mixed mesic	Typic Haplargids	Grand Junction, CO
Mayfield	fine-silty, mixed, mesic	Typic Torrifluvents	Grand Junction, CO
Billings	fine-silty, mixed (calcareous), mesic	Typic Torrifluvents	Grand Junction, CO
Throughfare	coarse-loamy, mixed (calcareous), mesic	Typic Torrifluvents	Grand Junction, CO
Reakor	fine-silty-mixed, thermic	Typic Calciothids	Roswell, NM
Reeves	fine-loamy, gypic, thermic	Typic Gypsiothids	Roswell, NM
Vinton	sandy-mixed, thermic	Typic Torrifluvents	Albuquerque, NM
Gabaldon	fine-silty, mixed, mesic	Ridic Cumulic Haplustolls	Lincoln, NM
Doak	fine-loamy, mixed, mesic	Typic Haplargids	Farmington, NM

Table 5. Acidity of grapes grown in the Four Corners' viticultural regions and California zones.

Four Corners		California	
Region	Grape Acid g/100ml	Zone	Grape Acid 0.47 g/100ml
HT	0.57	5	0.47
T_l	0.57	4	0.53
T_m	0.76	3	0.57
T_h	0.86	2	0.70
M	0.91	1	0.90

Table 6. Influence of regions on grape acidity and wine color.

Variety	HT	T_l	T_m	T_h	M
			Total Acid g/100ml		
Barbera	0.70	0.70	0.98	1.10	
Cabernet Sauvignon		.58	.75	.75	.87
Chardonnay	.68	.58	.82	1.06	.94
Gamay	.66	.70	.87	.78	1.03
Pinot noir	.56	.51	.72	.74	.81
White Riesling	.57	.64	.82	.90	.92
Zinfandel	.57	.56	.86	.89	1.10
			Color 420 + 520nm		
Barbera	.202	.324	.547	.406	
Cabernet Sauvignon		.354	.520	.536	.545
Gamay	.201	.190	.385	.324	.368
Pinot noir	.273	.298	.353	.282	.214
Zinfandel	.232	.334	.343	.332	.294

in all low-lying areas. Sites that were studied include Roswell, New Mex. and The University of Arizona Page Ranch.

T_h: These high-altitude, thermic soils are found at altitudes above 4,000 ft. Hillside areas where good air drainage exists are capable of producing premium white and red table wines from *vinifera* wine grapes. Varieties which have been found to produce wines of commercial acceptability are given later. A site which was evaluated was Babocomari, Ariz.

In the low-lying valley where one encounters Entisols, spring frost and winterkill would render the production of *vinifera* wine grapes uneconomical. In these areas, high-quality wine can be produced from French hybrid grapes. Typical site of this type was evaluated in Albuquerque, New Mex.

M: Mesic soils that border on thermic soils are capable of producing premium quality white wines from *vinifera* grapes. In these areas, frost and winterkill are a problem with even the most cold-resistant *vinifera*, and the growing season is too short for many *vinifera* red grapes. Red and white wines of high quality can be produced from French hybrid grapes. Sites of these soils which were evaluated include Lincoln, Placitas, Farmington, New Mex.; Moab, Bluff Bench, Montezuma Canyon, Utah; and Grand Junction, Colo.

The relationship of total acid in the must in the various Four Corner viticultural areas can be seen in Table 5. It will be remembered that the University of California's five grape zones are almost entirely on thermic soils. An average composition for three varieties from California may be compared with those for the Four Corners areas. Also, the relationship between the viticultural areas and color are shown in Table 6. It is interesting that the system as developed here seems to fit the California data. Thus, it may be possible to utilize much of the research findings from California in regions T_l, T_m, and T_h.

SITE SELECTION

Without a doubt the most important considerations which must be made in developing a successful grape vineyard is the selection of a site and the grape varieties to be planted. One may either evaluate a particular area for a site and varieties to plant at the site, or choose an area in which to plant certain varieties. In either case, one needs to be able to evaluate a site or possible site. As has been indicated earlier, the selection of site should consider the soil, air drainage and water available for irrigation. Every site is different but the recommended procedures followed are similar. The procedure will be presented along with an example.

The evaluation of a site should start with a soil map of it. Many areas within the Four Corners Regions are covered by reconnaissance surveys. These are useful in selecting a general area to select possible sites. See Figure 52 which shows a segment of a soil survey in which a site for closer evaluation was selected. Note that an 85-acre site has been selected as outlined on the map; also, there are only two mapping units shown on the survey (WgC and BhD). Upon consulting the text it is found that the mapping units can contain various percentages of several different soil series and that the soils within the site could contain all or just one of these series. Hence a detailed oil survey is best used to evaluate a site for establishment of a vineyard. A detailed soil survey of our example site is shown in Figure 53. If detailed surveys are not presently available, then such a survey can be

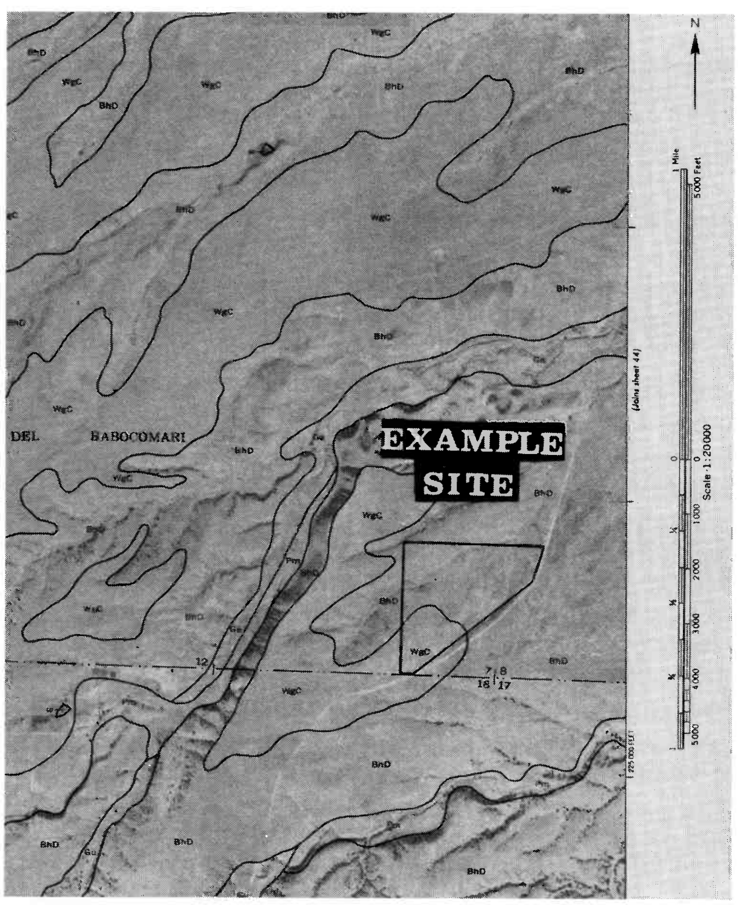


Figure 52. Reconnaissance Survey.


Figure 53. Detailed soil survey.

conducted by the Soil Conservation Service and map provided the owner. For those wishing to purchase a site and wishing to evaluate the site for grape production, it is recommended that they contact a consulting soil scientist with mapping experience in the area of interest. The State soil scientist of the Soil Conservation Service can provide a list of consultants for those interested.

Note that there are five mapping units on the intensive survey; WH, BR, SN, PM and HA. The description of these mapping units are provided by the SCS and shown in figures 54, 55, 56, 57 and 58. Note also that the soils are deeper than 60 inches and are suitable for irrigation. The complete soil names may be requested from the SCS. For example:

Soil Conservation Service—Arizona August 1968

LAND CAPABILITY UNIT IIIs8
(Irrigated)

Soils in this capability unit *have very slowly permeable subsoils*. They are nearly level and are subject to no more than slight water erosion. They have moderately fine through coarse surface textures and may contain lime and slight amounts of salt and alkali.

These soils are suited for growing most climatically adapted crops under conservation management.

Conservation treatment includes conservation cropping systems, crop residue use and irrigation water management.

Minimum tillage is important and care must be exercised in irrigating to attain adequate penetration of water in the slowly permeable subsoils.

Seasonal protection from wind erosion may be necessary on the coarse textured surface soils.

WH—White House gravelly loam, 0 to 5% slopes—This soil has a surface layer of gravelly loam about 6 inches thick. The subsoil is a clay to a depth of 40 to 60 inches, which is underlain by a clay loam substratum. Infiltration is moderate, permeability is slow, and water holding capacity is high.

Figure 54. White House.

Soil Conservation Service—Arizona May 1968

LAND CAPABILITY UNIT IVe6
(Irrigated)

Soils in this capability unit are gently sloping to moderately steep and *are subject to moderate to very severe erosion. They have coarse fragments in the soil profile.* Textures may vary from moderately fine to moderately coarse.

These soils are suited for growing most climatically adapted crops under intensive conservation management.

Conservation treatment includes erosion control measures, conservation cropping systems and irrigation water management.

BR—Bernardino very gravelly loam 8 to 40% slopes—This soil has a surface layer of very gravelly loam or gravelly loam about 6 to 8 inches thick. The subsoil is a gravelly clay or gravelly clay loam to a depth of 25 to 40 inches. The substratum is variable, typically a gravelly clay loam. Infiltration is moderate, permeability is moderately slow, and water holding capacity is high.

Figure 55. Bernardino.

Soil Conservation Service—Arizona August 1968

LAND CAPABILITY UNIT IIs7
(Irrigated)

Soils in this capability unit have *limited water holding capacity* in the soil profile. They are nearly level and are subject to no more than slight water erosion. They have moderately fine through coarse surface textures and may contain lime and slight amounts of salt or alkali in the profile.

These soils are suited for growing most climatically adapted crops under conservation management.

Conservation treatment includes conservation cropping systems and irrigation water management. Special attention to frequency of irrigation and the amounts of water applied is important. Minimum tillage is desirable, particularly on the moderately fine textured soils.

SN—Sonoita sandy loam, 0 to 3% slopes—This soil has a surface layer of sandy loam about 6 inches thick. The subsoil is a sandy loam or heavy sandy loam to at least 60 inches. Infiltration is rapid, permeability is moderately rapid, and water holding capacity is medium.

Figure 56. Sonoita.

Soil Conservation Service—Arizona | August 1968

LAND CAPABILITY UNIT I-1
(Irrigated)

Soils in this capability unit are nearly level and are subject to no more than slight erosion. *They are deep and well drained with moderately fine through medium textured surface and subsoils.* They have moderate to moderately slow permeability and good water holding capacity (1.5 inches or more AWC per foot of depth). They are relatively free of salt or alkali.

These soils are suited for growing all climatically adapted crops under normal management.

Conservation treatment includes conservation cropping systems and irrigation water management. Minimum tillage is desirable, particularly on the moderately fine textured surface soils.

PM—Pima silty clay loam, 0 to 1% slopes—This soil has a silty clay loam surface about 10 inches thick. The substratum is a silty clay loam or clay loam to at least 60 inches. Infiltration and permeability are moderately slow and water holding capacity is high.

Figure 57. Pima.

Soil Conservation Service—Arizona | August 1968

LAND CAPABILITY UNIT IVe6
(Irrigated)

Soils in this capability unit are gently sloping to moderately steep and *are subject to moderate to very severe erosion. They have coarse fragments in the soil profile.* Textures may vary from moderately fine to moderately coarse.

These soils are suited for growing most climatically adapted crops under intensive conservation management.

Conservation treatment includes erosion control measures, conservation cropping systems and irrigation water management.

HA—Hathaway gravelly loam, 8 to 30% slopes—This soil has a surface layer of gravelly loam about 8 inches thick. The substratum is a calcareous loam or clay loam to at least 60 inches. Infiltration is moderate, permeability is moderate, and water holding capacity is high.

Figure 58. Hathaway.

White House—fine, mixed, thermic; Ustollic Haplargids
Bernardino—fine, mixed, thermic; Ustollic Haplargids
Sonoita—coarse-loamy, mixed thermic; Typic Haplargids
Pima—fine-silty, mixed (Calcareous), thermic; Typic Torrifluvents
Hathaway—Loamy-skeletal, mixed, thermic; Aridic Calciustolls

The elevation of the example sites is between 4000 and 5000 ft. for the White House soil, from the family name, we see it is thermic, and also contains the formitive element Ust, oll, Hapl, arg and id, all of which are associated with grape soil, see p. 26. Since the family, subgroup, great group, suborder and order are identical for Bernardino, you would also conclude it would be a good grape soil.

The Sonoita is also a thermic soil and contains the formitive elements Hapl, arg and id. These again are elements commonly found in grape soil, so it would indicate that this series would also be useful for the production of grapes.

For the Pima soil, elements include Torri, fluv and ent. Although Torri would have a good conotative fluv, and ents indicate that these are flood plain soils, one would not expect good cold-air drainage.

Hathaway series contains the elements id and oll which have a positive influence. However, it also contains calc, which indicates a calcic horizon that contains over 16% $CaCO_3$, and would have very adverse effects on grape nutrition.

Our example site is located in an area that falls about 4000 ft. Thus, these soils fall under viticulture area T_h. Since the pima soil is an Entisol, see page 25, they should only be used for the production of French hybrids. However, they are in such a narrow channel they would best be left as a grass waterway for erosion control. The Hathaway would not be a good soil for producing grapes and location where it is found would be best used for utility areas.

For the Sonoita, Bernardino and White House soils several varieties (see page 101) could be considered for planting. Since most of the area would be plantable to good grape varieties, one would conclude that our example site would be acceptable.

Vineyard at Las Cruces, New Mexico

VINEYARD ESTABLISHMENT

Land Preparation

On previously cultivated land not much preparation is usually necessary. On new land it is necessary to remove trees, stumps, rocks and any noxious weeds. It is best to destroy rodents at this time.

Weeds

On previously cultivated land which has been properly cared for, there are not many problems with perennial weeds. If the land has been poorly managed, or the area has not been cultivated, several noxious, perennial weeds may exist. The main weed problems encountered include: Field Bindweed, Puncture Vine, Bermuda Grass, Johnson Grass and Nut Sedge. While cultivation can reduce populations, it is time consuming. Chemical control is usually the better choice. It is best to try to control these perennial weeds prior to planting the vineyard.

Animals

The main animal pests include gophers, ground squirrels, rabbits and deer. Animals are more of a problem on native and cultivated land which borders on wild areas. Gophers and ground squirrels may be controlled using poisoned bait. Rabbits may be reduced by hunting, however, they cannot be eliminated. Reducing the local population will only result in others moving in from outside areas. The best control is to construct a fence 2½ ft high around the field. The fence should be buried 6 inches into the soil to prevent burrowing under. Deer are also best kept out by the construction of a fence. It must be as high as 12 ft to completely prevent entry; however, 6 to 7 ft fences are often sufficient to discourage entry. Deer repellants have been used, but they are not always effective. Antelope may be excluded by using woven wire since they do not jump over fences, but may crawl through or under a barrier. For further information see the section on pests and diseases.

Drainage

Because grapes are deep-rooted, drainage is a greater concern than in other fruit crops. Drainage problems seldom exist on natural slopes; however, low-lying areas are frequently poorly drained. If the drainage problem is caused by compaction or the presence of hard impervious layers (hardpan), ripping or deep subsoiling is helpful in breaking up the layer to allow moisture to drain into lower, sandy layers. On heavy soils, where the moisture cannot drain to the lower depths, or in areas where high water tables exist, it is usually necessary to install drain lines. As mentioned earlier, drainage problems are mainly associated with Entisols.

Leveling

The necessity of, and degree to which, leveling is employed depends on the soil, the type of irrigation system, topography and the amount of water available. Flood or furrow irrigation systems require that the soil be level or nearly so. If drip or sprinkler system is used, little if any leveling is usually needed.

Regardless of the irrigation system employed, it may be necessary to construct terraces or contours on steep soil in order to collect the available rainfall, prevent erosion and in some cases provide an area which can be cropped. If possible, grapes should not be planted where the surface soil has been removed.

If the water supply is limited, sprinkler or drip irrigation system can stretch the available supply.

Soil Preparation

Assuming the soil is cleared at the desired slope and is uniform in texture, it is only necessary to plow 8 to 10 inches deep. It is then smoothed to aid planting. If the soil is compacted or underlain by impervious layers, such as durapan, it will be necessary to rip the soil to loosen these areas. If it is nonuniform in either texture or depth, it will be necessary to design the irrigation system to deliver water properly to the entire area. This is necessary if uniform growth and production is to be obtained. Sandy areas tend to be too dry, while areas of heavy soil could remain too wet and cause root damage.

Laying Out the Vineyard

A well-planned and well-laid out vineyard is not only aesthetically pleasing but eases cultural operations which may result in increased quality. Any operation requiring mechanization will be performed more quickly with less damage in the well-planned vineyard.

Length of Rows

Fewer, longer rows means less time involved in cultural operations and more vines per acre. Wider row spacings result in cheaper operating costs, since wider equipment can be used, thus reducing travel time per acre.

The major consideration in determining the length of row is the type of irrigation system used; this in turn is a manifestation of soil texture and uniformity, slope and the quantity of water available and the distribution of size of the line in the case of a precision irrigation system. On light, sandy soils where surface flood or furrow irrigation systems are used, row lengths rarely exceed 320 ft. On heavy soils with relatively low amounts of water available and nearly level conditions, runs of 660 ft are not uncommon. Sprinkler irrigation runs may be up to 1000 ft long, depending on the volume, output and size of the main and lateral irrigation lines. Drip or trickle irrigation system, range from 300 to 600 ft in length.

Spacing

The best spacing of vines within the row and between the rows depends on the texture of the soil; the climatic conditions, especially temperature and humidity; the varieties grown; the amount of moisture in the soil; the fertility of the soil; the methods used for cultivation; the topography and the available labor supply. Most of these factors contribute to the vigor of the vine, and more vigorous vines require a larger amount of growing space.

Economics also plays a role in determining the best spacing. Wider spacings make cultural operations less expensive, especially where mechanized equipment is employed. Wide spacings make it easier to mechanically haul the fruit out of the field rather than to manually carry it. Brush may be more easily incorporated into the soil of wide-row spaces rather than removed manually. This becomes very important where laws prohibit burning of agricultural wastes. The mechanized application of sprays and dusts is not only faster, but provides better coverage than manual application. Travel down the rows is necessary to cultivate for weed removal and to make the breakdown irrigation furrows.

On the other hand, high costs for land promote the concept of high-density planting. With new plantings, as the number of vines planted per unit area increases, productivity per unit area increases. Vines come into bearing quickly and reach their mature capacity in about 5 to 7 years. During this short period, any increase in planting density will increase production. Economically, the increased cost of plant, stakes and cultural operations is not offset by the increased production from temporarily increasing plant densities.

When deciding what spacing to use, the basic rule is: use the widest possible spacing which will not reduce productivity.

For *vinifera* and French hybrid grapes grown, using full mechanization, normal between-row spacings are 10–12 ft, and in-row spacings are 6 to 8 ft. In desert areas and warm valleys 8 x 12 ft spacings are used for table fruit. Research by the University of California has shown that vigorously growing wine varieties planted 7–8 x 12 ft, while in cool areas, spacings may be as close as 7 x 7 ft for low producing varieties. Other viticultural areas, such as in France and Germany, practice even closer spacing. With cane or cordon pruned varieties, the normal spacing is 6–7 x 11 ft. Nine–10 ft between-row spacing is the minimum which can be used where mechanical harvesting is anticipated. On steeper slopes, where terraces are used, single rows are planted on each terrace, and terraces are 12–25 ft apart. In-row spacing is 6–7 ft.

American varieties are generally less vigorous, and can be planted at higher densities. These commonly range from 8 x 8 ft to 10 x 10 ft. The most common spacing for Concord is 8 x 9 ft.

Drive Rows

Where between-row spacings are 12 ft or larger, no drive rows running parallel to the rows are needed. If the between-row spacing is less than 12 ft it is necessary to construct 16-ft wide drive rows approximately every 660 ft. Avenues running across the rows are usually spaced every 330–660 ft depending on the length of the irrigation runs. The minimum width of the avenues should be 20 ft to enable equipment to turn, but 30 ft is better.

Row Direction

Where contour terraces are used, a single row is planted following the line of the contour or terrace. In larger areas where a uniform pattern of plants can be established rows are generally established in direction of the longest contour. If the area to be planted is larger than the longest practical irrigation run, orientation is based on the grapes.

In the production of early table grapes, row orientation is usually in the north-south direction. This orientation allows maximum light exposure of the greatest amount of foliage, thus increasing the rate of sugar accumulation.

Vine Location

Where vines are planted in a single line on a contour or terrace the vines are simply set in place a standard distance apart in the predesignated line. Where larger blocks are established and the plants arranged in some type of organized pattern (usually rows), it is necessary to establish position of the rows and the location of the plants in the rows by the establishment of base lines. Two base lines are constructed, both straight and at right angles to one another for rectangular plots.

The line for the first row of plants (the plant line) is established in the direction of orientation desired. It is usually established along one side of the field using the property line (if the property line is straight). The second line establishes the distance between rows (the row line) and the location of the first vine. The row line is established at right angles to the plant line using a transit.

Neither the first plant line nor the row line nor the first plant in the row can be established directly on property lines. Some space is required on all sides of the plants for normal management operations. Normally a distance equal to the between-row spacing is left at the side of the field. This side land area should be wide (16 ft) if it is to be used as a primary road through the vineyard and is bordered by a fence. Headlands, the area between the first (or last) plant in the row and the edge of the field, should be great enough to allow equipment to turn around. The minimum distance is approximately 20 ft; however, 30 ft is better. Some growers shorten this area if they are located next to a county road or highway. It should be noted that county officials frown on growers using the public roadways for turning equipment, because the practice may leave dirt and debris on the road, or the heavy equipment may damage the road surface. It is also unsafe since motorists may not see the equipment in time to avoid hitting it.

Once the first plant line and the row lines designating the first and last vines in each row are established it is an easy matter to locate the remainder of the plants. The first and last vine in each row are usually designated by a small stake. A planting wire or tape measure can be used to locate the plant within the row. The planting wire can be either purchased or made. It consists of a length of 11 guage smooth galvanized wire with buttons of solder placed at the designated intervals of planting. When the wire is stretched in the row it is then a simple matter to locate the plants.

Where the soil is fairly loose and the planting hole dug by hand, small stakes are usually used to mark the vine location. If the permanent stakes are not to be placed in the field until the first winter after planting, the vines are planted to these small pegs. If the permanent stakes are to be placed prior to planting, the small pegs serve as locators for the stakes. If the planting holes are to be dug with an auger, small stakes can be used to locate the vines by marking, with stakes, each vine location in the first and last row and the end vines in all in-between rows. A single shank mounted on the rear of a tractor is used to mark lines across the field which indicate location of the rows and the position of the vines. Planting holes are then augered in at the intersection of the lines. For the system to work well the tractor operator must be able to drive straight lines. Small variations in placement of the vines within the row is not too critical. Deviations in row spacing, however, are critical in terms of movement of specific equipment.

Planting Stock

In picking the planting stock it is necessary to know what vines will do well in a specific location. For recommendations on varieties consult the secontion on varietal recommendations. In addition to knowing what will grow, one must know if there is a market for the fruit, because a grower must be able to sell his produce. The producer might be able to grow the best Cabernet Sauvignon, but if wineries are only interested in white fruit, the market is limited. One should, therefore, have an outlet in mind when selecting varieties. If a contract with a winery can be arranged prior to planting, this should serve as a guide to what should be planted.

Own-Rooted Vines

In most parts of the United States vines are established on their own roots. This is not true of the rest of the world. Own-rooted vines are the cheapest to buy and the easiest to propagate. Cuttings (a piece of cane 12 to 18 inches in length with three to five buds) are the cheapest source of material available. These may be planted directly into the field or they may be established in a nursery for one season before being transplanted to the field as rootings. The direct planting of cuttings is not recommended since the percent take is low (60 to 80%) and it is necessary to cultivate a large area to care for the plants. Vines started in the field do respond faster the first few years; however, by the 3rd or 4th year there is no difference. Plantings of rootings (1-year-old rooted cuttings) results in faster completion of planting as the survival rate is approximately 95%.

If propogating material is at a premium and it is necessary to propagate large quantities of plants quickly, greenhouse propagation of green rooting may be done. These plants are generally short, and unless care is taken, the crown of the root system may be established too close to the soil surface. This may affect winter survivability in climates where the soil freezes. Survivability of planting in warmer areas is about the same as for rootings if the plants are properly conditioned to withstand direct sun and lower humidity.

Rootstocks

Rootstocks are frequently used whenever there are problems with nematode, phylloxera or root rots. Specific rootstocks may be helpful in increasing winter hardiness.

Rootstocks may be established in the field as described for the own-rooted vines. Once they are established they can be budded or grafted to the desired variety. It is possible to do the grafting before planting. Bench-grafted vines, while more expensive, already have the desired top on the desired root system. The bench grafts are handled as though they were own-rooted plants except in regards to planting depth (see below). For bench-grafted vines, the buds of the rootstock should be removed to prevent their needless growth. They usually come into production 1 year earlier than if rootstocks are planted in the field and then budded or grafted.

Plant Quality

The price for cuttings, rootings and greenhouse-propagated plants varies greatly from nursery to nursery and with the quality of material. The most common quality grades (not size or age) are certified, registered and common (or standard). Certified vines are those which are propagated from a mother plant which was tested (indexed) and found to be free of viruses and diseases. To be able to propagate a certified vine, the mother plant must be reindexed every 5 years.

Plants propagated from a mother vine not reindexed every 5 years are said to be registered. Registered vines may also be propagated from other vines which were established from registered materials. While registered vines are not guaranteed to be free of objectional viruses or diseases they are usually clean if normal care is taken at the nursery.

The third classification is common. These plants have an uncertain background. While they are selected from vines with no visual symptoms at the time the cuttings are taken, they may be contaminated.

Plants found to be contaminated with viruses and diseases can be free of the condition by a heat-treating process. This treatment can be completed by specific plant introduction centers. This process not only gets rid of the known problem but destroys any unsuspected problems as well. Heat-treated vines are available at a higher price than certified ones. While the idea of removing all viruses from wood may initially seem desirable this may not be the case. It is generally assumed that all viruses or diseases are objectionable and reduce production and quality, but viruses and diseases may be beneficial. There are reports from around the world which indicate yield and quality have been reduced by heat-treating. This is not to say that a grower should not select heat-treated wood, but that one should be careful. A grower should not purchase or propagate wood with known virus and disease problems.

Soil problems (ie. nematodes, phylloxera and root rots) may be spread by contaminated soil which is moved from an infested area to a new area by cultivation equipment. Another way to move these problems is to propagate vines in a contaminated area and then transfer them to a clean area. This is not done knowingly, but it can and does happen. While treatments are available which may kill the objectionable organism, these are not sure guarantees that the problem is solved. It is best to propagate the vines in clean areas only. Tests can be made to determine if soil problems exist.

Propagation

Plants can be propagated in two ways, either sexually or asexually. Sexual propagation is done using the seed, which bears characteristics of both parents. In grape production, propagation by seed is used only in breeding programs, to give rise to new varieties.

Asexual propagation, or reproduction from vegetative plant portions, is used to increase the number of plants of each fruiting and rootstock variety. Plants propagated in this manner are exact genetic duplicates and therefore maintain the qualities of the plant from which the vegetative plant portion was taken. Originally all vines are propagated by cuttings, and most vines in the United States are grown on their own roots. If necessary, grapes may be propagated onto rootstock which are resistant to specific soil problems. This propagation is done by budding or grafting the desired scion (fruiting) variety onto the selected rootstock. Bud and grafting can also be used to change varieties in an established vineyard if changes in the market occur.

Cuttings

Cuttings are made from 1-year-old dormant canes. This wood is the most desirable because it yields the highest percentage of rooting. Two-year-old wood may be rooted but with a lower rate of success. The ease with which varieties root is variable. Most of the *vinifera* cultivars root very easily. American and French hybrid varieties root a little less easily, and the native American species are sometimes difficult to establish.

Making the Cuttings

The best cuttings are made from wood approximately 1/2 inch in diameter that is properly matured with normal intermodal length. Wood which is smaller than this may not have sufficient reserves to root properly. Ability to root, and strength of growth is directly related to stored carbohydrates. Canes which are larger than 1/2 inch and have long internodes tend to root poorly.

Well-matured canes will have a tan color. If the cane has a grayish appearance, it is either poorly-matured or may be contaminated with powdery mildew. Cuttings are made 12 to 18 inches in length and should contain 3 to 5 nodes. The basal cut is made through the node. This both kills the bud and exposes the diaphragm of cambium, which increases the rate of callusing and root development. The upper cut is made 1 to 1-1/2 inches above the top node and at a 45 degree angle. Thus, when the cuttings are later planted, it is very easy to tell the top from the bottom, and they may be properly inserted.

Storage of Cuttings

The cuttings may be planted immediately to the nursery row or greenhouse, or they may be stored for a period of time. For storage the cuttings are bound together in bundles of 50 or 100. They may be buried in moist sand outside, if weather conditions are suitable, or stored in cold rooms if properly protected against drying. The room should be held between 35 and 40 degrees F. To keep the cuttings moist they may be stored in plastic bags with moist toweling or peatmoss, shavings, sawdust. Redwood shavings are particularly good as they will retard molds and fungi.

Planting: Cuttings are normally rooted outside in nursery rows. The cuttings are placed in rows 36–40 inches apart, and 4–6 inches within the row. A trench is formed with a shank or a plow, into which the cuttings are inserted, and the soil is pressed back to seal them. The soil is usually fumigated prior to planting to destroy harmful organisms which are present. The cuttings are placed perpendicularly in the soil with only the top bud exposed. The rows are then watered to settle the soil, and the exposed bud is covered with 2 inches of loose moist soil to keep it from drying. The cuttings may be irrigated by flood or sprinkler; however, care must be taken to prevent the soil surface from forming a crust which would prevent the shoot from emerging.

Cuttings may also be established in the greenhouse to get an earlier start on growth. Unsealed, 1 quart milk cartons make excellent containers for rooting vines. The milk cartons are placed upright in a box or flat, filled with a suitable potting mix and the cutting pushed into the container. The base of the cutting should be approximately 3 inches from the bottom of the container. The cuttings are watered as necessary, and the temperature is held at 70 to 80 degrees F (soil heat underneath is usually beneficial). Within several months the cuttings will have developed roots and shoots and are ready to be hardened off so they may be taken to the field as soon as the chance of frost is past. When planted, the milk carton may be pulled above the soil line, affording protection to the young plant.

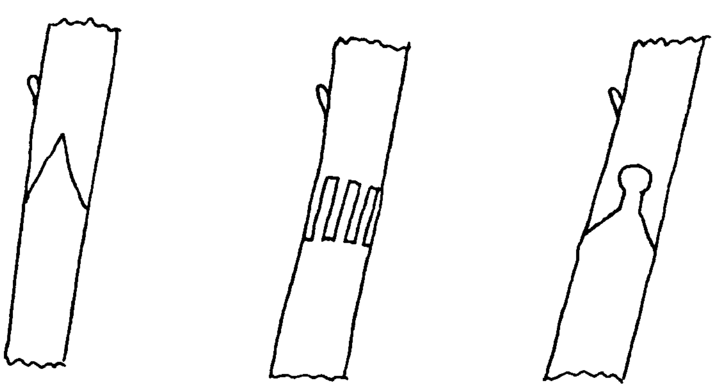
Often sufficient wood is not available to start enough 12- to 18-inch cuttings. With greenhouse propagation techniques smaller two-bud cuttings can be made. They will root and grow as well as the longer cuttings. Special care must be taken with the smaller cuttings so the root crown will be planted deep enough when planting in the field.

Softwood Cuttings: Where the supply of propagating material is extremely limited it is possible to quickly build the number of new plants in the greenhouse. Cuttings are made from shoots during the current growing season. These green shoots are cut into one-bud segments with the leaves attached. They are dipped into a rooting compound and placed in vermiculite or perlite on a bench in the greenhouse. Heating tables are used to maintain the rooting medium at 80 degrees F, and a mist system is used to prevent the succulent leaves from drying. Within 6 to 8 weeks the cuttings will have rooted and developed a shoot 6 to 8 nodes long. These new shoots are then cut into one-bud pieces and the procedure repeated. It is possible to propagate six generations in 1 year. Assuming an average of seven new cuttings from each plant in each generation, it is possible to generate 16,800 plants from each originally started node.

Digging the Rootings: Cuttings rooted in the nursery row are allowed to develop during the summer and enter rest in the fall. They are dug during the winter with shovels or a mechanical knife mounted on the back of a tractor. The top of the rootings is cut to a single shoot with two buds. The rootings are sorted to remove any which made too little growth, those with deformed root systems or other disorders. Rootings which made too little growth may be replanted in the nursery row to grow for another year. Roots on the healthy rootings are cut back to 3 to 4 inches and any broken or deformed roots and any roots within 8 to 10 inches of the soil surface removed. The rootings are tied into bundles of 50 or 100 and stored as described for cuttings. It is extremely important that the root systems not be allowed to dry.

Grafted Cuttings:

Where necessary for some particular soil problems (i.e. lime, nematode, phylloxera) it is possible to graft a desired scion variety onto a rootstock which is resistant, or highly tolerant to the problem. In making grafted cuttings, a short one-bud piece of scion is placed onto either a rooted or unrooted scion. This is referred to as a French graft or bench graft as it is done on a workbench rather than in the field. Three types of bench graft can be made. These are the inverted "V," saw-kerf or omega.



Inverted V   Saw-Kerf   Omega

Machinery is available for making all of the grafts; however, the omega is in greatest use today.

After the physical cuts are made it is necessary with all but the omega cut to fasten the union with staples to physically support the graft until callusing has occurred. The grafted cutting or rooting is placed in a callus box. The grafts are packed with moist peatmoss or shavings and held at 80 degrees F for 2 to 4 weeks to allow the callus to join the stock and scion. Leaving the grafts in the callusing box for a longer period does not result in better callusing. The longer the grafts are left in the box, the greater becomes the chance of infection with bacteria which will destroy the graft.

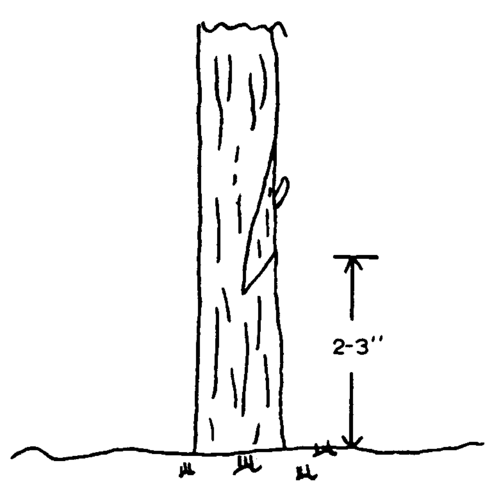
After the grafts have callused they are taken from the callus box, dipped in water to remove any dirt, dipped briefly into wax and then dipped immediately into cold water to cool the wax. They can then be rooted in the greenhouse under mist. While both cuttings and rootings can be grafted, it is much easier to work with the cuttings due to the absence of roots. The purpose of the wax is to prevent the callus from drying while the healing process occurs.

Regular paraffin wax can be used; however, rose wax will give better results as it is better able to respond to changes in temperature without cracking. The wax is heated to the point where it is soft and flowable. If the wax becomes too hot, it will damage the callus. The scion and union are dipped rapidly into the wax and then immediately into cold water. This cools the wax to reduce the chance of injury, but the wax will not prevent the development of the bud. The grafted cutting is then rooted in the greenhouse under mist. The mist is necessary to prevent stress to the shoot while the vascular system is reestablishing itself in the callus at the union.

Budding

Vines may also be propagated by placing the scion wood onto the rootstock after the rootstock has been established in the field. This process can also be used for changing the variety grown in the field if market conditions change. Either a chip bud or a "T" bud can be used.

Chip Budding: In chip budding the rootstock is planted in the winter or spring and allowed to grow for the first summer. In the fall a bud is grafted onto the 1-year-old wood. A chip of wood approximately 2 to 3 inches above ground is removed from the rootstock (see below). A similar chip, containing a single bud is removed from the scion and set into the rootstock. It is wrapped in place securely with grafting tape, and the soil is mounded over the union to prevent it from drying. The budding is done late enough in the fall so the bud will callus into the stock but not begin to grow.



In spring the soil is removed from around the union and the grafting tape is also carefully removed. By scratching the scion just below the bud it is possible to tell if the bud has healed in (the tissue should still be green). If the bud is alive the rootstock is cut off above the union to direct all the growth into the new bud. A tube is placed around the union to direct growth upward. The developing shoot is tied to the stake for support.

When it is desirous to change varieties in the field, chip budding can be used. It is done higher on the trunk to promote more rapid renewal of the fruiting region and done in the spring at the onset of growth. The chip is removed from the trunk 14 to 18 inches below the height of the head or cordon. The top of the old vine is not cut off at this time. On a trunk 1 and 1/2 inches or larger, in diameter, two buds are inserted. The buds are wrapped tightly with grafting tape.

Once shoots from the old head are 2 to 3 inches long, the top of the old vine is removed. The shoots from the chip buds will develop rapidly. Care must be taken to prevent the tape from girdling the new shoots. The bud union is weak and the rapidly developing shoots should be tied to the trellis for support.

"T" Budding: "T" buds may be used in place of chip buds. The procedure is basically the same except the "T" bud must be placed when the cambium is actively growing (the chip bud may be placed when the vine is dormant). As with chip budding, the budwood must be mature. As no mature buds are available on the vine in June, when "T" budding is done, it is necessary to collect budwood while the vine is dormant and store it as described above. In "T" budding, a "T" cut is made deep enough into the bark to reach the cambial area. The flaps created by the two cuts are lifted carefully and a chip of scion including a single bud is slipped into the cut. The union is wrapped tightly with grafting tape to exclude air. The graft is then handled as described for chip budding. The bud may be placed low on the rootstock, or within 8 to 10 inches of the head or cordon wire.

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Vineyard in Tucson, Arizona

Training:

Pruning has greater effect on the production of grapes than perhaps any other operation. Proper pruning allows for the development of good vegetative growth and optimum yields. It also allows for proper distribution of the fruit within the vine canopy, resulting in maximum quality.

Pruning is considered to be the removal of vegetative portions of the vine including leaves, shoots and canes. Removal of fruit or flowers is termed thinning. Pruning is used to establish the shape of the vine, and therefore, the number and position of fruiting buds. Proper establishment of vine form will facilitate necessary vineyard operations (cultivation, insect and disease control, harvesting) and reduce labor. It allows the proper distribution of the fruit over a given vine area producing the largest high quality crop. As a method of crop removal, pruning is cheaper than thinning since a single cut can eliminate a number of fruit clusters.

FRUITING HABIT OF THE GRAPE

To properly prune grapes, one needs to know certain facts about the fruiting habits of the vine. Clusters are formed on the basal buds of leafy shoots on current season's growth. These shoots arise from overwintering buds on the previous season's growth of woody canes. In the fall, after the leaves have fallen from a shoot, it is referred to as a cane. Figures 1 and 2 show the principal parts of the vine.

PARTS OF THE VINE

Arm—Main branch or extension of the cordon.

Cane—A shoot which has lost its leaves.

Cordon—The main branch or branches arising from the trunk.

Internode—The part of the shoot or cane between the nodes.

Laterals—The side branches of a shoot or cane.

Nodes—The joints on the shoots or canes where the leaves, buds or clusters are attached.

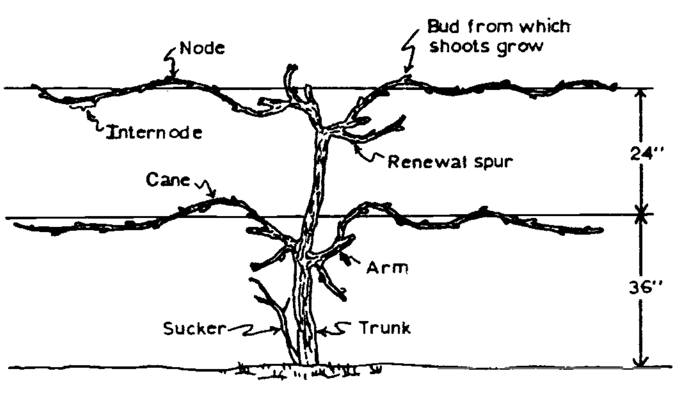

Figure 59. The four-cane Kniffen system, showing the major portions of the vine. Adapted from Larsen, 1955.

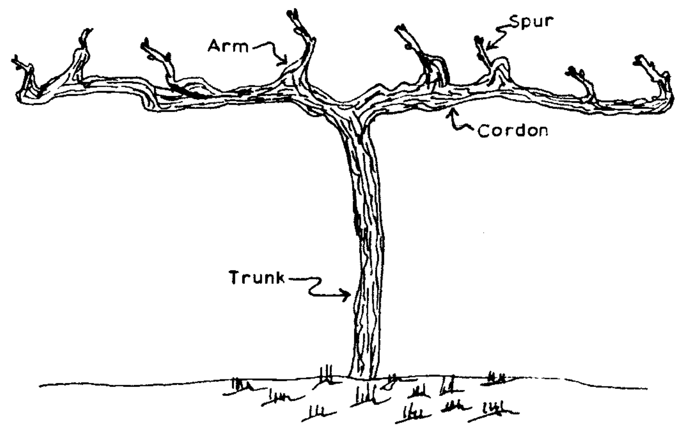

Figure 60. The bi-lateral cordon training system.

Renewal spur—In a cane pruning system a cane cut to a stub of 1 or 2 buds to produce next year's fruiting cane.

Shoot—The present season's growth, containing the leaves and fruit clusters.

Spur—A cane pruned to a stub of one to three buds, which produces this year's fruiting shoots.

Sucker—Shoots arising from below the ground or near the base of the trunk.

Trunk—The main body or stem of the vine.

PRUNING VERSUS TRAINING

Training encompasses all those practices including pruning and fastening the vine to a support, which are used to shape a vine. Whereas pruning determines the number and position of developing buds, training determines the form and direction of the trunk and arms and position of the shoots which develop from buds retained at pruning.

The primary interest in training is the establishment of a single, straight, strong shoot to serve as the trunk, and several well placed laterals, forming the permanent framework. Potential production in the early years is sacrificed in order to obtain the well-shaped vine as quickly as possible. On the older producing vine the pruner must consider both the vegetative growth and the crop, since a proper balance is required for the production of high quality fruit and continued large crops.

TRAINING GRAPEVINES

The training of young vines follows an explicit procedure. This includes the use of both pruning and disbudding to direct growth. Young shoots are tied to stakes, or sometimes trellis wires, to obtain the desired shape. Three to four years are required to complete the training of a grapevine.

First Year

The main objective of first year growth is to establish a vigorous and healthy root system. For this reason there is usually no pruning. Cultivation, fertilization and irrigation of the vine should be directed towards developing a strong root system. Irrigation is helpful in stimulating the growth of young vines. The amount of water and the frequency of application will be dependent on the climate encountered. In a cool climate a single irrigation may suffice; however, in very hot areas weekly applications may be necessary. It is important that late summer or early fall applications, which may prolong vegetative growth, be avoided. This is to permit hardening of the vines to reduce the risk of damage caused by early fall frosts, and to reduce the chances of winter damage.

By the end of the season the top of the plant should be well-matured and the root system well-established. (See Figure 61.) During the winter, all growth except the strongest, well-placed cane is removed. This cane is shortened to two or three well-formed buds. At this time the stakes and trellis should be installed if it was not done prior to planting.

Second Year

The primary objective during the second year is to develop a single, strong cane into a permanent trunk. This is accomplished by removing lateral buds which will direct all growth onto one shoot. After growth has begun and the new shoots are about 8 to 12 inches in length, the strongest, most well-placed shoot is tied loosely to the stake. The second most well-placed shoot is left intact and untied, and all other shoots are removed. As the shoot grows it is tied loosely to the stake to keep the trunk straight. (See Figure 62.) It should be tied approximately every 6 inches. After the shoot is tied for the second time the reserve shoot is removed. The shoot is allowed to grow until it reaches 12 to 18 inches above the point at which the trunk will divide to form the arms of a head trained vine, or the cordons of a cordon trained vine. The cane is topped by cutting through the node just above where the branching is to occur. Topping in this manner prevents further elongation of the shoot and stimulates vigorous, lateral branching.

At this point the training of cordon pruned vines will differ from that of head and cane pruned systems.

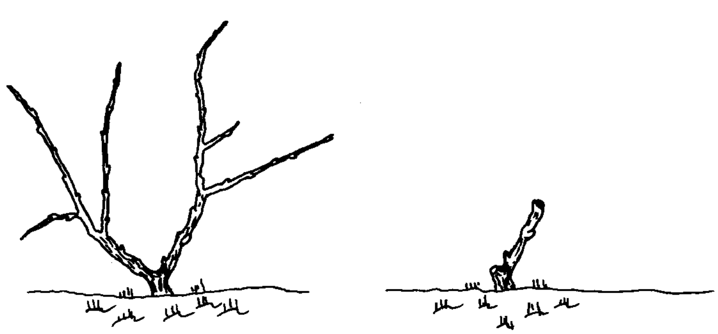

Figure 61. At left, appearance of the vine in a dormant condition following the first year's growth. At right, appearance after pruning.

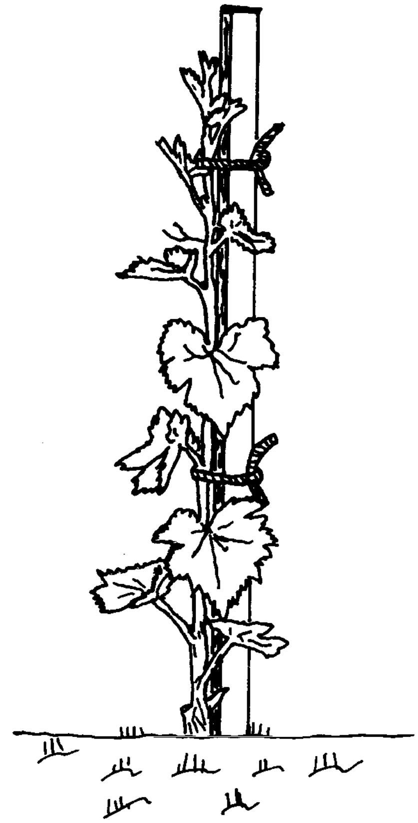

Figure 62. Formation of the trunk during the second growing season.

Head-trained System

If the vine is to be trained to either a short spur or long cane system, the laterals on the upper one-half to one-third of the trunk are allowed to develop. Some of these will form the permanent arms. In warm areas development of the trunk and laterals will occur in the second season; in cooler areas it may be necessary to develop the trunk in the second year and the laterals in the third season.

During the second winter (third in cool areas), the vines should have a well-developed straight trunk and several well-developed laterals. The trunk is cut off at the node just above desired head position. The cane is cut through the bud, killing it, but leaving the enlarged area. This will make trying easier. To tie, two half hitches are made around the trunk, just below the enlargement of the cut node. The half hitches are drawn tight, pulling the trunk firmly against the stake. The twine is wrapped twice around the trunk and stake and tied as tightly as possible with a square knot. In addition, the trunk is loosely secured to the stake in one or two places below, for additional support.

All laterals on the lower one-half to two-thirds of the trunk are removed. Two to six laterals are left on the upper portion of the trunk to form the permanent arms. These spurs are pruned to one to three buds depending on the vigor of the cane. Usually a maximum of six to eight buds are left on the vine in the second (third) dormant season. If the vine is to be trained to a long cane

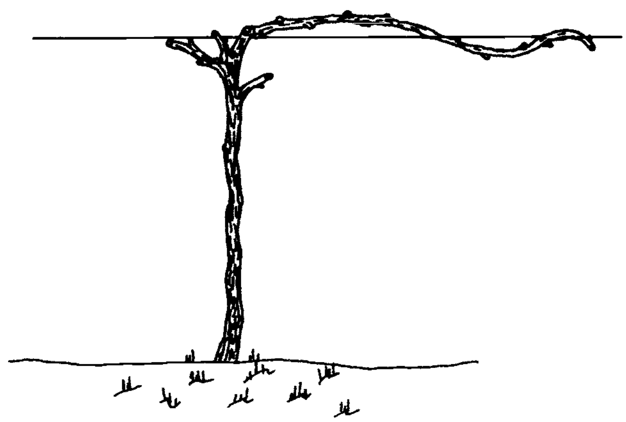

Figure 63. Appearance of a virorously growing cane pruned vine, after pruning in the second dormant period.

system, one or two lateral canes are left, approximately 12 buds long. (See Figure 63.) These are wrapped two to three times around the trellis wire and secured at the end with a piece of twine.

In cool areas, or if the vine is slow growing and has not reached a minimum size of 5/16 inch diameter at the desired head height, the main shoot is cut to two buds, as in the first winter.

Cordon-trained Systems

To form the bilateral, horizontal cordon, two lateral shoots developing just below the height of the desired cordons are selected. All other laterals are removed. The point where the branching occurs should be 6 to 10 inches below the wire which will support the cordons. When the laterals are approximately 18 to 24 inches in length, one is tied in each direction to the training wire. To support the laterals as they develop, the shoots are tied loosely to the wire every 6 inches. It is important that the 10 to 12 inches of elongating tip not be tied to the wire as this interferes with elongation. When the shoot is approximately 16 to 18 inches past the halfway point to the next vine, the shoot tip is pinched out.

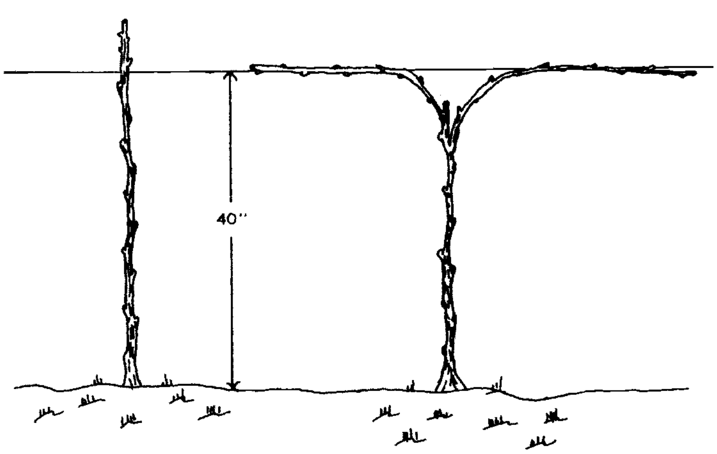

Figure 64. At left, appearance of a cordon trained vine from a cool growing region, after pruning during the second dormant season. At right, appearance of a 2-year-old vine from a warm growing region.

Cordon-trained vines at the end of the second season (third in cool areas) should have a well-developed trunk and two partially to well-developed laterals (See Figure 64.)

During the second (third) dormant pruning, the laterals are cut back to 3/8 inch in diameter. On vigorous vines where the diameter of the laterals is greater than 3/8 inch at the mid point between two vines, the laterals are cut at the midpoint. If the laterals are not sufficiently vigorous to reach at least 6 inches on the wire beyond the bend, the lateral is cut back to a two-bud-long spur, and the lateral developed the next year. All other laterals forming on the trunk are removed, and unless the vine is extremely vigorous, all secondary shoots developing from the laterals are also removed. To keep the cordons straight they are wrapped one and one-half times around the wire and secured at the end. If they are not wrapped around the wire, the weight of the developing shoots and fruit will cause the cordon to sag. If the cordon is wrapped too many times around the wire it may be cut or girdled by the wire or may be injured when later removal from the wire is necessary.

Third Year

During the third summer, the vines will bear a crop in direct proportions to the number of fruitful buds which were left on the vine during pruning. Even though the vine will bear its first crop, it should be remembered that the prime objective is still to develop a strong framework.

Head-trained systems

Remove all shoots which begin to grow on the lower half of the trunk and unwanted ones on the upper half. Shoots left on the upper portion of the plant may grow without further attention unless they become too long. If they become too long they may be stopped by pinching out the terminal bud.

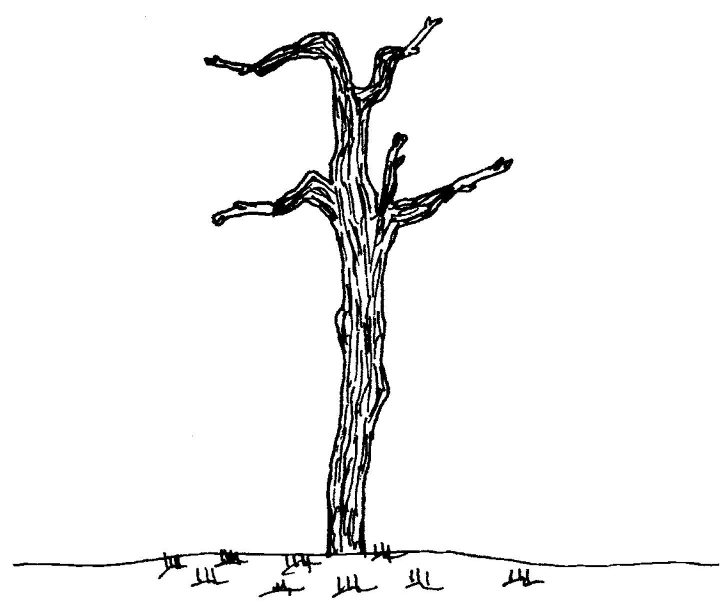

Figure 65. Appearance of the head trained vine pruned to short spurs, after the third growing season (fourth season in cool climates).

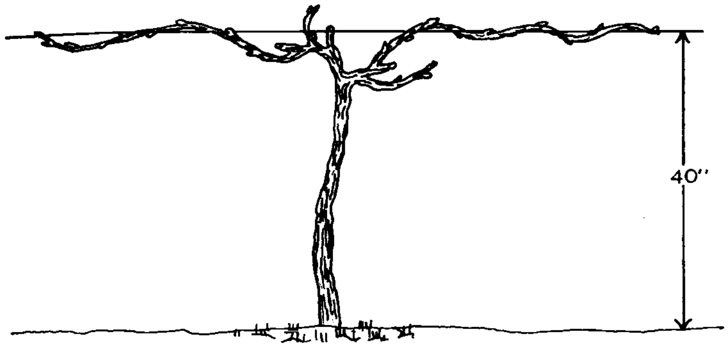

Figure 66. A head-trained system pruned to two long canes at the end of the third growing season.

By the third dormant season (fourth in cool areas) the primary framework should be established. (See Figure 65.) Generally four spurs with two buds each are left; however, the vigor of the vine during the previous season must be kept in mind. On vines with low vigor, the number of buds may be reduced. On vigorous vines, more buds may be left on each spur or more spurs may be left.

Using a second head-trained system, one or two fruiting canes are left, eight to fifteen buds in length. The number of canes and their length is determined by the vigor of the vine. These are attached to the trellis wire by wrapping the canes twice around the wire and securing them with twine. To supply canes for the following year, two to four renewal spurs, two to three buds long, are left in desirable locations. (See Figure 66.)

Cordon-trained Systems

When growth begins, any shoots developing from buds on the lower side of the cordons are removed by rubbing them off. Shoots arising on the upper portion of the cordon are spaced 8 to 10 inches apart. All shoots arising from the trunk or the bends below the trellis wire are removed. If all the shoots do not develop at the same rate, the slower developing ones can be stimulated by pinching out the terminals of the vigorous developing ones when they are about six leaves long.

If the cordon had not developed to its entire length, a terminal bud, preferably a lower one, is allowed to develop and is then tied to the wire to keep it straight.

When the lateral shoots have developed sufficiently, three or four laterals are tied to the uper wire to prevent the weight of the fruit and developing shoots from over turning the cordon. If left uncorrected, this problem will prevent the development of a good cordon.

With young cordon-trained vines, overbearing is a distinct problem. Although buds growing from the underside of the cordon are removed, and shoots on the upper side are thinned, overproduction may still be a problem. Depending on the vigor of the young vines, it may be necessary to remove fruit by the removal of part of the clusters.

During the third dormant season 10 to 12 spurs are left. These are equally distributed on the two cordon arms, approximately 8 inches apart. If necessary, the cordons are untied and then retied to the wire to correct any sagging which may have occured. This practice is necessary to insure even development of buds on the spurs, and therefore even maturation of the fruit. See Figure 60 for a mature cordon.

Fourth and Later Years

During the fourth and later years, the aim of training is to perfect the structure of the vine while obtaining the largest crop of high quality fruit. Head-trained vines are developed into a symmetrical shape. The arms on cane-pruned vines are trained into the rows to prevent interference with cultural operations.

Arms on cordon-trained vines are spaced evenly along the cordon and are kept growing in an upright manner by tying the developing green shoots to the upper wire until the framework is heavy enough to support the developing fruit and foliage.

A continued effort is necessary to remove suckers from the trunk and watersprouts from the upper trunk and head area, as well as downward growing shoots on the cordon-trained systems. The amount of suckering and disbudding necessary will decrease with time.

TRAINING SYSTEMS

In addition to the head-trained short spur, long cane, and cordon systems, several modifications of these systems are available. The four-cane Kniffen system (Figure 59) and the Umbrella Kniffen system (Figure 67) are used on varieties which have low fruitfulness in their buds or small clusters. These systems allow for a larger crop than would be otherwise possible.

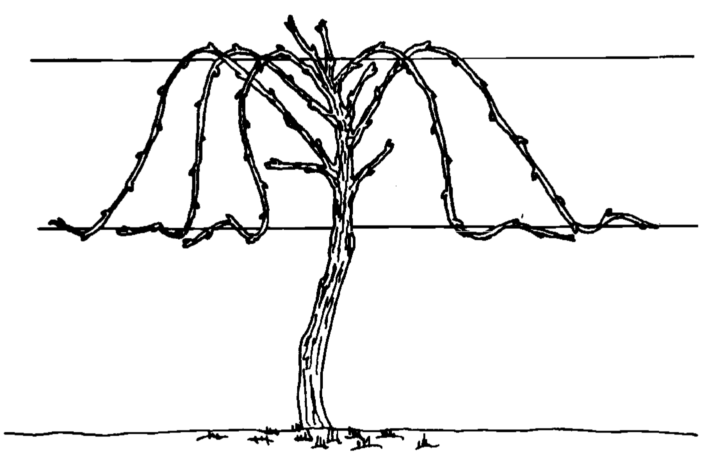

Figure 67. The Umbrella Kniffen System

The four-cane, head-trained system with the three-wire sloping trellis (Figure 68) is utilized in the production of table fruit, where spacing of that fruit is necessary for production of large berries. In addition, the sloping trellis prevents sunburn by providing good leaf coverage of the fruit.

The fan-shaped system (Figure 69) has been used in colder climates to reduce the chance of winter (freeze) damage. Low attachment to the trellis of the fruiting

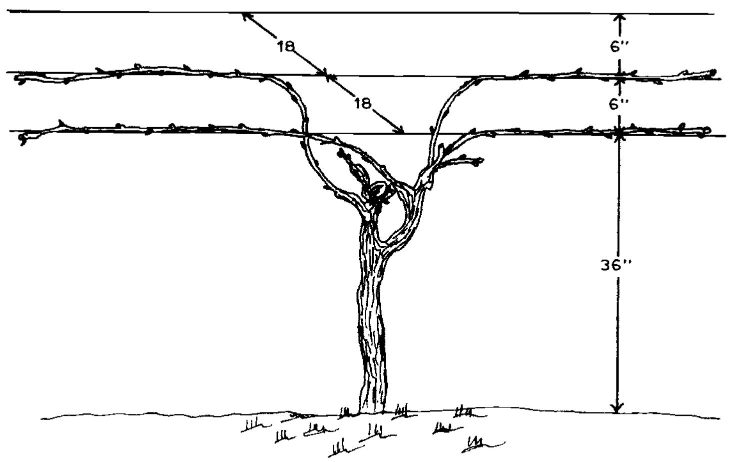

Figure 68. The four-caned, head-trained system used for table fruit production.

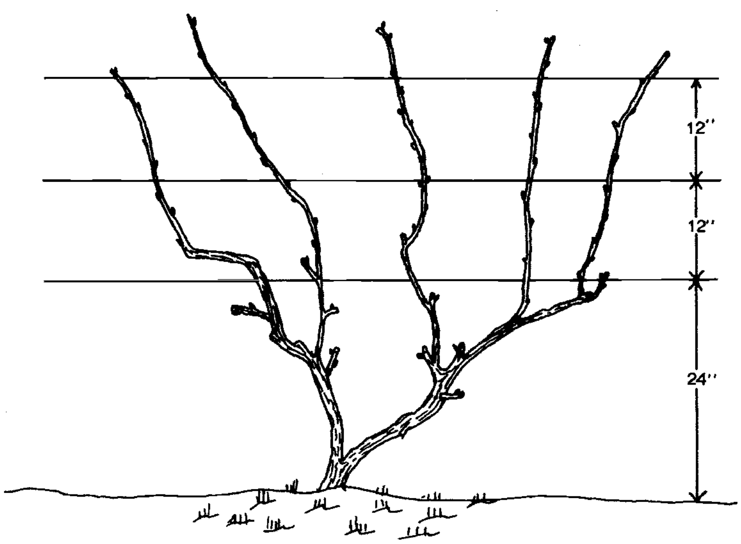

Figure 69. The fan-shaped training system, used in colder climates.

canes makes it possible to remove the canes from the wire and bury them for protection during the winter. In the spring the canes are retied to the wires. While this system offers greater protection from the cold it requires excessive labor to untie and bury the canes and then retie them for the commercial grower.

In addition, more time is necessary to sucker the vines, and the system does not adapt well to mechanical harvesting.

The Geneva Double Curtain is used where light intensities are low. This system allows the foliage to spread over a large area, causing maximum accumulation of sunlight and maximum production of high quality fruit.

PRUNING

PRINCIPALS OF PRUNING AND PLANT GROWTH

Bearing wood—Those spurs and canes which produce fruit and vegetative growth for the following year.

Renewal spurs—Short (two to three bud) spurs left to produce vegetative canes which would be used for fruit production the following year.

Replacement spurs—Short spurs left to replace an arm on an older vine or left to shorten the size (length) of an existing arm and therefore the head area.

The length to which a cane is pruned depends entirely on the pruning habit and vigor of the vine. The number of fruitful buds left on a vine is directly related to fruit production. In most varieties all buds, especially the basal ones, are fruitful; however, in some varieties (Thompson Seedless) the basal buds are sterile. In this case longer canes must be left. When making decisions about pruning several criteria must be considered. If a bud is fruitful, one must then ask, "How fruitful is it?" How many clusters are produced on each developing shoot and how big is each cluster? Varieties which produce many clusters on each shoot, or a few large clusters on each shoot, can be pruned to a short spur system; however, on those varieties where few or small clusters are found on each shoot, long canes must be used to insure a normal sized crop.

THE GROWTH HABIT

Anytime foliage is removed from a plant, the growth of that plant is stunted. Reduction in the total amount of growth, and hence the leaf area, results in reduction in the total photosynthetic capacity of the plant, even though the photosynthetic capacity of the remaining area is increased on a per unit area basis. This reduction in total photosynthates results in less sugar and starch to nourish roots, stems, shoots, flowers and fruit. The size of the crop is directly related to the number of shoots allowed to develop, as the number of clusters developing on each shoot will be the same. When fewer shoots are allowed to develop, each becomes more vegetative. Even though the number of shoots has been reduced, the total amount of vegetation is larger. Reduction in the number of clusters per shoot and the number of berries per cluster results in larger-sized berries but lower total production. In general, therefore, pruning increases production on the remaining units while decreasing overall production. The objective of pruning is to maximize the former and reduce the latter.

There are several factors which affect fruit quality, such as crop levels. A heavy crop in any one year was probably preceded by a light one, and probably will be followed by a light one the following year. Overcropping results in reduced quality of the fruit. A vine has a fixed capacity to manufacture sugar. The larger the total crop, the longer it will take the fixed photosynthetic system to bring the sugar content up to an acceptable level. The other main factor relating to fruit quality is the level of total acids. The acid level is highest at the time when ripening begins and then drops as the fruit ripens. The rate of acid decline is controlled by temperature and time. Higher temperature or longer time involved in ripening will lower the total acid level. Where heavy crops remain on the vine, obtaining a minimum sugar level is delayed, and total acid level may be reduced. If the acid level is too low, the resulting fruit, juice or wine will be flat and of poorer quality. This principle can be used to an advantage with varieties which are too high in acid; allowing a larger crop to develop will allow more time for the acid level in the fruit to drop without gaining excessive sugar. This assumes that the growing season is long enough to permit this. From the inverse standpoint, varieties which tend to have too little acid at maturity can benefit by crop thinning, and, therefore, more rapid sugar accumulation and acid retention. This operation too has its limits as the date of maturity can be advanced for only a few days.

The presence of a heavy crop also reduces the ability of the plant to survive adverse climatic conditions. A vine which is heavily cropped does not have sufficient reserves to mature the wood properly. This improperly matured wood is more likely to suffer from low temperature and dessication injury during the winter. In addition to being less able to survive adverse winter conditions, developing shoots are less vigorous and less able to withstand adverse climatic conditions in the spring. The fruit buds will not be as fruitful.

Growth usually begins at the terminal ends of the canes. If buds on spurs, canes or cordons are at different heights, a different rate of development will be observed. Shoots will develop first and most rapidly from the highest position. Those which develop first will always be the most vigorous. Vertically developing shoots from buds on the top of a cane will be more vigorous than those developing from the bottom of the same cane. It is therefore highly desirable to keep fruiting buds similarly located.

At each node three buds are located within a single set of bud scales. These are referred to as the primary, secondary and tertiary buds. The primary bud develops first, and unless it is damaged, the secondary bud may not develop. If the primary bud or shoot is damaged or killed by a spring frost or low winter temperatures (the primary is the most sensitive to frost) the secondary bud can develop. Development of the secondary bud will be delayed by about 2 weeks. While it will be fruitful, the secondary bud will produce only about 50 to 60% of the crop produced by the primary bud. The fruitfulness of the secondary bud is varietal dependent. The tertiary bud can develop if something happens to both the primary and secondary; however, production will be quite low. A knowledge of the status of the buds at the time of pruning is useful. If a grower determines that a certain percentage of his primaries are dead, compensation can be made by leaving more buds and still produce a full crop.

TIME OF PRUNING

The normal time for pruning is during the dormant period, between leaf fall and bud break, the best time being from December through March. In warm climates leaves tend to persist even after the plant has entered dormancy. The time at which pruning occurs has no effect on the vigor of the vine but may affect the survivability of the vine. When pruning is delayed too late in pruning season growth of the vine is delayed in the spring. When growth does begin, it begins from the tip. This reduction in the rate of development of the basal buds by delayed pruning may lessen or eliminate the chance of spring frost injury. Pruning just before a warming thaw during the winter may encourage bud development during the warming period. If cold weather follows, serious damage may occur. Where spring frosts are common or where cold may occur after a brief winter thaw, it is best to delay pruning until as late as possible.

Pruning Systems

Many types of pruning systems are in use today. Some are used in specific areas in response to specific climatic conditions. Others are used for specific groups of varieties. Regardless of the system used, it falls into one of three basic systems; head-trained short spur, head-trained long spur (cane) or cordon.

Head-trained Short Spur

This system is more commonly referred to as a head-trained system. It requires a vertical trunk with four to six arms. Each arm holds a single spur with one to four buds. The number of buds left on each is dependent on the vigor of the vine. If the shoot is less than 1/4 inch, a single bud is left. If the shoot is between 1/4 and 1/2 inch, 2 buds are left. If the shoot is between 1/2 and 3/4 inch, 3 buds are left. If the shoot is over 3/4 inch in diameter, four buds are left.

Advantages of the head-pruned system are its simplicity and ease of training. It is the cheapest system to establish as it requires a stake instead of an elaborate trellis system. The stake is needed to provide support for the first 5 to 10 years, until the vine is strong enough to support itself. Without the presence of trellis wires, cross cultivation is possible. This is very beneficial where weeds are a particular problem.

One disadvantage of the system is the severe reduction of growth. This is caused by the limited number of shoots which can develop. The potential yield is small unless it is used on varieties which produce large clusters. The fruit is massed in a small area which makes some cultural operations more difficult. Harvest becomes especially difficult if clusters become intertwined with tendrils, leaves or shoots. Disease control, particularly of Powdery Mildew, becomes much more difficult and bunch rots become a greater possibility.

Head-trained Long Spur

The head-trained long spur system is more commonly referred to as a cane system. It differs from the head-trained system in that the foliage is trained in a fan-shaped manner in the direction of the row. Only two to four arms are left, each supporting a cane eight to fifteen buds long. The production of new canes which provide the fruiting wood for the following year is left to renewal spurs. This system is mainly used for varieties such as Thompson Seedless where the basal eight to ten buds are sterile, or varieties which produce small clusters (Cabernet Sauvignon, White Riesling, Pinot noir and the French hybrids).

The advantage of the system includes the fruit being spread over a larger area. This allows for easier cultural operations and fewer pest and disease problems. This system is particularly suited to table fruit production where both cluster and berry thinning are needed.

There are several drawbacks to a cane system. The greatest disadvantage is that most varieties tend to overbear. Unless cluster, and in some cases, berry thinning is performed, overproduction results in a reduction of quality. Other drawbacks are the cost of developing the cane-pruned system and the presence of wires. The minimum requirement is for a one- or two-wire vertical trellis for raisin or wine production. For most table fruit varieties a three- or four-wire sloping top trellis is used. The presence of wires in the rows prevents cross cultivation. Weeding in the row must be done by hand, chemicals or the use of specialized equipment (French Plow or automatic Rotovator).

Cordon

The cordon pruning system is perhaps the most widely used. There is a simple trunk with two lateral branches (cordons) instead of a definite head. Each cordon supports five or six arms, each supporting one to two spurs with one to three buds. While both vertical and unilateral cordons are used the bilateral system is preferred. No shoots are allowed to develop in the area below the horizontal cordons as this results in excessive vigor.

The greatest advantage of the system is the resulting fruit distribution. Not only is the fruit disbursed over a large area, but is found at a uniform elevation above the ground. This allows for the uniform development of the vine and even maturation of the fruit. Other advantages of the cordon method is that it becomes the easiest system to maintain. Concentration of the fruit in a single line, at a uniform elevation, makes bird protection relatively simple.

The greater length of the trunk and the permanent cordons makes the early training period very important. The need for developing the flat cordons and the upright growing arms requires both more labor and more highly skilled labor. The system cannot be used on varieties which have either sterile basal buds or produce very small clusters.

PRUNING MATURE VINES

Pruning of mature vines is relatively easy if a few simple rules are followed. Renewal and replacement spurs, when used, are one to three buds long. This is dependent on the vigor of the vine and individual shoots. The emphasis of pruning is to produce the largest possible crop of quality fruit while maintaining the shape and health of the vine. Where renewal spurs are used, one is left for each cane. Usually canes in the most desired location, in respect to the trellis, are cut back for the renewal spurs, and less well-placed canes are used for fruiting. If two shoots develop from the renewal spur, the one coming from the upper bud is utilized for the fruiting cane while the one produced from the lower bud is cut back to form the new renewal spur. This prevents the arms from becoming progressively higher.

The best rule to follow in determining how many buds, spurs or canes to leave is to observe the previous year's performance. If a large well-matured crop were produced the previous year, the same number of spurs with the same number of buds are left. If a cane-pruned system is used the same number of canes the same length are left. If the vine was overly vegetative with less than optimal size of crop, more buds could be left on each spur or cane, or more spurs or canes developed. If a large crop of poor quality fruit was produced, more vegetative growth could be encouraged by a reduction in the number of fruitful buds. If a reduction is needed, it is usually not wise to eliminate canes or spurs, as these are difficult to replace. It is better to reduce the number of buds on each unit, unless it is found that a reduction is needed each year. The proper pruning of the vine, therefore, requires a knowledge of the previous performance of the vine.

Guidelines do exist which allow the inexperienced pruner to develop a starting place in determining the amount of wood to remove. These are referred to as balanced pruning systems, and described as 30+10 or 20+10. In the 30+10 system, 30 buds are left for the first 1 lb. of prunings removed and 10 buds are left for each remaining pound of prunings. These systems have found the greatest application in small-clustered varieties such as the American grapes and the French hybrids. This system requires a greater amount of time and the pruner must be provided with a pair of scales.

SUMMER PRUNING

Summer pruning includes suckering, crown suckering, pinching, disbudding, topping and leaf and shoot removal. Suckering refers to the removal of shoots which develop from the below-ground root portions. It is important that these be removed promptly, as their vigorous nature reduces the productivity of the top. Where scion varieties have been budded onto a rootstock, or the fruiting variety has been hanged by topworking, fruit produced on the suckers would not be the same as the main variety.

Crown suckering refers to the removal of water sprouts and latent buds developing in the head area on the upper trunk and bending portions of the cordon. These shoots if not removed are excessively vigorous and the fruit produced is of lower quality. Ripening usually occurs earlier on these shoots than on those which develop from the normal spurs.

Pinching out the terminal bud temporarily reduces the rate of shoot elongation. This allows weaker developing shoots to develop without causing lateral branching. Topping the shoots—removal of 1 to 2 ft of growth—reduces the length of the shoot and reduces the chance of wind damage. This allows the development of lateral shoots and increases the rate of maturation of the main shoot.

Removal of unwanted leaves and shoots increases the rate of development in the remaining foliage. This is partially due to the increased sun exposure of the remaining foliage. Exposure of the clusters to direct sunlight prior to maturation accelerates the rate of acid metabolism in the berries.

The resulting crop will have a lower acid content at maturity. This is extremely useful on varieties which tend to be high in acid. Use of the practice in the United States is not widespread, however, due to the high labor requirement involved. Removal of leaves and tendrils on table fruit varieties which might become intertwined in or cause abrasion to the fruit clusters helps to maintain the high quality.

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Supports

Although grapes can be grown without any supports, to be successful commercial production must make use of some type of support system. Without supports the incidence of disease, insect infestation and dirt contamination is much greater. Additionally, cultural operations are more difficult and time consuming, and labor costs are higher due to necessarily reduced use of mechanization. In addition, the quality and size of the crop is reduced.

Supports can be of a long- or short-term nature, and are designed for head, cane and cordon-trained vines. The basic types of systems are the single stake for the head-trained pruning system, the standard one or two-wire vertical trellis used for both caned-pruned and cordon-trained wine varieties. The standard three-wire "T" trellis is used for either cane or cordon-trained table varieties or wine varieties grown for mechanical harvest. The three or four-wire sloping-top trellis is used for cane or cordon-trained table fruit varieties.

Head-Trained

Supports for head-trained vines consist of a simple stake. Split redwood 2 inch x 2 inch stakes 4 to 7 ft in length are preferred due to their strength and freedom from warping. However, due to limited availability and extreme costs of redwood, they are seldom used. Commonly used materials include: Sawn redwood, fir, cedar or sawn Malaysian hardwood. To lengthen their life, the stakes are treated with 5% PCP (pentachlorophenol) or creosote.

Supports for head-trained vines are considered to be temporary in nature. Mechanical support is needed for 5 to 10 years depending on the variety and height of heading. Normally the vine is able to support itself when it is 3 to 4 inches in diameter. Even though the supports are considered to be short-lived, they are not removed once the vine is strong enough to support itself. The limited remaining life of the stakes does not warrant the cost of removing and cleaning them.

The length of the stake, 4 to 7 ft, is dependent on the height at which the vine is to be headed. Normally the stake is sunk 2 ft into the soil, and the top should extend 6 to 12 inches higher than the height of the anticipated head. The stakes are either placed in the ground by burying them at the time of planting the vine, or they are inserted later. If inserted later, the stakes are either driven into the ground with sledges, mechanical stake drivers or truck or tractor mounted hydraulic units. They may also be augered in or placed with the aid of a water injection probe.

Caned-Pruned

With caned-pruned training systems, in addition to the stakes, some type of trellis system is necessary to support the developing canes, foliage and fruit. A simple single-wire system is used for wine varieties, such as Cabernet Sauvigonon, Pinot noir, White Riesling, Sauvignon blanc and the French hybrids. All of these varieties normally produce small fruit clusters. In windy areas a two-wire trellis is usually used to provide additional support for the developing shoots.

Stakes, 2 inches x 2 inches of wood or steel x 7 ft, are used at each plant. These are inserted 2 ft into the ground. For the single-wire system the wire is usually placed at a 40 inch height above the soil to permit ease of harvest. Where a two-wire trellis is used, the lower wire supporting the canes or cordons is established at 38 inches. The secondary wire for support is placed 12 to 16 inches above the lower one.

End posts, usually 4 inches x 4 inches redwood or cedar, or 3½ to 4½ inch pealed fir, 8 ft long, are set 3 to 4 ft deep. Railroad ties may also be used. Trellis wires coming from the posts are anchored to deadmen, made of concrete. Deadmen are normally 4 inches in diameter 30 inches deep. The wires are attached to a piece of 5/8 to 3/4 inch rebar imbedded in the concrete.

Where rows are less than 660 ft in length, 12 gauge smooth galvanized wire may be used. Fourteen gauge high tensile galvanized wire may be substituted. The advantage of the high tensile wire is reduced costs due to more wire to the foot; however, it is more difficult to work with. The wire is fastened to the stakes with #14 staples.

Table Fruit: With table fruit production there is a greater need to space production to obtain the highest quality crop. This is accomplished with the use of a crossarm trellis. The three or four-wire sloping top systems are the most popular. The sloping-top trellis permits the foliage to be spread over a large area. This increases the rate of sugar accumulation. The fruit hanging beneath the canopy is protected from sunburn, and is free from abrasion from nearby foliage or intertwining shoots and tendrils.

A crossarm, 2 inches x 2 inches x 36–40 inches, is attached to the verticle stakes with 12d nails. The crossarm is locked in position 30 degrees from horizontal with the use of 14 gauge wire ties or metal braces. Three or four wires (12 gauge smooth galvanized or 14 gauge high tensile galvanized) are attached to the crossarms with three #14 staples. The head of the vine is placed just below the height of the wire closest to the stake. Where a three-wire sloping-top trellis is used, the fruiting canes are attached to the lower two wires. Where the four-wire trellis is used the canes are attached to the two middle wires.

Cordon-Trained

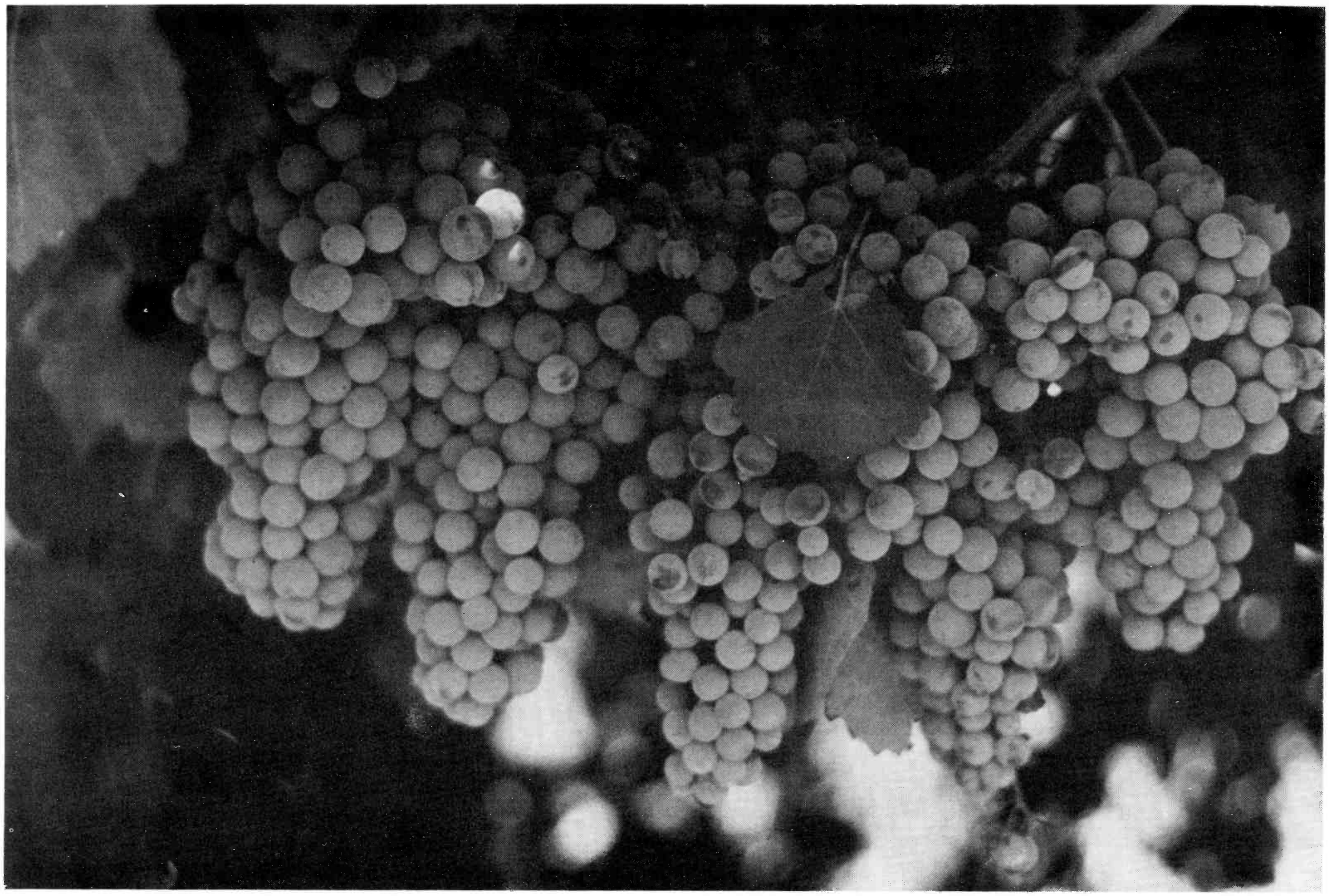
If a unilateral cordon or a bilateral cordon, with cordons longer than 18 inches, is used vine strength will be insufficient and a support system will be necessary for the life of the vine. For wine varieties the standard two-wire trellis, described above, is used. It is usually desirable to replace the lower wire with a heavier one. Eleven gauge smooth galvanized (12 gauge high tensile galvanized) is usually the best choice. Twelve gauge smooth galvanized (14 gauge high tensile) may still be used for the top support wire.

Where high winds are encountered or cordon-trained table production is desired, the upper wire is replaced with a 24 to 30 inch crossarm with a wire at each end. Normally 12 gauge smooth galvanized wire is sufficiently heavy. The system may be converted to mechanical harvest by using double bracing and 11 gauge smooth galvanized wire (12 gauge high tensile) in place of the lighter wire.

The "T" trellis may be further modified for use in support of the Geneva Double Curtain system. Instead of stakes at every vine posts are used in the middle between every third and fourth vine. Crossarms, 2 inches x 4 inches 36–40 inches long are used on every stake. Eleven gauge smooth galvanized (12 gauge high tensile) wire is used throughout.

Modification of these systems is possible to fit the system to a particular variety of climatic region. When planning a system it is best to keep in mind the simpler the system, the less initial expense involved and the less labor and cost involved in maintenance. All wood coming in contact with the ground should be treated to prolong its life.

While galvanized wire is the most desirable, plain steel, copper or plastic covered steel may be substituted. Plastic monofiliment can be used, however it is short-lived due to accelerated breakdown by ultraviolet rays under southwestern climatic conditions. Additionally, it is more prone to sag under high temperature conditions and may become brittle at cold winter temperatures. It is also more prone to damage by cutting during pruning.



Clusters of Gray Riesling from Dateland, Arizona

Fertilization

Only 10% of the total nutrients taken up by the grape plant accumulates in the fruit. The remaining 90% is in the leaves and vines and can be returned to the soil if leaves and pruning are incorporated into the soil following harvest.

Grapes are less demanding than most other crops. They do well on soils having marginal fertility. The roots on the vine are able to efficiently explore the soil available to them. Southwestern soils are generally quite fertile and adequate for grape production in areas which have been previously cropped. This is especially true if the previous crops were cotton, grains or alfalfa. Non-cropped or virgin soils, generally used as range for cattle production, may be deficient in both nitrogen and phosphorus. Where soil pH is high and where soils have a high lime content, zinc and iron deficiencies occur. Such conditions must be corrected before grape production can begin.

Nitrogen

Little nitrogen is found in the fruit. Nitrogen is a component of proteins, amino acids and chlorophyll. It is essential for photosynthesis and is the prime element involved in the regulation of both vegetative and fruiting growth. If nitrogen is deficient, the plant exhibits reduced growth and fruit set. In addition, berries and clusters are small, and the fruit is generally low in sugar and acid and therefore of poor quality.

Excess nitrogen produces vines which are vegetatively vigorous. A small crop results due to a reduced number of fruit clusters being initiated. The berries are generally very large with thin skins, making them more prone to insect and disease attack. Excess nitrogen also results in a poor set, including many water berries. Ripening, which is uneven, occurs somewhat later in the season, leaving fruit more susceptible to early fall frosts. Vigorously growing vines will harden later in the fall and to a lesser degree than vines growing normally. This can lead to higher incidents of winter frost damage, particularly in colder regions.

Nitrogen Requirements: The actual amount of nitrogen which needs to be applied varies with the type of grape grown (raisin, table, wine), the variety, climate, amount of irrigation, water quality and soil type. Sandy soils or those which may be heavily leached will generally require greater nitrogen applications than the heavier soils. Wine grape and table varieties, especially colored ones, require about 20 to 40 lb of actual nitrogen per acre per year.

Form of Nitrogen: The form in which nitrogen is applied to the plant is not important, at least in terms of the benefit to the plant. Either organic or synthetic forms may be used. Costs, soil type and time of application will dictate which type of nitrogen to use. The lease expensive source of the actual nitrogen is usually the best. Due to less leaching time, specific soil conditions may make one form more desirable. Fresh manures and all poultry manures should be avoided since they contain high levels of salt which can be injurious to the vines.

Time of Application: The greatest need for nitrogen occurs in the spring, when there is a rapid flush of spring growth and flowering and fruit set. After bloom has occurred, only enough nitrogen to maintain the foliage is needed. Excess nitrogen later in the season tends to divert the photosynthates from the maturing fruit to new vegetative growth. This is especially true with table fruit and where high soil moisture content is encountered.

The fertilizer should be applied as close as possible to the time when growth begins. The actual time of application will vary with the form of nitrogen, soil type and temperature. Nitrogen in the ammonium form needs to be converted to the nitrate form before it can be utilized by the plant. It is, however, more resistant to leaching. Anhydrous ammonia is usually the cheapest form of nitrogen. The conversion from ammonia to nitrate occurs less rapidly in cool soils. The nitrate form, while more readily available to the plant, is more easily leached. If applied too early, especially on sandy soils where heavy rains may occur, high losses due to leaching may occur. Several forms are available for use as foliar sprays. While these are very effective in correcting immediate or spot problems, they generally are an expensive form of nitrogen. They are, however, included with other nutrients which are best applied in a foliar form. The addition of nitrogen to these materials usually enhances the uptake of the nutrients. If excessive nitrogen levels are encountered late in the growing season, the use of a grain cover crop to "dry up" the excess nitrogen is recommended.

Phosphorus

An average crop of grapes removes only about 3 to 6 lb of phosphorus per acre per year. On previously cultivated soils, phosphorus is usually not a problem. In the Four Corners Region, native grasslands and non-cropped soils are occasionally deficient in phosphorus, so applications are sometimes required. Phosphorus is needed in the manufacture of nucleoproteins and for photosynthesis and normal sugar metabolism. Deficiencies cause a reduction in growth, uneven ripening, early defoliation and the appearance of reddish-purple foliage in the fall. The color symptom, however, may be confused with the presence of leafroll virus in the plant.

Forms of Phosphorus: Phosphorus may be added in various forms and various ways. Phosphate is tied up in most soils. Rock phosphate is unavailable to plants in basic soils. Where phosphorus deficiencies occur on native soils, ammonium phosphate can be used at a rate which will supply both the vine's nitrogen and phosphorus needs.

Zinc

Zinc is an essential catalyst in many enzymatic reactions. It is essential for photosynthesis and responsible for cell division and enlargement.

Visual symptoms of a zinc deficiency include the appearance of small leaves near the shoot terminal and reduced internode elongation. This gives the appearance of a rosette condition, and is sometimes referred to as "Little Leaf." In addition, interveinal chlorosis can develop on the younger leaves. This appears similar to iron deficiency; however, when zinc is deficient the minor veins are no longer visible, and the incidence of shot berries increases; in addition there is decreased production and delayed ripening. Deficiencies are usually found on sandy soils, soils with high lime contents, soils with a high content of manure or where old feedlots have existed. Grape varieties vary in their ability to withstand zinc deficiency. Dogridge and Salt Creek rootstocks are especially prone to deficiencies and will quickly exhibit visual symptoms.

Zinc Forms and Applications: Most of the forms in which zinc may be applied are rapidly fixed in the soil making soil applications generally impractical. An exception is very sandy soils where application to the soil of 1 to 2 lb of zinc sulfate per plant as zinc chelates may also be applied to the soil as chelating reduces soil fixation.

Foliar sprays provide the best and fastest way of correcting zinc problems. Usually two applications are made. The first is applied 2 to 3 weeks prebloom. The second is applied several weeks after bloom. The normal spray consists of 4 lb zinc sulfate and 2 lb of a low biurette urea per 100 gallons of water. This is applied to run-off. Zinc chelates, especially the 138 form, may be substituted for the zinc sulfate. Use them at the rate recommended by the manufacturer. If low biurette urea is not available, Uran 32, which is a liquid containing 32% urea may be substituted. It is usually applied at a rate of 2 pints per 100 gallons of spray. The addition of the nitrogen source in Uran 32 improves zinc uptake.

Iron

Iron is required for the production of chlorophyll even though it is not physically present in the molecule. A deficiency of iron results in an interveinal chlorosis of the young, terminal growth. The minor veins remain dark green, giving a net-like appearance. Basic soil pH results in reduced availability of iron. The appearance of visual deficiency symptoms is usually caused by 5% lime in the soil or high soil moisture. Iron deficiency rarely occurs with most *vinifera* varieties, however, the problem is usually severe with the American varieties, and intermediate with the French hybrids. When lime content in the soil exceeds 15%, special rootstocks must be used.

Iron Form and Application: Most forms of iron are tied up in the soil, making them unavailable to plants. If soil application is required it is best to use the chelated forms. Generally 20 to 25 lb per acre will correct the problem. Though the material is more expensive, it is less likely to be tied up in the soil. Iron, like zinc, is best applied foliarly. Iron sulfate may be substituted for zinc sulfate as described above. Chelated iron sprays should be made according to the manufacturers' directions.

Other Elements

Boron

Boron deficiencies are rarely found. The usual problem with boron is its toxicity. One part per million (ppm) in the soil is sufficient and 5ppm is usually toxic.

Boron deficiencies cause dry flowers, light set and many shot berries. A deficiency in boron also results in reduced sugar production and problems with metabolism of sugar by the fruit. Deficiencies are usually correctable with B_2O_3 or borax.

Boron toxicity is visually exhibited by a puckering of the leaves. This is caused when the margins of the leaves cease to grow while the middle of the leaf continues its development. Toxic symptoms may be similar to herbicide damage (dalapon). The only way to correct the toxicity is to leach the soil to remove the excess element. This is assuming the water does not have a high inherent boron content.

Magnesium

Magnesium is part of the chlorophyll molecule. Few occurrences of magnesium deficiency have been reported. It has usually shown in young vines growing on sandy soils. Visual symptoms are the presence of an interveinal chlorosis on the older leaves. Magnesium deficiency may also be induced by excessive potassium in the soil. Magnesium is usually applied as a 1% magnesium oxide or 2% magnesium sulfate spray.

Manganese

Manganese is important in chlorophyll. Deficiencies, although rare, show up as an interveinal chlorosis on the older leaves. Manganese is also important in oxidation-reduction reactions and normally prevents iron reduction in the plant. As energy transfer systems are involved, even a minor deficiency in manganese may result in a drastic reduction in yield and a reduction of fruit quality.

Determining Fertilizer Needs

There are several ways to determine the nutritional status of a plant for fertilizer application. The easiest, from the growers' standpoint is to wait for the appearance of visual deficiency symptoms. While this method works, it is not recommended, since a reduction in yield and quality occurs before symptoms arise. Soil analysis reveals nutrient levels to the plant, but cannot determine availability of these nutrients to the plant or actual uptake by the plant. Tissue analysis provides a measure of nutrients actually assimilated by the plant. Once levels in the leaf or petiole are correlated with the plant performance, there is a basis for determining the type and quantity of fertilizer to apply. Table 7 provides information on the desired nutrient status. It should be remembered that these values will serve as a starting point, as actual levels may vary with variety and location.

Table 7. Nutrient composition of grape petioles.

Element	Petiole Content (ppm)		
	Deficient	Normal	Excess
Nitrogen (NO_3-N)	350	600–1200	1800
Phosphorus (P)	1500–2000	3000–6000	—
Potassium (K)	10000	10000–12000	30000
Magnesium	3000	5000–8000	10000
Zinc	15	25–50	—
*Boron	25	40–60	300
Chloride	—	500–1500	5000

From: Winkler et al., 1974.
*Blade content

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Water Quality

Quality of the water used for irrigation is as important as the quantity of water. Water quality for irrigation is based on the chemical composition of salts in the irrigation water. Basically there are three considerations.

1) The effect of irrigation water on physical properties such as infiltration of water into the soil;
2) The effect of the water on the salt content or salinity of the soil and
3) The effect of specific species of dissolved constituents on the growth of plants.

Physical properties

The importance of having and maintaining good soil structure cannot be overemphasized. Infiltration of irrigation water into soils and the maintenance of adequate aeration are two of the more important soil properties affected by the physical condition of the soil. It has long been known that sodium ion, Na^+, plays an important role. A method used for assessing the effect of irrigation water on soil is the sodium adsorption ratio, SAR,

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where Na^+, Ca^{++} and Mg^{++} are the concentration in meq/L of the ions indicated in the irrigation water. This ratio is related to the expected Na^+ concentration in soils irrigated, and in turn, to adverse effect which may be encountered. The sodium content which adversely affects soil depends to a large extent upon the clay mineral present in the soil. For any given clay mineral increasing sodium content will cause a reduction in infiltration. However, adverse effect does vary between clay minerals. It is found that the infiltration problems of soils containing Montmorillonite are greater than those for soils containing illite which are greater to those for Vermiculite which are greater than those containing Kaolinite. This is reflected in the classification system for water quality given in Table 8. It will be remembered that the predominate clay mineral is given as a part of the family name. Most soils are mixtures of the minerals, so for these mixed clay systems, the intermediate, (the Illite-vermiculite) values should be used. Many waters that are in the range of increasing problems to severe problems can be changed by adding small amounts of gypsum, $CaSO_4 \times 2H_2O$, to the water. As can be seen from Equation 1, the addition would lower the SAR.

Another factor affecting the infiltration of water is the effect of the salt concentration on soils. Low salt waters tend to disperse clay minerals, thus causing clogging and reduction of permeability, whereas, high salt concentrations flocculate clay, hence increase infiltration. Since dissolved ions are responsible for the conductance of electricity through water, this conductance gives a measure of salt concentration in water. Research has shown that infiltration becomes restricted at about a conductivity of 0.5 mmhos and becomes severely restricted at a concentration of about 0.2 mmhos. (See Table 8). As with the sodium problem, the problem with infiltration due to low salt content can be controlled by adding enough sypsum to bring the water to >0.5

mmhos, or by blending the water with waters containing higher salt contents.

Some soils do not show adverse effects until much higher values than would be indicated by Table 8. The table should be considered to be a guide of possible problems. Corrective measures such as addition of gypsum should only be utilized if it is found that the indicated problem is indeed developing.

Specific Ion Toxicities

Two ions frequently found in irrigation water are toxic to grapes. These are boron, B and chloride, Cl^-. Grapes are considered a plant sensitive to boron. Sensitive plants are first affected at about 0.75 mg/L and severe problems are encountered by 2.00 mg/L. Chloride toxicity is encountered in water as low as 4 meq/L. Severe problems may be found when the concentration in the irrigation water reaches 10 meq/L. Rootstocks may be used to increase tolerance. It is reported that Dog Ridge and Salt Creek are three to four times more tolerant of chloride than Cardinals. Sprinkling with sodium may cause toxicity at the levels shown in Table 8.

Bicarbonate ion, HCO_3^-, like sodium, can cause foliar burning when used for sprinkler irrigation. The concentrations causing various degrees of problems are shown in Table 8.

Nitrogen often occurs in irrigation water. If found in high levels it can cause excessive growth, leading to over-production. When plants need to be stressed for winter protection, excessive nitrogen could indirectly be responsible for winterkill. The pounds of N per acre-foot of irrigation water can be found by multiplying the N- in mg/L from the water analysis by 4. Provided 2 ft of irrigation water are used, 5 mg/L in the irrigation water would supply the plants with the normal nitrogen requirement for wine grapes, whereas above 10 mg/L would be excessive for table grapes. Note that nitrogen fertilizer should be reduced to compensate for N found in the irrigation water.

Salinity

All irrigation water contains salt. Grapes selectively remove water from the soil and leave behind the salt. The higher the salt concentration in the irrigation water, the higher will be the salt level. For grapes, when the electrical conductivity of the irrigation water becomes greater than 1 mmhos, reduction of yield occurs. This reduction continues as the salt level in the water increases. When the salt level in the water gives a conductivity reading of 4.5 mmhos, a yield reduction of 50% would be expected. Intermediate values are given in Table 8. Accumulating salts left behind by the grapes must be removed from the rooting zone.

Irrigation

Water is held to soil particles as a film. The thickness of the film varies, depending on particle size and the amount of moisture available in the soil. Both air and water occupy the pore space of the soil. Pore space constitutes 30 to 50% of the soil volume. Sandy soils have larger pores but less total pore space than does a heavy textured soil where the pores are smaller.

When the pore space of the soil is nearly filled with water the soil is said to be saturated. A soil is not able to hold water in a completely saturated condition and the excess moves downward by gravity. The water remaining after complete drainage, usually 24 hours following

Table 8. Water quality for grape irrigation.

Irrigation Problem		Degree of Problem		
		No Problem	Increased Problem	Severe Problem
Permeability				
SAR				
Montmorillonite		< 6	6–9	> 9
Illite—vermiculite		< 8	8–16	>16
Kaolinite		<16	10–24	>24
EC_W mmhos		>0.5	0.5–0.2	< .2
Specific Ion				
Boron (toxicity) meq/l		< 0.75	0.75–2.0	>2.0
Chloride (toxicity) meq/l		< 4	4–0	>10
Sodium (sprinkling leaf burn) meq/l		< 3	3–9	> 9
Bicarbonate (sprinkling leaf burn) meq/l		<1.5	1.5–8.5	>8.5
Nitrogen (excess folier growth) NO_3–N mg/l		<5	5–10	>10
Salinity		Percent Crop Reduction		
	0	10	25	50
EC_W mmhos	1.0	1.7	2.5	4.5

application, is in the form of a film. At this point the soil is said to be at field capacity and contains the upper limit of water available for plant growth. The amount of water in the soil is 5 to 35% by weight.

As water is removed from the soil by evaporation or extraction by the plant, the tension holding the film of water to the soil particle becomes greater. Tension increases until the plant is no longer able to exert enough pressure to remove further moisture. This level of water in the soil is referred to as the permanent wilting point and unless immediate attention is given, the plant will die. At the permanent wilting point the soil holds 3.5 to 21% moisture by weight, depending on soil texture. Sandy soils hold less moisture by weight than do clays. Thus the moisture available for plant growth and development (field capacity minus permanent wilting point) is 1.5 to 14% of the soil weight.

The presence of salts in the soil increases the tension on the water available to the plant. The addition of water to the soil dilutes these salts making it easier for the plant to obtain water. Irrigation with salty water, assuming no leaching occurs, increases the salt content of a soil and reduces the amount of available moisture. Leaching these salts lower into the soil, below the root zone, makes more water available to the plant. With proper leaching, water with a fairly high total salt content can be successfully used for crop production.

Water Movement

Assuming the soil has uniform texture with no impervious layers (hardpans), cracks or channels, irrigation water or rainfall moves downward through the soil, wetting it to field capacity as it moves. Impervious layers or greatly differing textures retard the downward movement of water until the layer above the barrier becomes saturated. Further rainfall or irrigation does not increase the amount of water in the saturated zone, but allows an increase in depth of the wetted area.

Lateral movement of water is much less than the downward movement unless the water stands at only one level (above a hardpan). This is an important limit to consider when deciding the type of irrigation system to use or, in furrow irrigation systems, the spacing between furrows.

Grape roots explore a soil very effectively if moisture is available for growth. The depth to which the root system will develop is dependent on the soil type. In heavy clays the roots may extend downward only 2 to 3 ft, while in loamy soils roots may extend down to 5 to 8 ft. In sandy soils, roots may be effectively found 8 to 12 ft below the surface, and in gravely soils they may extend downward 10 to 20 ft. The depth to which the roots explore usually depends on how deeply oxygen can penetrate the soil. The larger the area the roots can explore, the larger the reservoir or potential reservoir, to supply the vine.

Water Uptake

Absorption of water by plants is limited to root hairs at or near the end of the growing root tip. Thickening of the root prevents water absorption in other areas of the root system. The area in which water is absorbed remains on the periphery of the root system, moving outward as the root system grows and more root hairs develop. However, roots can develop only where water exists.

While some water is lost through the soil due to evaporation, the majority is lost by transpiration from the vine leaves. The total amount of water lost, therefore, is dependent upon the total leaf area of the plant. Fruit load affects transpiration rates only indirectly, by either increasing or decreasing the amount of vegetative growth and consequently total leaf area. Reduced vegetative growth usually means the plant has a smaller root system and accordingly, less access to water.

Insufficient Water

Wilting is one early symptom of water stress. It occurs anytime transpiration exceeds the rate of water uptake by the root system. This may occur as a temporary phenomenon in the afternoon under hot, windy conditions or both, or as a permanent condition if the plant has extracted all the moisture available in its pool. Other symptoms of water stress include a soft, yellow-green appearance of the growing tip, with the older leaves becoming hard and darker gray-green in color. Later the leaves yellow and die. Moisture stress lasting for a few days results in either a reduction or total cessation of terminal growth. Canes growing on water-stressed vines usually exhibit a grayish-brown cast which is indicative of poor maturation.

The fruit also shows signs of moisture stress. When it is severe the berries give up their moisture to the plant, resulting in shrivelled or raisined berries. With less severe conditions the berries take on a dull appearance. There is also a reduction in the size of individual berries and in total cluster size and weight. If water stress occurs during bloom, the flowers may dry, preventing pollination and fruit set and resulting in poorly filled clusters and a high incidence of shot berries. Stress late in the growing season reduces maturation of the vine while early cessation of growth may protect the vine against damage by an early frost. Also, poorly-matured wood may not harden sufficiently to survive winter temperatures.

Water Requirements

Depending on the climate, grapes require 16 to 54 inches of water per year to properly produce and mature the fruit. Also, table fruit production generally requires more water than wine grape production, especially later in the growing season. Increased water consumption is necessary to get the large size demanded of table fruit. Factors influencing water use are soil type and depth, air temperature and humidity and vine vigor. Vigorously growing vines or those fed excessive nitrogen require more water.

Cultural conditions and operations can also influence water use by grapes. As previously discussed, the majority of the water lost is due to transpiration not evaporation. The presence of weeds increase total transpiration and yields competition for nutrients as well.

Climatic conditions during the time of water application influence the amount of irrigation necessary by influencing efficiency of use of the water applied. For example, sprinkler systems will not apply water uniformly under windy conditions, and water applied when air temperatures are very high and humidity is very low will evaporate quickly.

Principles of Irrigation

In general the purpose of an irrigation is to wet the root zone. Application of water to a larger area becomes wasteful. An exception to this is when extra water is being applied to serve as a leaching factor to move salts out of the root zone.

In practice more water is applied than is theoretically needed. This is due to several factors, including the possible presence of nonuniform soil conditions. This means more water will be applied in one area (or will wet the soil to deeper levels) to insure that sufficient water will be applied to the remainder of the area. An example of this would be sandy spots in a field. The uniformity of an irrigation is dependent on the type of delivery system, soil type and length of irrigation runs. Long runs with a flood irrigation system on a sandy soil usually results in more water being applied to the head of the field. Typical irrigation efficiencies run in the range of 50 to 80%.

The root zone should be at field capacity in the spring, when growth starts, since the greatest rate of growth occurs right after bud break. After the grand period of growth begins, irrigations are primarily used to prevent the soil moisture reservoir from becoming depleted. It may be unnecessary to wet the soil area to the full depth of the root development. Application of water to a depth of 1.5 to 2 ft is usually sufficient.

Irrigation Scheduling

Timing of irrigations, their number and the amount of water applied in each are dependent primarily on soil type, climate and rooting depth. Sandy soils with a lower moisture-holding capacity require more frequent irrigations with smaller amounts of water at each irrigation to replenish the soil moisture lost. Depth to which the irrigation must penetrate is another consideration when scheduling irrigations. In hotter climates plants require more frequent irrigations to keep up with transpiration losses.

The type of grape grown can play a major role in irrigation practices. As we have already noted table grapes require more water in the later stages of ripening, in order to obtain the large-sized fruit. With wine grape production it is somewhat desirable to stress the plant slightly to promote early ripening. In general, one to six or more irrigations are needed. Overwatering at flowering may result in loss of fruit set.

Irrigation scheduling can play a big role in hardening the plant so it will withstand low winter temperatures. To some extent, slight water stressing is valuable in stopping the vegetative growth of the plant and in promoting maturation of the wood. This can provide for the reduction in low temperature losses because of early fall frosts. However, moisture is required for the development of full hardiness in grapevines and other plants. If the plant is stressed too much, the full degree of winter hardiness may not be obtained. In addition, the plant may die from prolonged dessication in the winter as in the summer.

In general, root systems do not develop as deep a resting state as do the top portions of the plant. Therefore, roots are easily injured if the soil freezes, so it is necessary to reduce soil freezing as much as possible. Water itself has a specific heat. Colder temperatures or a greater duration of cold are needed to freeze a moist soil than a dry one. One or more irrigations may be needed to maintain soil moisture and minimize the depth of soil freezing.

Distribution System

In theory, any system will work if it can apply water uniformly. In practice, the type of system used depends on water availability and quality, the cost of the system and the topography of the irrigated area. Four main systems used include: furrow, strip basin, sprinkler and trickle or drip.

Furrow: This is the most common irrigation system used in grape production. Where 12 ft row spacings occur either two wide-bottomed or three regular furrows are used. The important factors to consider when determining how many and what type of furrows to use is the rate of lateral water movement and water quality. Broad, flat-bottomed furrows to prevent salt buildup on the soil surface, are better where salty water is used. Soil texture will determine the length of run. It will be shorter on light soils and longer on heavy soils. To obtain even distribution of the water it is necessary to have the furrow filled completely and to add water at the rate at which it is absorbed by the soil. With this system, as well as the strip basin, it is necessary to have the field in a level condition, or nearly level, to prevent water pooling.

Strip Basin: The strip basin can be likened to a large furrow. This works well in fine soils where sufficient water is available to cover a large area quickly. This system is better than small furrows when little lateral water movement occurs. The width and length of the runs will be dependent on the supply of water available, soil slope and the rate of infiltration. The highest efficiency is obtained if the area is dead level and sufficient water exists to cover the entire area quickly.

Sprinklers: Sprinkler systems have the advantage of applying water more uniformly given a differing soil types and topographies. Good distribution is obtained under sandy porous soils. Levelling is not required and no erosion will occur if the rate of infiltration is equal to or greater than the rate of application. In addition to irrigation solid set overhead sprinklers can be used as a means of frost protection.

If overhead sprinklers are used, the quality of the water must be high. As was seen in the previous table, the limit of ion content, particularly sodium, is lower if the water is to be used for sprinkler irrigation. Water containing high salts usually results in deposits on the leaves which are toxic and reduce photosynthesis. Additionally, sprinklers are less efficient where windy conditions occur. The systems have a high initial installation cost.

Trickle/Drip: Trickle or drip irrigation is one method to apply water efficiently and so reduce water loss to runoff and evaporation. This system of irrigation, which uses plastic tubing with emitters to deliver a set amount of water, has been practical where there is a concern for water scarcity and quality or on sloped terrains. In the United States approximately 133,000 acres were established in 1975 in trickle irrigation systems and by 1980 the figure should approach 500,000 acres. In comparison with other irrigation systems water efficiency can be increased by 40% in many cases over sprinkler and furrow methods with no significant difference in yields.

The equipment and design network is usually composed of a control head, main lines, lateral lines and emitters. The control head is often located by the source of water and may include a system of valves, pressure regulators and filters. Filters are necessary to remove suspended solids from the water to reduce clogging. The main line is used to connect the controls with the laterals and is usually constructed with rigid PVC pipe. The line is usually buried and is about 2 inches in diameter. The laterals vary from 3/8 to 1 inch of PVC tubing and run along the ground or are attached to the stakes to prevent damage during cultivation. Emitters allow water to pass from the laterals at designed rates of 0.5 to 2.5 gph (2 to 10 lph). A spray-spitter system, which uses an emitter with a larger orifice to allow a greater delivery of water, may reach quantities of 15 gph (57 lph). The design of the system must meet the water requirements of the plant by achieving an adequate distribution of water throughout the root zone.

Expenses for trickle irrigation are similar to solid set sprinklers. Cost is determined by grade and quantity of plastic tubing and the sophistication of the equipment used in the control station. Cost vary from $600 to $1,000 per acre. A cost analysis by the University of Arizona (Department of Agricultural Economics, Report No. 14, 1976) lists the average charges per acre and years of usefulness for the different segments of a drip system, as follows:

Item	Cost	Useful Life
1. Irrigation Pipe and Fittings	$ 91.11	25 years
2. Valves	22.78	15
3. Lateral Lines	265.75	10
4. Pumping and Filtration Equipment	167.04	15
5. Emitters	212.60	10
Total	$759.28 per acre	

The amount of irrigation depends upon insuring that the plant has an adequate supply of water in the soil to serve its life functions. This amount is dependent upon the rate of evapotranspiration, the extent of the rooting area and the quality of the irrigation water. Evapotranspiration (ET) involves the loss of water through the soil and plant. It has been reported that plant water stress is directly related to greater tension between soil and water. Such soil and water relationships can be measured with tensiometers. Thus, one can irrigate by the reading on the tensiometer according to the scale. Another method is to compile data from a U.S. Class A pan to study potential evapotranspiration (PET). The second step is to establish the crop coefficient (Kc), which expresses the ratio of a specific plant's ET to the PET of the pan. From research conducted by R. Smart of Australia and D. Bucks of the United States they have reported the Kc of grapes to be 0.4. To estimate the evapotranspiration of the vineyard use the formula: ET = KcPET.

Young vines, because of their reduced rooting, may require more frequent irrigations to insure an adequate supply of water near the surface. In terms of water quality, plants will absorb water and leave behind salt residues in the soil and so increase soil-water tension. In a properly run system, trickle irrigation should drive most of the salts beyond the root zone or provide a constant zone of moisture in the rooting area to minimize the salt influences.

Frequency of irrigation may occur at intervals up to 1 week or 10 days for established vines. Research has shown that a greater distribution of water was achieved with weekly rather than daily irrigations with the same application rate and quantity of water for a one week period on loam soil.

Clogging of the lines or emitters is probably the most serious problem since clogging may be due to soil particles or algae growth. The use of proper filters and periodic flushing of the lines should reduce the incidence of clogging. Damage of the lines can also occur due to rodent bites and tractor cuts.

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Weed Control

Weeds must be controlled. If not removed they compete for both water and nutrients, harbor insects and disease. Their presence hampers many cultural operations, expecially those where hand labor is involved. Fruit harvested in a weed-free environment is cleaner and of a higher quality than fruit harvested among weeds. Weeds can be controlled by mechanical means, chemical means or both.

Methods of Weed Control

Mechanical weed control refers to the physical removal of the weed from its normal growing state. This might involve complete removal from the vineyard or incorporation of the material into the soil. Equipment used includes hand hoes, discs, harrows and "Kirpy" or French plows.

Chemical weed control is a good farming practice. For every dollar wisely spent on herbicides, several dollars are realized as a result of increased production and increased fruit quality. Chemical control means there are less trips which have to be made through the vineyard, resulting in less soil compaction. Reduced tillage results in less injury to the roots and less damage to vine trunks. It may also allow the construction of permanent irrigation furrows.

There are several classes of herbicides including: contacts, pre-emergence and systemics. Contacts (Paraquat) kill only the portion of the plant (or vine) which is wetted. Pre-emergence herbicides (Treflan, Princep) are applied prior to germination of the seed and control weeds by either preventing germination or destroying the root tip as germination occurs. These materials do not have an effect on established plants. Systemics can be used to control perennial weeds. These materials (Roundup, dalapon) are sprayed on the above ground portions of the plant and are translocated to the roots where the plant is killed.

Application of Materials

To be effective, chemicals must be applied properly. The old adage "if a little is good, more is better" does not apply to chemicals. Reducing the amount of material applied may save money on the application but results in losses due to incomplete weed control or necessity of a second application. Increasing the rate of herbicide application to get a better kill may result in damage to the vines.

It is important that trash present in the vineyard be removed. This is particularly important when applying pre-emergence herbicides. If it is possible, the vineyard should be pruned before applications are made. This not only reduces physical obstructions to spray equipment but prevents contamination of the canes by spray materials.

Pre-emergence herbicides should be applied prior to a rain if possible. This eliminates the need for an irrigation necessary to carry the materials into the soil.

Uniform application of herbicides is necessary for proper weed control. Equipment should be accurately calibrated to apply the desired rate. Spraying should be done during periods of low air movement or drift, reducing measures used to prevent contamination of the vines or adjacent fields by the spray materials.

Drift

Drift is the most important cause of damage to treated or adjoining crops. It is one of the causes of illegal residues on treated crops. No chemical can be applied by either hand, ground or aerial equipment without at least some drift occurring. Generally less drift will occur with ground rather than aerial applications. Dusts are usually more of a problem than sprays.

Drift can be kept to a minimum if certain rules are followed. Timing the applications to periods of low wind activity will greatly reduce the drift. Usually early morning is the time when winds are the lowest. Reducing the spray pressure as low as possible, while still getting uniform application, will increase droplet size and therefore reduce the drift. Anti-drift or drift reducing materials are available which can be mixed with the active ingredient to reduce drift hazards. These materials should be used according to the manufacturers recommendations.

Suggestions for Correct Use

Herbicides vary in their toxicity to plants, animals and man. The following suggestions will help to reduce the risk of exposure to man, animals and other plants not the objective of the spray.

Read all precautionary labeling directions before using the material. Note the warnings and cautions before opening the container. Reread the container before every use, even though you are familiar with the materials.

Apply the material only on the crops listed on the label. Use them only at the recommended rate and at the proper time in the development of the plant. Some materials have a waiting period before harvest can be done.

Keep all chemicals out of the reach of children, pets, irresponsible persons and livestock. Chemicals should be stored outside the house under lock and key away from food, feed and seed.

Always store materials in their original container and keep them tightly closed.

Never smoke, eat or drink while spraying chemicals.

Avoid inhaling sprays or dusts. Avoid spilling chemicals on the skin. Wear protective clothing as recommended by the manufacturer. If accidental contamination occurs remove the material immediately and wash the affected area as recommended by the manufacturer. Know these procedures prior to using the material.

If symptoms of illness appear during or shortly after spraying materials, call a doctor or take the affected person to proper medical care.

Wash your hands and face and change to clean clothing after applying herbicides. Wash clothing each day before reuse.

Cover food and water containers when working around livestock areas. Do not contaminate streams, ponds or lakes. Do not dispose of leftover materials where they can enter drainage channels.

Rinse and crush plastic and metal containers to prevent reuse. Dispose in an approved burial site or burn paper containers in an approved manner.

Do not use the mouth to siphon liquids from containers or to blow out clogged lines, nozzles.

Do not work in the drift of the spray or dust. Keep drift to a minimum.

Herbicide Materials

The following table lists those materials which have been used to control weeds in grapes. Not all of the materials are registered for use in all areas. Check with your local county agent or agricultural commissioner as to the materials cleared for use in your area. The use of trade names is for identification only and does not imply any endorsement of the product named or a criticism of a similar product not mentioned.

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GRAPE HERBICIDES

Herbicide	Application Rate (per acre)	Weeds Controlled	Remarks
Amitrole	1 lb.	Emerged weeds	Combine with diuron or simazine for control of emerged weeds. Spray only dormant vines 3 yr. or older and use directed spray to keep spray off trunks.
Dalapon	Spot spray, 1 lb. in 10 gal. water	Johnsongrass Bermudagrass	Spray Johnsongrass at 12 to 18 inches, bermudagrass at 4 to 6 inches. Spray to wet foliage but avoid runoff into the soil. May need two applications.
Diuron	1.6 to 3.2 lb. first season. 1.6 lb. following seasons.	Annual weeds	Use as band treatments in vine row, Dec., Jan., Feb. on bearing vines 3 yr. or older with trunk diameter 1½ inch or larger. Reduce rate on lighter soils. Do not use on coarse sandy soils.
Oil-Aromatic emulsion	40 to 100 gal.	All weeds	Directed spray. Spot treatment.
Paraquat	½ to 1 lb. in 50 to 100 gal. water plus surfactant.	All weeds	Apply to thoroughly wet foliage of small weeds. Use low pressure to avoid drift or application to foliate or canes.
Roundup	2 to 4 qt. in 20 to 100 gal. water	Perennial weeds listed on label	Apply as directed spray to foliage as needed. Do not spray dormant canes. Do not tank mix with other herbicides.
Simazine (Princep)	1.6 to 4.8 lb.	Annual weeds	Use as a band treatment in vine row, Dec., Jan. or Feb. on bearing vines over 3 yr. Use lower rates on lighter soils. Do not use on sandy soils. Do not use with sprinkler irrigation.
Treflan	1 to 2 lb.	Summer annual weeds	Apply to the soil in spring and incorporate by mechanical means or irrigation.
2,4-D	1.5 lb.	Field Bindweed	Apply as spot treatment using great care to avoid drift. Use a hooded boom and low pressure to create coarse droplets. Do not use when temperatures exceed 85 degrees F. Use only amine forms.

American Hybrid Vineyard in Moab, Utah

PESTS, DISEASES and DISORDERS

This section includes the common pests and diseases that are associated with viticulture in the Four Corners Region. This section includes attacks by fungal, bacterial and viral organisms; nematodes; various insects and other problem pests.

Fungal Diseases

Texas Root Rot

Phymatotrichum omnivorum, the fungus causing Texas root rot, has clearly become the most important disease of grapevines in the Southwest. The disease occurs from Arkansas, into central and western Texas, through New Mexico and Arizona and is limited to points just east of the Colorado River in California. The disease is also known in northern and central Mexico. The disease is prevalent during the warm months of June through September, and may persist until the first frost.

Various factors seem to encourage development of the disease in this region:

1. **Soil.** Heavy or clay soils that are alkaline in nature seem to have a high incidence of the disease. In these soils growth is also enhanced by shallow soils that are poorly drained. The past history of any cultivated crops should be studied to determine if root rot was present. Soil may harbor sclerotia, or resting bodies of the fungus for years.
2. **Elevation.** The elevation of the land seems to correspond to the presence of the disease. This may be due to the colder winter temperatures found in the higher elevations which control the growth of the fungus. The incidence is by far greater below 3,500 ft than between 3,500 to 5,000 ft. At altitudes about 5,000 ft the disease is rare.
3. **Moisture.** Tests have shown that spores will fail to germinate in soils kept dry, but at very minimum water levels will begin to grow during the warm months. The fungus seems to desire high levels of soil moisture for optimal growth, and may produce spore mats on the surface around diseased plants.
4. **Temperature.** Higher temperatures found in July and August seem to encourage a greater incidence than cooler periods in May or October. The disease is finally controlled when the first frost occurs.

Symptons

On the roots the fungus appears as a yellowish, thread-like strand. It will penetrate the outer living tissue and destroy the root. The death of the vine is hastened should the fungus attack the crown of the root.

Early symptoms of the disease show yellowing of the leaves and early coloring of the grapes compared to healthy vines. The next step shows further wilting of the foliage and softening of the berries. Badly affected vines show a great deal of defoliation, dead wood, decayed roots and raisined clusters. The entire process may occur in just a few days. There may also be vines that show reduced foliage following bud break and others with stunted or no growth.

Transmission

The fungus is spread underground along the roots. Transmission to other soil sites is usually limited to being carried by nursery stock. The disease may also be spread by cultivating implements and, possibly, manure.

Treatment

The incidence may be high for nonnative plants in the Southwest. When involved with calcareous soils with signs of infestation from other plants, it is best to avoid this land. For calcarious soils one possible method to combat the disease is to use native plants as rootstocks, the vines can later be grafted to *V. vinifera* vines. One native vine to the Southwest is Dog Ridge, a seedling of *V. champini*, it has been reported in Texas to be tolerant to root rot. Tests are currently underway at the University of Arizona to determine what *vinifera* varieties are compatible with Dog Ridge and to verify the resistance of this rootstock.

Treatments have been made with soil sulfur to lower the pH and so control the growth of Texas root rot. It appears that the disease may be controlled in this manner on noncalcareous soils. The University plot at Page Ranch near Oracle has applied this method and research is now underway to further study the quantity of sulfur needed to control the fungus.

Powdery Mildew

Powdery mildew is the most important and most widely spread disease of grapes in the Four Corners Region. The disease spreads rapidly when climatic conditions are right and can damage or destroy the fruit and vines.

Powdery mildew lowers fruit quality. On white grapes mildew spots cause the berries to turn dark with the formation of scar tissue. With colored grapes these scarred areas fail to color normally. If the fruit is to be used for the production of juice or wine, usually objectionable flavor will be imparted. It may also cause fruit decay and attract insects.

Organism and Disease

A fungus (*Uncinula necator*) is responsible for powdery mildew. The fungus grows over the outside surface of leaves, shoot stems, cluster stems and berries. As it grows, hyphal strands of the fungus produce appressoria which fasten the hyphae to the surface of the green tissue. Infection pegs (small, thread-like structures) develop at the center of the appresoria and penetrate the outer cell layer. Upon entry into the center of the cells the infection thread enlarges to form a global structure (haustorium) which obtains the nutrients the fungus needs from cells of the grapevine. Early in the infestation hyphal strands produce conidiophores, short stalks which grow perpendicular to the surface. One conidium (spore) is produced on each conidiophore each day. Often these conidia pile up in chains on top of the conidiophore, producing a powdery, web-like appearance. Once infection has occured the fungus spreads rapidly from the point of infection over the surface of the host.

Infections on young tissue cause deformation and dwarfing of leaves, shoots and clusters. Infection of the fruit, in addition to causing small, stunted berries with low sugar content, results in the formation of scar tissue. As the berries enlarge this scar tissue may crack open providing entry for secondary molds and rots which result in further quality loss.

Varietal susceptibility: Grape cultivars vary widely in their susceptibility or resistance to powdery mildew. The most susceptible varieties include Cabernet Sauvignon, Carigname, Chardonnay (Pinot Chardonnay), Grey Riesling, Sylvaner and Valdepenas. French Colombard, while not inherently susceptible to powdery mildew, usually will exhibit symptoms as its dense foliage makes coverage by sulfur sprays difficult. Some of the least susceptible varieties include Petite Sirah, Royalty, Rubired, Salvador and Semillon.

Overwintering

Powdery mildew will continue to grow and spread whenever climatic conditions are favorable. The overwintering stage, a small spore case called a cleistothecium, usually begins to develop in the fall (late September to October). These cleistotheria are spherical (about 0.4 mm in diameter), and dark brown with long appendages. They appear as reddish-brown specks on the surface of the canes and leaves. During the winter, asci form within the cleistothecia. Each ascus will contain from 4 to 8 ascospores.

Powdery mildew may also overwinter as hyphal strands in bud scales. The shoots developing from the infected buds are usually dwarfed, covered with the fungus and serve as sources for further infection.

Climatic conditions

Under favorable conditions powdery mildew can develop and spread very rapidly. Conidia will geminate, infect the tissue and form new conidia which can be blown with the prevailing wind. By the time the fungus is first noted, usually the middle of June, it is usually in its third or fourth generation.

Powdery mildew is a cool, dry-weather disease. It develops most rapidly at temperatures from 70 to 80 degrees F (21 to 27 degrees C), but can grow at temperatures as low as 45 degrees F (7 degrees C). At temperatures above 100 degrees F (38 degrees C) growth stops. In controlled temperature chambers at 55 degrees F (12.5 degrees C) 12 days are required to complete one life cycle (from seeding of conidia to the production of new conidia), while at 78 degrees F (25.5 degrees C) it takes only 5 days. At constant leaf temperatures of 98 degrees F (33 degrees C) conidia which are produced could not reinfect tissues.

Moisture has little effect on the germination, infection and development of powdery mildew. Studies have shown that at temperatures from 70 to 90 degrees F (21 to 32 degrees C) conidia can germinate at near zero relative humidities. Also, the fungus develops more abundantly in shade or diffuse light than it did in bright or direct sunlight.

Prevention

Prevention is the most effective means of controlling powdery mildew. Sulfur dust, if properly applied to entirely cover the green tissue, will prevent the fungus from developing. The fungus will be killed if the sulfur comes in contact with the germinating condidia before it has had a chance to infect and establish itself in the tissue. The degree to which dusting sulfur is effective is directly related to the amount of coverage obtained. Both sides of the foliage need to be completely covered. It will require 5 to 10 g per plant (5 to 10 lb/acre) to obtrain adequate coverage, depending on the size of the vine and efficiency of the duster.

Sulfur should be applied when: 1) the shoots average 6 inches in length; 2) the shoots average 12 inches long; 3) the shoots average 18 inches long; and 4) additional applications every 14 days until veraison. When the daily maximum temperature exceeds 95 to 100 degrees F (35 to 38 degrees C) sulfur dust may burn leaves, shoots and fruit. Treatment should therefore be discontinued until maximum daily temperatures decrease or a sulfur spray is substituted.

A sulfur spray can be made mixing 0.25 to 0.50 kg (½ to 1 lb) of a wettable sulfur such as Ortho Wettable Dusting Sulfur® to 100 gallons of water (1 tablespoon per gallon). The addition of a spreader will aid in coverage. This spray can be used to replace dusting entirely. It will require about 200 to 600 gallons per acre, depending on the size of the vine (½ to 1 gallon per plant).

Eradication

If the early sulfur dusts or sprays have been omitted, or heavy colonies of the fungus are established, or if heavy infestations occurred the previous year, control becomes more difficult. The colonies may be eradicated with the addition of 3 to 4 oz of a wetting agent, such as Triton B-1956® per 100 gallons of the sulfur spray. Complete coverage of all surfaces of the plant is essential as the wetting agent and sulfur eradicate the mildew by causing the fungus to imbibe water so rapidly it bursts. The sulfur provides an additional barrier to prevent reinfection.

Bunch Rot

Bunch rot attacks grapes under favorable conditions and causes softening of the berries, discoloration, loss of juice, unpleasant odors and shriveling of the berries. Bunch rot is caused by various fungi that usually gain entry into the berries by skin breakage or the presence of heavy moisture around the grapes which may offer a suitable area for growth. In most cases tight-clustered varieties are more susceptible to attack. Overall warm and humid weather favor the growth of numerous organisms that are liable to cause damage.

Botrytis or gray Mold is a form of bunch rot caused by *Botrytis cinerea* that under favorable conditions may enhance the fruit and produce a highly regarded wine. In France it is referred to as the "noble rot." Such conditions appear to be cool and humid weather which may discourage growth of other organisms. In dry and warm weather the berries tend to only shrivel and discolor.

Bacterial Diseases

Bacterial organisms can affect the plant at any time. They are more of a problem in hotter, humid climates. They are difficult to control once they have been established within the plant. Control is usually to prevent infection.

Pierce's Disease

Pierce's Disease is currently found in Texas and California and is not presently a threat to the Four Corners Region. The bacterium is spread mainly by the sharpshooter leaf hopper in warm, humid climates. The disease may also be spread by grafting or pruning.

Symptoms are delayed shoot growth in the spring, mottling and a dwarfing of the shoots in the early summer. In late summer the affected leaves are usually brown and dry. Canes mature unevenly and are more susceptible to winter injury. The fruit shrivels and colors prematurely and unevenly. Vines usually die in 2 or more years.

There is no cure for the disease. Pierce's Disease does not survive in the soil. When found, removal and destruction of the infected vines is in order. Clean vines may be replanted. Elimination of the vectors and alternate host is usually not practical.

Viral Diseases

Viruses are not usually a problem in a new grape area where registered or certified plant material is used. However, once a vine has become infected with a virus there is no control. The best thing to do is remove the affected vines and replant with clean material.

Leafroll

Leafroll is the most widespread virus attacking vines that was observed in the Four Corners Region. Visual symptoms usually appear in July or August. As the season progresses, margins of the leaves roll downward and the leaves become progressively redder while the veins remain green.

The disease causes a reduction in the general vigor of the vine. Production may decline very little or severe reduction may result. The reduced activity delays sugar buildup in the berries and hence delays ripening. The common transmission of this virus is the use of untreated cuttings from an infected mother vine.

Other viral diseases that can be transmitted by cuttings are: yellow mosaic, asteroid moisaic, corky bark and yellow vein. The best control over these diseases is to insure that only certified, virus-free rootings are employed.

Nematodes

Nematodes are thin, worm-like parasites that attack the roots and cause further damage by allowing for secondary infections by other organisms in the soil. In the Four Corners Region there are three common nematodes that have the potential to cause problems in a vineyard. They are the Root Knot Nematode (*Meloidogyne incognita*), Root Lesion Nematode (*Pratylenchus vulnus*), and the Dagger Nematode (*Xiphinema americanum*).

Root Knot Nematode

The root knot nematode feeds on the roots where they cause abnormal swellings and growths called galls. The growths are usually found on one side of the rootlet and have a characteristic hook-shaped knot. The gall consists of a mass of broken tissue. Root function is disrupted, causing the vines to do poorly. This is particularly true in colder areas where infestations may lessen the tolerance of the vine to low temperatures. The vines usually appear stunted, with a faint yellow-mottling, and are more sensitive to water stress.

The mature female is pearly white, and pear or gourd shaped. She is slightly larger than a pinhole. Males are smaller and worm-shaped. Eggs are deposited in a mass either partly or entirely within a root. They hatch into active larvae which move to another location on the root. The larvae can also move through the soil on water film. They cannot develop while free in the soil but may survive for months. The larvae enter the plant at the root tip and cease all activity except feeding and reproducing. A single female may lay 500 to 1,000 eggs and there are five to ten generations per year.

Root knot nematodes prefer the lighter soils. They are usually spread to a new area via introduction of infested plants to that area. They are also spread by soil on cultivating equipment or in flood irrigations. Nursery plants suspected of being infested can be treated with a hot water dip which kills the nematode without injuring the plant.

Root Lesion Nematode

The root lesion nematode causes poor growth in vines and reduced yields. In contrast to the root knot nematode it does not produce knots on the roots. It is a migratory pest, moving in and out of the root tissue. Damage is usually greater on finer textured soils than coarse ones.

Dagger Nematode

The common dagger nematode found in the Four Corners Region is *X. americanum*. It is usually present in small numbers and associated with other nematodes. By attacking the roots the nematode reduces plant activity and production.

Insect Pests

Western Grapeleaf Skeletonizer

The western grapeleaf skeletonizer, *Harrisina brillians*, is native to Arizona and New Mexico. The destructive larvae emerge in the summer months from eggs laid on the underside of the leaves. The larvae are yellow with several purple bands and feed side by side, eating the soft leaf tissue from the underside of the leaf, usually leaving only the major veins. Mature larvae are 1 inch in length. The insect overwinters in the pupal stage, on the ground, in fallen leaves and trash. The adult moths, which are black metallic-looking, emerge in late May. Eggs are laid in masses of a few to 100 on the undersurface of the leaf.

Grape Berry Moth

The larvae of the grape berry moth are the most common reason for wormy-appearing grapes. It occurs primarily in warm, humid climates. Adult moths appear at bud break and are purplish-brown with a ½ inch wingspan. The small, flat eggs are laid on the stems, flower buds and berries. The mature larvae are 3/8 inch long and are dark green to purplish in color. To make a cocoon, the larvae cuts a three-edge piece of leaf, folds it over and seals it down with a web. The pupa emerges from the cocoon 12 to 14 days later. There are two to three generations each year.

The first generation feeds on the young flower buds, blossoms and berries. The attacked portions are abscessed. Larvae formed from the second generation bore into the green and ripening berries to feed on the pulp and immature seeds. A purplish spot forms at the point of entry.

Flea Beetle

Several flea beetles exist. They are characterized by their ability to jump. The most common species (*Altica torquata*) is steel-blue to purple and 3/16 inch long. The adults emerge from overwintering in time to attack and destroy the opening grape buds.

Grape Leaf Folder

The grape leaf folder, *Desmia funeralis*, is a major pest in warm, dry areas. The adult moth is dark-brown to black with a 1 inch wingspan. The moth emerges in early April to late May and begins to lay its eggs on the underside of the leaves. The eggs hatch in 10 to 15 days, and the young larvae feed in groups on the leaves which have been webbed together. They eat the entire leaf with the exception of the upper epidermis and main veins. They later make rolls at the margins of the leaves and feed on the inner edge of the rolled leaf. Mature larvae are 1 inch long, dark green with a brown head. There are normally three generations per year.

Damage to the leaves reduces photosynthesis, reducing production and delayed maturity. Late, heavy infestations may also feed on the fruit clusters causing scarring.

Grape Leaf Hopper

The grape leaf hopper, *Erythroneura* spp., is one of the most widely distributed grape insects in the West. Adults are 1/8 inch long, pale yellow with various color markings. Adults overwinter near the ground, under leaves, vegetation and trash. The insect moves to new foliage in the spring. Eggs are laid on the underside of the leaves. The nymphs pass through five molts before developing wings. There are usually three generations per year. Each female normally lays 75 to 100 eggs. Feeding is usually done from the lower leaf surface.

Phylloxera

In Arizona phylloxera, *Dactylasphaera vitifoliae*, attacks the leaves of wild grapes and has not been a problem with commercial growers at the present time. It has not been reported elsewhere in the Four Corners Region. In Europe and California phylloxera has caused widespread damage by attacking the roots of the vines and therefore, stunting of the vine growth. It was originally native to the northeastern United States and was spread by infested rootings to Europe and California in the 1860s. It attacks all species of grapes. *V. vinifera* is particularly susceptible to infestation which results in death of the root system. Other wild species while carrying the pest are relatively tolerant to damage.

The adults are oval, 1/25 inch in length, and vary from yellow-green to yellow-brown. Eggs are lemon-yellow. They are laid in late fall, hatch into larvae, and hibernate on the roots. When soil temperatures are about 50 degrees F (10 degrees C), they develop to maturity. There are usually 3 to 5 generations per year.

Phylloxera feed by sucking and form hook-shaped galls at the point of entry, causing the root to stop growing. In certain areas, such as Arizona, phylloxera develop winged forms while in California only the soil-living nymph qtage occurs.

Other Pests

Birds

Birds eat both ripe and unripe fruit. Most susceptible to damage are those vineyard which are isolated or those varieties which ripen early. Many systems are available to control or attempt to control birds. These include Carbide Cannons, lights, cages, biosoncis, toxic bait, mesh nets and chemicals.

Carbide Cannons: Carbide Cannons or explosive sound guns make noises similar to that of a 12-gauge shotgun. They may be operated from either calcium carbide or bottled gas. They are automatically controlled and have adjustable periods between explosions. These devices are initially effective but must be frequently moved in order to retain their limited effectiveness.

Lights: Lights are particularly effective in controlling birds in warehouses. Rotating yellow beacons do not prevent the presence of the birds, but do prevent their nesting. Populations are reduced as birds tend to feed in areas adjacent to their nest. These are not effective under field conditions.

Traps and Cages: Traps and cages may be used to reduce the populations of birds which are protected by law and cannot be killed. Birds are usually attracted to the trap by some type of bait, enter through slots in the top, but cannot get out. Once caught, the birds are released in areas away from the vineyard. In addition to physically trapping the birds, distress calls by the trapped birds may scare others away.

Biosonics: Biosonics make use of distress calls to scare away potential pests. Distress calls are recorded and played back at intervals through loud speakers. Birds quickly become accustomed to the calls and will roost on the speakers. A system sold by Av-Alarm makes use of several tapes operating on differing cycles to constantly change the sound amplified. While this type of system is more effective it is still of questionable value, but becomes more effective when used with other methods of control.

Toxic Baits: Toxic baits are helpful in controlling birds. Grain or peanuts treated with a variety of materials is spread in the vineyard, either on the ground or in trays above the trellis systems. While this method can reduce the population of bird pests it is nonselective, killing all birds and animals which are able to feed on it.

Mesh Nets: Mesh nets stretched over the vine or vineyard are extremely successful in keeping birds from getting at the fruit. To be effective the fruit must be entirely covered with no openings left through which the birds may enter. While the mesh netting is effective it is expensive and requires a good deal of hand labor to put in on and remove it. Several types of material are available which are inexpensive and are used for one season only, but there is a disposal problem with these materials. A filamentous synthetic material resembling spider webbing has been effective under field conditions. In addition to reducing bird damage it excludes bees and wasps which may feed on the ripening berries causing secondary disease infestations. This material hampers hand harvesting because of its nuisance to the workers and may clog mechanical harvesters.

Chemicals: Several chemicals exist which, to a greater or lesser extent, repel birds. Some interfere with feeding. These materials are spread on the cordons or trellises and irritate the birds' feet when they roost or feed. They are somewhat effective but require frequent reapplication. Another chemical now in the testing stage is a carbamate insecticide (similar to Sevin) originally intended to control mites. It makes the birds sick for several hours, after which they recover. Reportedly the birds are able to sense the presence of the chemical, and after a few have become ill the rest of the flock will avoid the area. This material is presently under test in various parts of the country. This chemical as well as any other should not be used until it has been thoroughly tested and registered for use.

Deer

The best way to control deer is to prevent them from entering the vineyard. This is usually done by fencing the vines. Woven wire is usually sufficient. It may be necessary to build the fence to 12 ft in height but usually 6 ft should discourage most deer.

Repellants may also be used. Materials are available which repel by either taste or smell. Taste repellents are generally impractical because they must be reapplied following each rain. Aromatic repellents are generally more effective. Good results have been obtained by hanging small sacks containing blood meal from each vine. Varying degrees of effectiveness have been obtained by using wild animal feces around the perimeter of the vineyard. Feces from the Bengal tiger and lion have been the most effective.

Mice and gophers

Both mice and gophers cause damage in vineyards, and both animals can girdle the vine at the ground level. Mice are more of a problem in colder areas where snow cover is present. They tend to congregate in grass and trash surrounding the base of the vine and then feed on the bark. This problem is especially severe where cold or prolonged winter periods occur.

Gophers may girdle the vine at the base of the trunk or burrow holes 2 to 3 inches in diameter through the soil. In addition to causing destruction of the root system and loss of vigor and productivity, they increase water losses by diverting water away from the plant.

Poisoned bait may be used to control these rodents. Trapping is also effective for gophers. Mechanical applicators have been developed to create artificial burrows into which the bait is places.

Rabbits

Rabbits are a particular problem where vineyards are isolated or next to native range or grassland. They are primarily a pest of young vines where they chew off the young, tender bark. Individual wire baskets may be placed around the plot; however, a mesh fence 2 and 1/2 ft high around the field is the best answer. The base of the fence should be buried 6 inches below ground to prevent the rabbits from burrowing under.

Nonparasitic Disorders

Alkali Injury

One problem in arid regions is an excess of sodium. Vines growing on alkali soils are smaller, with smaller leaves and shorter internodes. Leaves often show burning (beginning at the margin) if the soil becomes desiccated. The leaves have large, whitish-yellow spots between the main veins. Vines may be partially or completely defoliated and may die. Irrigation or reduction in temperature may allow the vines to begin growth again.

To correct the problem, drainage and water sufficient for leaching are required. Application of gypsum or sulfur may be useful in correcting the problem.

Bud Failure

Failure of the bud to begin growth on time is caused by inadequate bud development which in turn is caused by immature wood formed the previous season. Vines affected with this disorder are more subject to winter injury. The less mature the wood, the greater the injury. The extent of bud failure is dependent on the temperature, the length of exposure to cold and whether a frost or freeze occurs early or late.

Failure of wood to properly mature may be caused by a variety of factors which include: overcropping; late vegetative growth (high nitrogen or water); vine defoliation by insects, diseases or water stress, lack of potassium; or viruses (Leafroll).

Coulure, Shelling and Shot Berry

Flowers which are not properly fertilized drop from the cluster approximately 10 days after bloom. Straggly clusters caused by heavy flower drop are referred to as coulure or shelling. Some non-fertilized flowers do not fall and develop into small, round seedless berries. These are normally called shot berries.

Failure to properly set berries may be caused by low carbohydrate reserves, nutritional deficiencies (zinc and boron) or an excess of flowers.

Red Cane

Red cane is a condition caused by failure of the canes to properly mature. They remain green until late in the fall, when cool night temperatures cause them to turn red. This red part may be found only on the tip of the canes. This is normal, because it is impossible to completely mature the cane to its tip. The most common cause of red cane is overcropping which delays cane maturation. Starch content is very low in the affected canes.

Salinity Injury

Salinity injury is caused by high total salts. It is common to arid regions where irrigation water usually has a high total salt content. It may, however, be found in any area where insufficient leaching allows salt to build. The first symptom of salt injury is a marginal necrosis, followed by full necrosis. This becomes progressively greater until only the petiole remains unaffected. The grape is relatively tolerant to salt injury but variations exist between varieties.

Stem Necrosis

Stem necrosis begins at the stomates. As the cells die, polyphenols in cell walls and adjacent cells are oxidized. This creates the classic necrotic condition. This condition is a greater problem where hot, dry, windy periods or all these follow sufficient moisture. The disorder may be partially caused by reduced magnesium uptake, as magnesium sprays are partially effective in correcting the condition.

Water Berry

Two distinct disorders exist which result in water berry. They both involve a disruption of normal berry development. In one, the affected berries are confined to the tip of the rachis. In the other they are scattered throughout the cluster.

The former condition is caused by overcropping which prevents the proper nutrition to completely develop the cluster. If the disorder is minor only a few berries at the tip of the main stem are affected. If severe the symptoms may be observed at the tip of the tips of the laterals. Affected berries usually become dull and watery. In colored varieties the disorder is referred to as "Red Berry," and the berries fail to color properly. Potash treatment sometimes reduces the symptoms.

The second disorder, where affected berries are found scattered throughout the cluster, is not associated with overcropping or nutrient deficiency. The cause of the disorder appears to be stress-induced during hot periods, before the girdle wound is properly healed. Berries are effectively cut off from the remainder of the cluster by tyloses which plug the vascular tissue of the pedicels. If the plugging is complete, the berry dries; if the pedicel is only partially plugged water berries develop.

Weather Injury

Hail

Severe hail storms in midsummer may completely destroy the crop and reduce production the following year. This occurs because the reduced leaf area decreases fruit bud differentiation. No effective control of hail damage exists. After injury has occurred, pruning to encourage production of a few vigorous shoots for the following year's fruit buds is recommended. Occasionally hail is severe enough to beat young vines back to the ground. On young vines with excessive injury to the head or cordon, it is usually better to retrain strong, developing basal shoots into a new framework than to try to rejuvinate the injured head.

Heat Injury

Sudden temperature rises in the spring, after growth has started, may kill the terminal of the shoots. Injury is enhanced by drying winds. The degree of injury varies with the intensity of the heat. Usually injury is confined to the berries, which shrivel and turn brown. Sunburning may also occur.

The first symptom of sunburning is the appearance of wilted and shriveled berries. This is followed by a shriveling of the pedicels. The part of the cluster acropetal to the injury will dry and fall if the injury has happened early in the season. If injury occurs later in the season the affected portion remains with the cluster.

The severity of the condition can be reduced if the vines are kept vigorous via adequate pruning, proper trellising and adequate soil moisture.

Lightning

If the vines in small isolated areas suddenly die after an electrical storm, lightning may be the cause. In some cases shattered stakes may be found. More often necrotic areas appear along the canes and wilted or shriveled berries. The condition can be differentiated from insect damage due to the lack of excreta. The bark may be brown and the shoot tips dead. In trellised vineyards the damage is usually seen for a short distance along the row. Unless the damage is severe, the vine will remain alive.

Ozone Stipule of Leaves

Ozone stipule appears as small brown to black lesions on the upper surface of the leaf. This is followed by premature leaf fall. The condition is more common around industrial areas. There is no effective control in smoggy areas unless the quality of the air can be improved.

Ring Scarring

Ring scarring and buckskin-type corky areas occur occasionally on Thompson Seedless and Perlette varieties which have been treated with growing regulators to increase berry size. The injury is not due to the gibberellic acid used to increase size, but the wetting agent used to spread the material on the plant more evenly. The condition is controlled by using the sizing chemicals without a wetting agent.

Spring Frosts

Spring frosts cause damage anytime the temperature falls below 31 degrees F after warm periods have stimulated growth. Plant or tissue temperatures are more important than air temperatures. Actual tissue temperatures can be several degrees cooler than air temperature, due to the evaporative cooling effect caused by water evaporation. Temperature depression is greater at low humidities. The extent of frost damage is determined by the absolute temperature achieved and the duration of the cold. Temperatures 1 to 2 days prior to the frost are important because low, non-freezing temperatures cause an increase in tissue hardiness. Warm temperatures during the same period make the tissue more sensitive to injury.

The amount of crop reduction will depend on the number of shoots injured and the fruitfulness of secondary and tertiary buds. The secondary buds are usually only 60% as fruitful as the primaries. Tertiary buds may produce little or no fruit. Varieties producing fruitful buds at the base of canes and from side-growing points on the nodes rarely suffer as much damage as those which do not.

Developing buds are less-resistant to frost than dormant ones. The terminal buds on shoots develop first. Severe frost damage can be prevented if the canes are not pruned until late in the spring. Early growth will occur at the terminal, be susceptible to frost damage and prevent the basal buds from developing. When the chance of frost is past, canes may be pruned to proper length, thus encouraging rapid development of uninjured basal buds.

The probability of spring frost damage is perhaps the greatest factor limiting the area of commercial grape planting. Few areas are completely free of frost. Vineyards adjacent to the leeward side of large bodies of water are less likely to be injured due to the high heat capacity of water. Wind helps to reduce injury by reducing air stagnation and the development of critical low temperature masses. Cold air drains, as does water, to the lowest elevation. Therefore, (to reduce or prevent spring frost injury), avoid planting in depressed areas in which the low temperature air can accumulate. Proper handling of the vines yields hardy, mature wood, which is less susceptible to early fall frost.

Protection against frost can be afforded by the addition of heat to the vineyard, or the prevention of a cold air buildup, via heating, sprinkling or irrigating. The use of gas or oil-fired heaters may raise the temperature in the field 5 to 6 degrees, which is often sufficient to prevent injury. Heater systems are, however, quite expensive to operate due to high fuel prices and a high initial investment for heating equipment and fuel storage facilities is necessary.

Irrigation during the day and night preceeding the frost can lessen the severity of frost damage. Moist soil has a greater heat capacity than does dry soil and solar energy absorbed by the water will be released over a longer period of time, increasing vineyard temperatures. In addition, the evaporating water increases the relative humidity, in the vineyard, causing less tissue temperature depression, due to reduced evaporative cooling of the vines.

The use of overhead sprinklers can greatly reduce frost injury. Water has a high specific heat, and as it is cooled to freezing, a large amount of heat is released. By applying water to the vines this heat may be utilized to prevent frost damage. Water should be applied at a rate just fast enough to prevent the plant from becoming dry. As the air temperature drops below freezing, specific heat in the water is liberated to the atmosphere. Ice will form on the plant, but a continuous film of water over the ice will prevent the temperature of the plant tissue from dropping below freezing.

This system of frost damage prevention is not without disadvantages. The initial cost of the sprinkler system is high; however, it may also be used for irrigation, thus cutting down overall management costs. A second problem is physical. Structural damage may be caused by heavy loads of ice. This can be minimized by applying only as much water as is absolutely necessary, which will also reduce the potential problem of excessive soil wetness.

A difficult decision for growers to make is: when should the system be turned off? In many instances the vines have been protected throughout the night, only to suffer injury after the sprinklers have been shut down, and the temperature has risen above freezing. The system cannot be turned off unless all the ice is gone from the vine, despite the rise of the temperature above freezing. If the supply of water is removed while ice is still present, the ice will begin to evaporate. To do so heat must be utilized. This heat can come from the air, but usually is taken from the plant tissue. The withdrawal of heat from the tissue will cause the temperature to drop below the critical point, yielding frost damage.

Winter Injury

Severe winter cold may kill the above-ground portions of the vine and damage the roots by freezing the soil. Species vary in their ability to withstand low temperatures. *Vitis vinifera* is normally severely injured if the temperature falls below 0 degrees F. American cultivars can withstand temperatures down to −43 degrees F, while French hybrids are intermediate in their tolerance to freezing.

Covering the vines with earth or straw will afford protection by forming an insulating blanket around the plants. Special types of trellising and training systems are needed to allow canes to be buried. In addition to the special systems, the amount of labor required to bury and replace the canes is large. Some rootstocks may add additional hardiness to the vine.

Proper maturation of the vine is necessary if maximum hardiness is to be achieved. Vines which are excessively vigorous are delayed in entering rest and are more susceptible to winter injury due to reduced maturation. Water status in the plant is extremely important for development of maximum hardiness. Excessive moisture late in the season may delay the development of hardiness, while drying the vines will aid in stopping growth and including hardiness. The latter is very beneficial in protecting against early fall frosts.

The development of true winter hardiness is an active process which requires water. If water is withheld in the fall it may induce temporary hardiness but will not permit the vines to develop full hardiness, and may indeed reduce the survivability of the vines. Additionally, the vines may be injured and killed by drought stress. The vine is a living organism and requires water to continue its biological process including respiration. If insufficient moisture exists these biological processes will cease, and death will follow. Sufficient moisture must therefore be provided. The greatest degree of hardiness can be achieved by withholding moisture in the fall to stop growth and promote vine maturation. Once growth has ceased, sufficient moisture should be applied to allow the vine to develop maximum hardiness. The reapplication of water should be delayed until the chance of regrowth is past. Unless the vineyard becomes too dry, irrigation can be delayed until after the first frost has occured.

In cold climates it is necessary to plant the vines deeply because the root system does not achieve the same degree of hardiness as the top. The crown area is particularly sensitive. The vines should be planted deeply enough to place the crown below the frost line.

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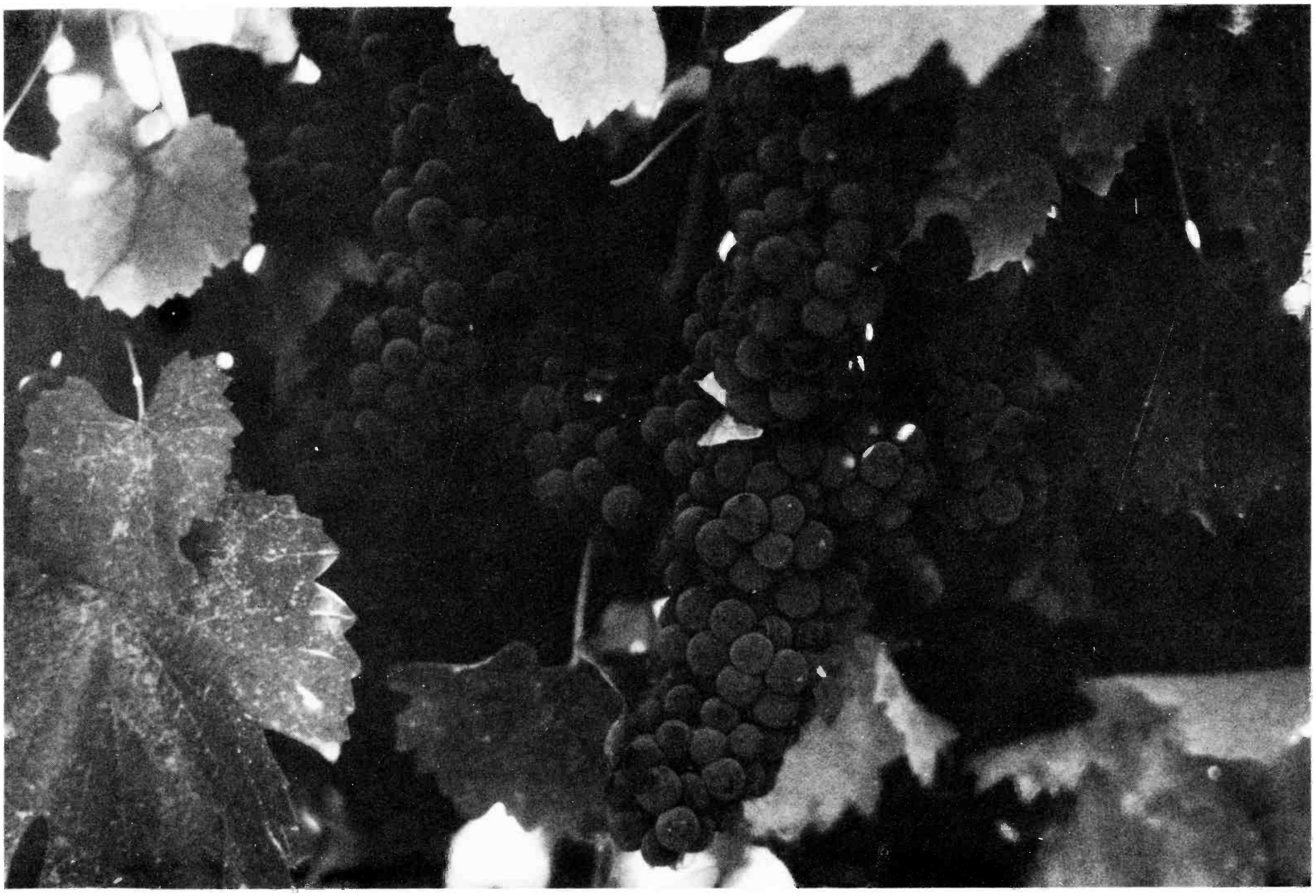


Pinot Noir Grapes in Arizona

SPECIAL VINE TREATMENTS

Girdling

Girdling is a very old practice used to promote the size, set and maturation of grapes. It is also referred to as cincturing or ringing. It consists of the removal of a strip of phloem 3/16 to 1/4 inch wide around the entire trunk cordon, arm, spur or cane. It is now used routinely to increase the size of seedless table grapes. It can be used to increase maturation when performed at verasion, but its use to advance maturation is very limited.

Why Girdle?

The effect of girdling varies with variety and the time at which it is performed. Timing is particularly critical since the effect wears off very quickly as the girdle heals. It must be open to exert its effect. As previously stated, it is used to increase size and advance maturity.

Size: The effects of girdling are greater and the increased size is achieved faster when it is done in the early stages of cell division. Cell division normally occurs between anthesis (flowering) and 14 to 21 days post anthesis. It is most effective when performed at 5 to 10 days post anthesis as this time correlates with the most active cell division in the pericarp. Girdling will have no effect on increasing size if the vines are overloaded.

Girdling for size control cannot be done alone. The increasing size of individual berries will cause pressure within the cluster, resulting in deformed and possibly split berries. This may lead to secondary infections. To be effective, girdling for size increase must be coupled with thinning to reduce compaction.

The girdling of seeded varieties has very little effect on size. Variable results have been obtained showing a 0 to 14% increase. Where these increases occurred, they were not large enough to offset the increase in labor to do the girdling. Berry and cluster thinning will give more consistent results in increasing the size of seeded varieties without the potential for causing damage to the vine.

Maturation: Girdling can be used to improve color development and hasten ripening. The girdle must be open late in the season and in cooler climates may not heal sufficiently to permit vine reserves to be restored to successfully survive the winter. Girdling for advancement of maturity is usually done just before verasion.

Girdling interacts with the size of the crop, the amount of vine growth and the seasonal changes in the climate. Overcropping, active vegetation and cool weather during the ripening period will negate any effects of girdling. Girdling will improve the color and uniformity of color in red table grapes. Its value for advancing the harvest date is doubtful with the exception of the very early regions where ripening advances may mean a few days earlier harvest and enough extra income to offset the risks of vine damage and cost. Girdling has no beneficial effects on advancing the maturity of Thompson Seedless and Perlette table fruit. Reports of soft berries, poor color and excessive sunburning have been reported from its use on these varieties.

Girdling the Vine

Girdling is done with a double-bladed knife, with the blades space 3/16 to 1/4 inch apart. While a single-bladed knife can be used it is more time consuming and usually results in a poorer job. Using the tips of the knives, a cut is made in the trunk, cordons or arms, and a piece of phloem (bark) about 1 inch long removed. The action is repeated until a ring of phloem has been removed completely around the vine structure to be girdled. Canes may also be girdled. To girdle canes, a special pair of pliers with a pair of double bladed knives is used.

To be effective, the ring of phloem must be completely removed. If a small strip remains, the effectiveness of the practice will be greatly reduced. The girdle should go only as deep as the cambium. If it goes into the xylem (wood) it will injure the vascular system which conducts water and nutrients to the top parts of the vine. This may cause the vine to suffer water stress, which will not only negate the effect of girdling, but reduce both the size and the quality of the crop.

Girdling may be done successfully year after year without injury to the vine, assuming the vine remains healthy and is not allowed to overcrop. If the vine does show signs of weakening, the process can be discontinued for a year, which is usually enough time for the vine to recover.

Effects on Vine Physiology

Girdling reduces the downward movement of many compounds, especially organics. The upward movement of minerals may be reduced. While most of the upward (acropetal) transport of water and nutrients is in the xylem, some of the mineral elements move upward in the phloem. The reduction in upward movement may result in chlorotic symptoms in the leaves. This is particularly apparent in vines with marginal, but non-visual deficiencies.

The weakening that a vine will experience is directly related to the length of time the girdle remains open and the length of time it takes it to heal completely and restore vascular activity. This normally takes 6 weeks, but in slower growing vines may take longer. In vines with slow healing rates it is advisable to make as narrow a girdle as possible.

The vine needs good cultural care during the healing process. Irrigation scheduling is critical since the vines should not be allowed to stress. Over cropping reduces the rate of healing. It is necessary to reduce the crop to 2/3 to 3/4 of what it would have been without girdling.

Young vines cannot be successfully girdled if they are to develop strong frameworks. It is not advisable to girdle before the third year of production.

Gibberellin

There are 52 known acidic gibberellins. One of these, GA_3 or gibberellic acid, can have the same effect as girdling when applied to the vine. When it is applied along with girdling the effect is greater than either practice used alone. Gibberellic acid is used mainly on the Thompson Seedless variety.

Application

Gibberellic acid is applied at very low rates (25 to 5 ppm) at 90% capfall (loss of the calayptra to expose the flowers) on Black Corinth. This increases the set and the formation of the desired seedless shot berries. The gibberellic acid also slightly enlarges the berries. This application can be put on much more quickly and less expensively than hand girdling.

Gibberellic acid is used in Thompson Seedless table grape production. It is applied in two applications. The first, 2.5 to 20 ppm, is applied at bloom (20 to 80% capfall). This treatment thins the berries by reducing set, increases berry size slightly and causes an elongation in the branchwork of the rachis, allowing more room for the developing berries. If the concentration of GA_3 is high the berries may become elongated rather than ellipsoidal. The second application is applied at shatter to further increase size. This second spray (20 to 40 ppm) is mainly responsible for the size increase. If the two sprays are used in combination with girdling the resulting berry will be about three times as large as an untreated control.

Thinning

Thinning refers to the removal of flower clusters prior to bloom, and immature clusters or parts of clusters after set has occurred. Thinning increases the physiological activity of the remaining clusters or parts of clusters, because it does not reduce leaf area. Crop size may actually be increased because less severe pruning is done, allowing a greater leaf area to support the thinned crop.

When thinning is performed, there is less expense involved than in other cultural operations. The looser cluster requires less costly hand trimming at harvest. The fruit has less rot and mold, increased and more uniform color, less deformed and higher quality berries. Thinning chemicals may be applied at three times for three different reasons to result in the highest quality fruit. They can be applied alone or used in any combination. Flower cluster thinning is used on varieties which set straggly clusters. Cluster thinning is used where the clusters are well set, but too many exist, and berry thinning is used to loosen compact clusters.

Flower Cluster Thinning

Flower cluster thinning is done between the time the shoot leafs out and bloom occurs. The earlier this is done the greater the effect will be. In reducing the number of clusters without decreasing the number of leaves there are more carbohydrates available to stimulate more uniform cell division, better set and less shot berries. Flower cluster thinning does not result in a reduction of crop. The crop is actually slightly increased in weight. The cluster size is also increased allowing more room for the developing berries.

Cluster Thinning

Cluster thinning refers to the removal of whole fruit clusters after the crop has set. This has no effect on the percentage set since it is done after set. Likewise it does not increase the length of the cluster. It is used on varieties which set fruit well within the cluster but simply have too much fruit. It is more expensive to thin after bloom than before; however, thinning after set allows the removal of small, misshapen or oversized clusters, which could not be done if thinning was performed prior to set. This method allows for the retention of only the best clusters.

This method is usually only used on table fruit where the extra income from the fruit offsets the higher labor cost involved. It has been used in the production of raisin and wine grapes in years where winter damage has occurred, but the extent of the damage is not known. Hopefully, by leaving more or longer shoots or spurs it is possible to get full production by allowing the vine to set more than enough clusters and then removing the excess. Usually economic considerations do not allow crop thinning on raisin or wine grapes in normal years. Pruning is a more efficient way to limit the crop.

Berry Thinning

Berry thinning refers to the removal of parts of the cluster or individual berries after set. This is done at shatter to prevent problems caused by overcompaction. It does change the normal characteristics of the cluster. The rachis (main cluster stem) is cut back to five lateral branches. These are usually long and allow movement of the berries. The lower, side branches are quite short and if not removed would not allow the berries to expand properly.

Berry thinning results in a 30% increase in berry weight of seeded varieties if it is done promptly at the time of shatter. If thinning is delayed for 1 week the increase would be only 20%. If it is delayed for 2 weeks, the percent increase in weight is only 10. For maximum size increase it needs to correspond with the period of rapid cell division. Total cluster weight is increased at harvest. Colored varieties show increased color development and harvest occurs over a shorter period of time due to more uniformity of ripening. Removing individual berries while leaving the cluster intact can be done in the field but is too expensive. It is, however, practiced in hothouse production in Europe (mostly Belgium), where the fruit demands a premium price.

Berry thinning will not effectively increase the size of seeded berries. It is used in seeded table grape production to prevent overcrowding caused by girdling and gibberellic acid. This prevents berries from rubbing against one another to remove the waxy bloom which adds to the quality of the fruit. It also prevents the formation of misshapen fruit, splitting and rot infestation.

Chemical Thinning

The importance of chemical thinning is increasing due to the high cost and unavailability of labor. It is also easier to perform a more timely thinning as the chemicals can be applied quickly. The reduced expense of chemical thinning allows it to be used on varieties which would not warrant hand thinning due to the limited financial returns.

When used as a prebloom treatment, gibberellic acid reduces set and increases the length of all parts of the cluster, not just the main rachis. It does increase the number of shot berries. It is usually applied 2 to 3 weeks prior to bloom when the clusters are an average of 3 to 4 inches in length. The concentration will vary with the variety treated. Some examples of average rates are:

Variety	ppm
Aleatico	2.5– 5
Carignane	2.5– 5
Chenin blanc	5– 10
Palomino	1– 1.5
Petite Sirah	5– 10
Tinta Madeira	1– 1.5
Valdepenas	2.5– 5
Zinfandel	5– 10

If gibberellin is applied at too high a concentration the vine or fruit may be injured. The symptoms of excess gibberellic acid are delayed bud growth the following spring (this may reduce spring frost injury, but the level of winter hardiness is not as great), decreased winter survival, and an increased number of shot berries. Seedless varieties are usually not injured.

PREPARATION FOR DORMANCY

In their natural habitat plants survive because they have adapted to the environment. Through breeding, varietal improvement and cultivation plants have lost their adaptations to a given region. Very often they have been moved to areas outside their natural habitat. For plants to survive in non-native habitats, man has tried to adapt them to the new environment.

Acclimation to environmental stress, specifically hardening against cold, is a two-stage process. The first stage is partially controlled by physiological phenomenon not related to temperature. The second stage is physiological but is induced by temperature.

COLD ACCLIMATION

Woody plants undergo a series of events leading to hardening. Many physiological events occur, resulting in quantitative changes in many organic compounds. Hardening, or cold acclimation, is a two-stage procedure. Stage 1 provides only a modicum of protection against cold. It is induced in the fall by shorter days and cool nights followed by warm days. Short day length triggers a compound or compounds, which in part induce growth stoppage. Cool nights, followed by warm days aid in establishing a minor level of hardiness. Very cold temperatures prevent acclimation.

Stage II is triggered by frost and cannot be induced until Stage I has occurred. Therefore, if a plant is to harden, growth must have stopped before continuous cold weather occurs. During the second stage, enzymes activated by the cold nights are operating during warm days which follow the frost. As hardening progresses, increasing amounts of cold stimulate further hardening until the maximum level is reached. Extended periods of warm temperatures during hardening will reverse the process, and a relatively short period of warm weather will drastically reduce the plant's hardiness. For this reason, deeper hardening occurs in eastern climates than in the more variable western climates.

Requirements for Hardening

There are several empirically determined principles which relate to the ability of a plant to adapt to low temperatures. They are:

A plant with depleated reserves cannot fully harden. During the first stage, leaves respond to short days. Low temperatures inhibit the short day response. During short days, leaves produce a translocatable hormone which promotes acclimation. The promoter moves through the plant from leaves to the trunk. Frost induces the second phase.

WAYS TO INCREASE HARDINESS

Though all the answers to the complete control of hardiness in a vine are not known, there are several things a grower can do to increase the chances that the vines will survive cold weather. Selecting the best variety or varieties for the area to obtain the maximum degree of hardiness, and in some cases, use of the correct rootstock, will increase the survivability of the vine.

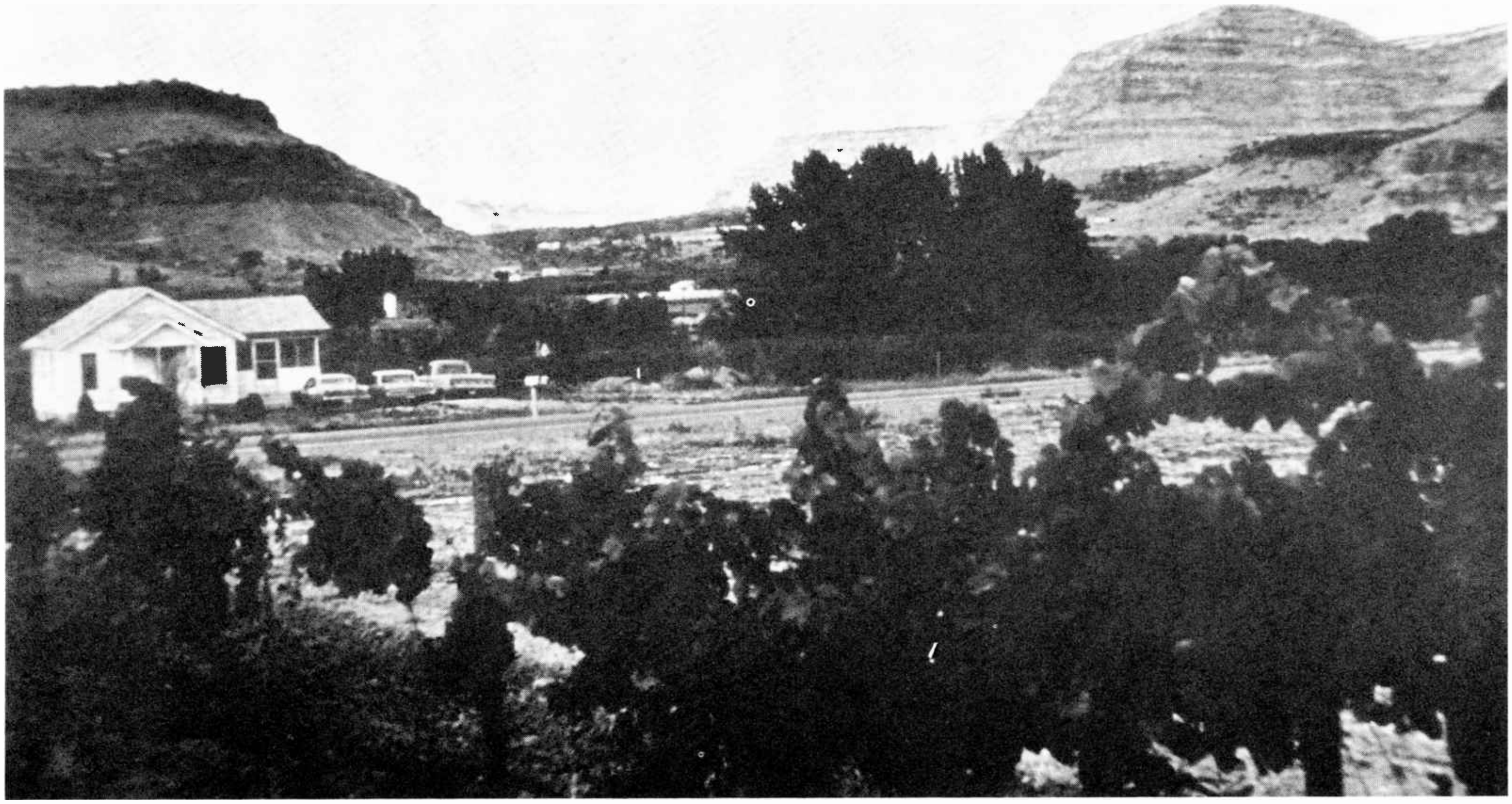
It is important to prevent the prolongation of growth, as a vegetatively growing vine can not harden. One of the main ways to prevent delayed growth is to control fertilization (particularly nitrogen). Excess fertilizer can cause vigorous growth without proper maturation. If excess nitrogen is present late in the season, seeding the area between the rows with a grain crop will help "dry out" the nitrogen. It is also important to watch the water status of the plant. Next to excess nitrogen, excess moisture is the greatest cause of delayed stoppage of growth. A slight degree of moisture stressing will aid the plant in stopping growth and will provide added protection against fall frosts and freezes. The minimum amount of water needed to keep the plant alive should be used before the onset of cold weather. After the first frost, the soil is best kept moist.

It is important to keep the leaves healthy as long as possible. Healthy leaves are able to fix CO_2 and produce photosynthates. They supply energy for growth, development and all physiological reactions. Damage to the leaves by insects and diseases must be prevented so Stage I may be attained fully.

Proper conditions need to be provided for Stage II. Although it is triggered by frost, the hardening itself is a physiological process. The plant needs water to survive and carry out its physiological processes. Where a deficiency of water aids in the induction of Stage I, it retards the deeper induction of cold hardiness in Stage II. Usually at least one irrigation after leaf fall has occurred is necessary.

Once the plant is resting in Stage II, everything to keep it in the most hardened condition possible should be done. Hardening is retarded by warm temperatures, and pruning stimulates growth of the plant. It is therefore wise not to prune during or just prior to a spring thaw, as the combined stimuli of pruning and warm temperatures would greatly reduce plant resistance to cold.

Growth begins at the terminal of the shoot. The more basal the buds, the more juvenile they will be and the more cold they will be able to tolerate. By pruning as late as possible and not pruning the canes which will become the fruit-bearing vines, more desired basal buds will receive less cold damage. These canes can be shortened to the proper length once the danger of frost is past.



Vineyard at Grand Junction, Colorado

COST ANALYSIS

The following tables provide cost information on establishing and producing various types of grape products in various locations. These reflect production for conventionally irrigated plantings.

ASSUMPTIONS

The tables presented herein are adapted from economic information developed by the University of California but are modified to reflect the diverse conditions in the Four Corners Region. These range from the hot low desert to the cool high valleys. In establishing these tables, certain assumptions had to be made. These assumptions may not hold true for every area of the region. It may be necessary to modify costs according to local conditions and the size of the operation. The examples presented span the broad range of situations found in the region. The following assumptions have been used:

These tables are based on a 40-acre unit with an 8 x 12 foot spacing. Managerial labor costs are figured at $4.60 per hour with $3.60 per hour for laborers. Equipment costs are $3.10 per hour for a tractor, $2.00 for depreciation and $1.00 for interest. Yields and prices vary with the variety and area of production and will be stated for each example.

Land cost include preparation for flood irrigation. Other preparation costs are extra. The irrigation costs are computed on the basis of pumping the water and delivering it through a pipeline. Irrigation districts would vary. The water is assumed to cost $20.00 per acre foot.

It is assumed that registered cuttings will be planted. Other material can be obtained at lesser or greater cost. Registered non-rooted cuttings are assumed to cost $.25 each.

Pest and disease control values are average values. Costs may vary widely from year to year, or from one area to another.

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Table 9. Cost of establishing girdled or non-girdled table grapes in a hot region.

	Costs Per Acre		
	1st Year	2nd Year	3rd Year
YIELD: Tons Fresh Fruit Per Acre	0	0	0
Pre-Harvest Cash Costs:			
Fumigate:	$ 235.00		
Pre-plant weed control:	19.00		
Land preparation: chisel, disc, float, etc.	65.00		
Rootings: 450 (20, 2nd yr.) @ 25¢	112.50	$ 5.00	
Trim and Misc. planting: 8 hr., + 1½ hr. 2nd yr	32.00	6.00	
Planting: 8¢	36.00		
Stakes (treated): 450, 7 @ $1.00		450.00	
End posts (treated): 11, 8 @ $4.65		51.15	
Stake and set end posts: 8¢ stakes and $2.50 end posts.		63.50	
Wire: #13 high tensile 2nd yr, 82 lb.; 3rd yr, 246 lb. @ $26/lb		21.32	$ 63.96
String wire and staple: one 2nd yr; three 3rd yr		22.00	44.00
Attach crossarms and braces: 32 hr			115.20
Crossarms: 3 ft @ 19¢, braces @ 4¢ + staples, nails, tie wire			124.00
Train and sucker: 24 hr labor, 2nd yr; 7 hr labor, 3rd yr		86.40	25.20
Prune and tie: 5 hr, 2nd yr; 18 hr, 3rd yr		18.00	64.80
Rabbit control	10.00	5.00	
Irrigation labor: 5 hr @ $4.60	23.00	23.00	23.00
Water-power and/or district tax	30.00	50.00	70.00
Irrigation preparation and weed control: 6 hr labor + 4 tractor hr, 1st yr; then 8 hr labor + 4 tractor hr	38.00	62.20	62.20
Fertilizer @ 30¢ applied (25 lb N, 2nd yr; 50 lb N, 3rd yr)		7.50	15.00
Mildew control: 2 hr labor + 2½ tractor hr			19.15
Pest management			45.00
Misc. labor, materials, tractor	22.00	18.00	22.00
County taxes	40.00	40.00	60.00
Repairs, except tractor	20.00	18.00	20.00
Business and office costs, operating capital, insurance	40.61	49.90	49.22
TOTAL PRE-HARVEST CASH COSTS	723.11	996.97	822.73
Harvest Costs:			
Contract @ $25/ton—pick and haul			125.00
TOTAL HARVEST COSTS			125.00
TOTAL CASH COSTS	$ 723.11	$ 996.97	$ 947.73
Depreciation:			
Irrigation system: $300, 20 yr life	15.00	15.00	15.00
Buildings and equipment, except tractor: $160, 12 yr life	13.33	13.33	13.33
Tractor: $2.00/hr	10.00	10.00	13.00
TOTAL DEPRECIATION	38.33	38.33	41.33
Interest on Investment @ 8%			
Irrigation system: 1/2 cost $150	12.00	12.00	12.00
Buildings and equipment, except tractor: 1/2 cost $80	6.40	6.40	6.40
Tractor: $1.00/hr	5.00	5.00	6.50
Land: $2000/A	160.00	160.00	160.00
Interest on accumulated costs		57.85	137.61
TOTAL INTEREST ON INVESTMENT	183.40	241.25	322.51
TOTAL COST FOR THE YEAR	944.84	1276.55	1311.57
TOTAL FOR FRUIT @ $100/TON			500.00
NET COST FOR THE YEAR	944.84	1276.55	811.57
TOTAL ACCUMULATED COST	944.84	2221.39	3032.96

Table 10. Cost of establishing wine grapes in a hot region.

	Costs Per Acre		
	1st Year	2nd Year	3rd Year
YIELD: (Tons/Acre)	—	—	4
Pre-Harvest Cash Costs:			
Fumigate:	$ 235.00		
Pre-plant weed control:	19.00		
Land preparation: chisel, disc, float, etc.	65.00		
Rootings: 519 (+25, 2nd yr) @ 25¢	129.75	$ 6.25	
Trim and misc. planting labor: 8 hr + 1½ hr 2nd yr	28.80	5.40	
Machine planting: $36/acre	36.00		
Stakes (treated): 519 7 @ $1.00		519.00	
End posts (treated): 11, 8 @ $4.65		51.15	
Stakes and set end posts: 8¢ stakes + $2.50 end posts		69.02	
Wire: 246 lb. 13 gauge high tensile (3 wires @ 26/lb.)		63.96	
String three wires and staple		44.00	
Training and suckering: 40 hr, 2nd yr; 10 hr, 3rd yr		144.00	$ 36.00
Tying materials		13.00	7.00
Prune and tie: 5 hr, 2nd yr; 12 hr; 3rd yr		18.00	43.20
Rabbit control	10.00	5.00	
Irrigation labor: 5 hr each yr @ $4.60	23.00	23.00	23.00
Water-power and/or district tax	54.00	66.00	80.00
Irrigation preparation and weed control: 6 hr labor + 4 tractor hr, 1st yr; then 8 hr labor + 4 tractor hr	38.00	45.20	45.20
Fertilizer: 30¢ applied (30 lb. N, 2nd yr; 50 lb. N, 3rd yr)		9.00	15.00
Mildew control: 2 hr labor + 1½ tractor hr + materials $5.00			18.35
Pest management			45.00
Misc. labor and materials, including 1 hr labor + 1 tractor hr	22.00	18.00	22.00
County taxes	40.00	40.00	60.00
Repairs, except tractor	20.00	18.00	20.00
Business and office costs, operating capital, insurance	41.61	58.86	31.18
TOTAL PRE/HARVEST CASH COSTS	762.61	1216.64	465.93
Harvest Costs:			
Contract @ $35/ton—pick and haul	—	—	140.00
TOTAL HARVEST COSTS			140.00
TOTAL CASH COSTS	$ 762.61	$1216.64	$605.93
Depreciation:			
Irrigation system: $300, 20 yr life	15.00	15.00	15.00
Buildings and equipment, except tractor: $160, 12 yr life	13.33	13.33	13.33
Tractor: $2.00/hr	10.00	10.00	12.00
TOTAL DEPRECIATION	38.33	38.33	40.33
Interest on Investment @ 8%:			
Irrigation system: 1/2 cost $150	12.00	12.00	12.00
Buildings and equipment, except tractor: 1/2 cost $80	6.40	6.40	6.40
Tractor: $1.00/hr	5.00	5.00	6.00
Land $2000/A	160.00	160.00	160.00
Interest on accumulated costs		58.09	153.19
TOTAL INTEREST ON INVESTMENT	183.40	241.49	337.59
TOTAL COST FOR THE YEAR	984.43	1496.65	983.85
TOTAL FOR FRUIT @ $125/TON			500.00
NET COST FOR THE YEAR	984.43	1496.56	483.85
TOTAL ACCUMULATED COST	984.43	2480.80	2964.65

Table 11. Cost of establishing trellised, irrigated wine grapes in a cool region. Production begins the fourth year.

	Costs Per Acre		
	1st Year	2nd Year	3rd Year
YIELD: (Tons/Acre)	—	—	—
Pre-Harvest Cash Costs:			
Fumigate:	$ 235.00		
Pre-plant weed control:	26.00		
Land preparation: layout	65.00		
Stakes (treated): 519 @ $1.00		$ 519.00	
Set stakes		72.66	
Rootings: 519 @ 25¢, + 25 2nd yr	129.75	6.25	
Trim and Plant	64.80	5.40	
End posts (treated): 11 @ $4.65		51.15	
Set end posts: 11 @ $2.50		27.50	
Wire: 164 lb. 13 gauge high tensile, @ $.26/lb.)		42.64	
String wire and staple			44.00
Training and suckering: 30 hr, 2nd yr; 20 hr, 3rd yr		108.00	108.00
Tying materials		10.00	10.00
Prune and tie: 5 hr, 2nd yr; 8 hr, 3rd yr		18.00	28.80
Rabbit control	10.00	8.00	5.00
Irrigation labor: 5 hr each yr @ $4.60	23.00	23.00	23.00
Water-power and/or district tax	20.00	30.00	35.00
Irrigation pump and weed control: 6 hr labor + 4 tractor hr, 1st yr; then 8 hr labor + 4 tractor hr	38.00	45.20	45.20
Fertilizer: 30¢ applied (20 lb. N, 2nd yr; 35 lb. N, 3rd yr)		6.00	10.50
Mildew control: 2 hr labor + 1½ tractor hr + materials	18.35	18.35	18.35
Pest management	15.00	15.00	25.00
Misc. labor and materials	22.00	18.00	22.00
County taxes	40.00	40.00	40.00
Repairs, except tractor	20.00	18.00	18.00
Business and office costs, insurance	41.61	49.90	38.50
TOTAL PRE/HARVEST CASH COSTS	768.51	1089.41	512.99
Depreciation:			
Irrigation system: $300, 20 yr life	15.00	15.00	15.00
Buildings and equip, except tractor: $160 12 yr life	13.33	13.33	13.33
Tractor: $2.00/hr.	10.00	10.00	10.00
TOTAL DEPRECIATION	38.33	38.33	38.33
Interest on Investment @ 8%:			
Irrigation system: 1/2 cost $150	12.00	12.00	12.00
Buildings and equipment, except tractor: 1/2 cost $80	6.40	6.40	6.40
Tractor: $1.00/hr	5.00	5.00	5.00
Land: $2000/A	160.00	160.00	160.00
Interest on accumulated costs	—	61.48	148.63
TOTAL INTEREST ON INVESTMENT	183.40	244.88	332.03
TOTAL COST FOR THE YEAR	990.24	1372.62	883.35
TOTAL ACCUMULATED COST	990.24	2362.86	3246.21

Table 12. Cost of production of girdled table grapes in a hot region.

YIELD: 522 lugs (23 lb.) shipped + 2.5 tons culls	Cost Per Acre
Pre-Harvest Cash Costs:	
Pruning: contract	$ 113.00
Brush disposal: all middles, contract	6.00
Tying	27.00
Fertilizer: 60 lb. N @ 30¢ applied	18.00
Girdling:	56.00
Gibberellin spray—materials & application	75.00
Thinning:	164.00
Mildew control: 2½ hr labor + 2 tractor hr + materials	24.20
Pest management	55.00
Irrigation preparation and weed control: 4 hr labor + 4 tractor hr	32.40
Irrigate: 6 hr labor @ $4.60	27.60
Water-power and/or district tax—4 A ft @ $20.00	80.00
Misc. labor: 8 hr labor + 2 tractor hr	35.00
Misc. materials, stakes, twine	40.00
County taxes	60.00
Repairs, except tractor	20.00
Business and office costs, operating capital, insurance	67.70
TOTAL PRE-HARVEST CASH COSTS	901.40
Harvest Costs:	
Pick and haul: contract	339.30
Packing: $1.90/lug	991.80
TOTAL HARVEST COST	1331.10
Depreciation:	
Vines, stakes, trellis: cost $3009, 30 yr life	100.30
Irrigation system: cost $300, 20 yr life	15.00
Buildings and equipment, except tractor: cost $160, 12 yr life	13.33
Tractor: 8 hr @ $2.00	16.00
TOTAL DEPRECIATION:	144.63
Interest on Investment @ 8%:	
Vines, stakes, trellis: 1/2 cost $1504.50	120.36
Irrigation system: 1/2 cost $150	12.00
Buildings and equipment, except tractor: 1/2 cost $80	6.40
Tractor: 8 hr @ $1.00	8.00
Land: $2000/A	160.00
TOTAL INTEREST ON INVESTMENT	306.76
TOTAL COST FOR YEAR	2683.89
CREDIT FOR FRUIT: 522 lugs @ $14.00	7308.00
Culls 2.5 Tons @ $75/ton	300.00
NET RETURNS	$4924.11

Table 13. Cost of production of non-girdled table grapes in a hot region.

YIELD: 457 lugs (23 lb.) shipped + 1.75 tons culls	Cost Per Acre
Pre-Harvest Cash Costs:	
Pruning: contract	$ 90.80
Brush disposal: all middle, contract	6.00
Fertilizer: 50 lb. N @ 30¢ applied	15.00
Mildew control: 3 hr labor + 2½ tractor hr + materials	29.75
Pest management, disease control & materials	70.00
Irrigation preparation and weed control: 4 hr labor + 4 tractor hr	26.80
Irrigate: 5 hr labor @ $4.60	18.40
Water-power and/or district tax—4½ A ft @ $20.00	90.00
Opening up vines: 17 hr labor	61.20
Misc. labor: 8 hr labor + 2 tractor hr	34.90
Misc. materials, stakes	40.00
County taxes	60.00
Repairs, except tractor	20.00
Business and office costs, operating capital, insurance	35.23
TOTAL PRE-HARVEST CASH COSTS	598.08
Harvest Costs:	
Pick and haul: contract	251.35
Packing: $190/lug	868.30
TOTAL HARVEST COST	1119.65
Depreciation:	
Vines, stakes, trellis: cost $3117, 25 yr life	124.68
Irrigation system: $300, 20 yr life	15.00
Buildings and equipment, except tractor: cost $160, 12 yr life	13.33
Tractor: 8½ hr @ $2.00	17.00
TOTAL DEPRECIATION:	170.01
Interest on Investment @ 8%:	
Vines, stakes, trellis: 1/2 cost $1559	124.68
Irrigation system: 1/2 cost $150	12.00
Buildings and equipment, except tractor: 1/2 cost $80	6.40
Tractor: 8½ hr @ $1.00	8.50
Land: $2000/A	160.00
TOTAL INTEREST ON INVESTMENT	311.58
TOTAL COST FOR YEAR	2199.32
CREDIT FOR FRUIT: 457 lugs @ $8.00	3656.00
Culls 1.75 Tons @ $75/ton	131.25
NET RETURNS	$1587.93

Table 14. Cost of producing Thompson Seedless grapes for wine in a hot region.

YIELD: 10 tons/acre	Cost Per Acre
Pre-Harvest Cash Costs:	
Pruning: contract	$ 88.23
Brush disposal: contract	4.00
Tying vines	15.00
Fertilizer: 50 lb. N @ 30¢ applied	15.00
Mildew control: 2 hr labor + 1½ tractor hr + material	18.35
Pest management	45.00
Irrigation preparation and weed control: 4 hr labor + 4 tractor hr	26.80
Irrigate: 5 hr labor @ $4.60	23.00
Water-power and/or district tax	80.00
Misc. labor: 3 hr labor + 1 tractor hr	13.90
Misc. materials	20.00
County taxes	60.00
Repairs, except tractor	20.00
Business and office costs, operating capital, insurance	38.66
TOTAL PRE-HARVEST COST	467.94
Harvest Cost:	
Pick and haul: contract	280.00
TOTAL HARVEST COST	280.00
Depreciation:	
Vines, stakes, trellis: cost $2679, 30 yr life	89.30
Irrigation system, cost $300, 20 yr life	15.00
Builds & equip, except tractor: cost $160, 12 yr life	13.33
Tractor: 6½ hr @ $2.00	13.00
TOTAL DEPRECIATION:	130.63
Interest on Investment @ 8%:	
Vines, stakes, trellis: 1/2 cost $1339.50	107.16
Irrigation system: 1/2 cost $150	12.00
Buildings & equipment, except tractor: 1/2 cost $80	6.40
Tractor: 6½ hr @ $1.00	6.50
Land: $2000/A	160.00
TOTAL INTEREST ON INVESTMENT	292.06
TOTAL COST FOR YEAR	1200.63
CREDIT FOR FRUIT: 10 tons @ $160/ton	1600.00
NET RETURNS	$400.37

Table 15. Cost of producing wine grapes in a hot region.

YIELD: 8 tons/acre	Cost Per Acre
Pre-Harvest Cash Costs:	
Pruning: contract	$ 88.23
Brush disposal: contract	5.00
Fertilizer: 60 lb. N @ 30¢ applied	18.00
Mildew control = 2 hr labor + 1½ tractor hr + materials	18.35
Pest management	55.00
Irrigation preparation and weed control: 4 hr labor + 4 tractor hr	26.80
Irrigate = 5 hr labor @ $4.60	23.00
Water-power and/or district tax	90.00
Misc. labor—3 hr labor + 1 tractor hr	13.90
Misc. materials	20.00
County taxes	60.00
Repairs, except tractor	20.00
Business and office costs, operating capital, insurance	38.30
TOTAL PRE-HARVEST CASH COSTS	478.58
Harvest Cost:	
Pick and haul: contract	272.00
TOTAL HARVEST COSTS	272.00
Depreciation:	
Vines, stakes, trellis: cost $2901. 30 yr life	96.70
Irrigation system: $300, 20 yr life	15.00
Buildings and equipment, except tractor: cost $160, 12 yr life	13.33
Tractor: 6½ hr @ $2.00	13.00
TOTAL DEPRECIATION:	138.03
Interest on Investment @ 8%:	
Vines, stakes, trellis: 1/2 cost $1450	116.00
Irrigation system: 1/2 cost $150	12.00
Buildings and equipment, except tractor: 1/2 cost $80	6.40
Tractor: 6½ hr @ $1.00	6.50
Land: $2000/A	160.00
TOTAL INTEREST ON INVESTMENT	300.90
TOTAL COST FOR YEAR	1189.51
CREDIT FOR FRUIT: 8 tons @ $300	2400.00
NET RETURNS	$1210.49

Table 16. Costs of producing trellised, irrigated, wine grapes in a cool region.

YIELD: 5 Tons/Acre	Cost Per Acre
Pre-Harvest Cash Costs:	
Pruning: contract	$ 88.23
Brush disposal: contract	5.00
Fertilizer: 40 lb. N @ 30¢ applied	12.00
Mildew control: 2 hr labor + 1½ tractor hr + materials	18.35
Pest management	40.00
Irrigation preparation and weed control: 4 hr labor + 4 tractor hr	26.80
Irrigate: 5 hr labor @ $4.60	23.00
Water-power and/or district tax	45.00
Misc. labor: 3 hr labor + 1 tractor hr	13.90
Misc. materials	20.00
County taxes	60.00
Repairs, except tractor	20.00
Business and office costs, operating capital, insurance	38.30
TOTAL PRE-HARVEST CASH COST	410.58
Harvest Cost:	
Pick and haul: contract	275.00
TOTAL HARVEST COST	275.00
Depreciation:	
Vines, stakes, trellis: cost $3246, 30 yr life	108.20
Irrigation system, cost $300, 20 yr life	15.00
Builds & equip, except tractor: cost $160, 12 yr life	13.33
Tractor: 6½ hr @ $2.00	13.00
TOTAL DEPRECIATION:	149.53
Interest on Investment @ 8%:	
Vines, stakes, trellis: 1/2 cost $1623	129.84
Irrigation system: 1/2 cost $150	12.00
Buildings & equipment, except tractor: 1/2 cost $80	6.40
Tractor: 6½ hr @ $1.00	6.50
Land: $2000/A	160.00
TOTAL INTEREST ON INVESTMENT	314.77
TOTAL COST FOR YEAR	1149.88
CREDIT FOR FRUIT: 5 tons @ $500/ton	2500.00
NET RETURNS	$1350.12

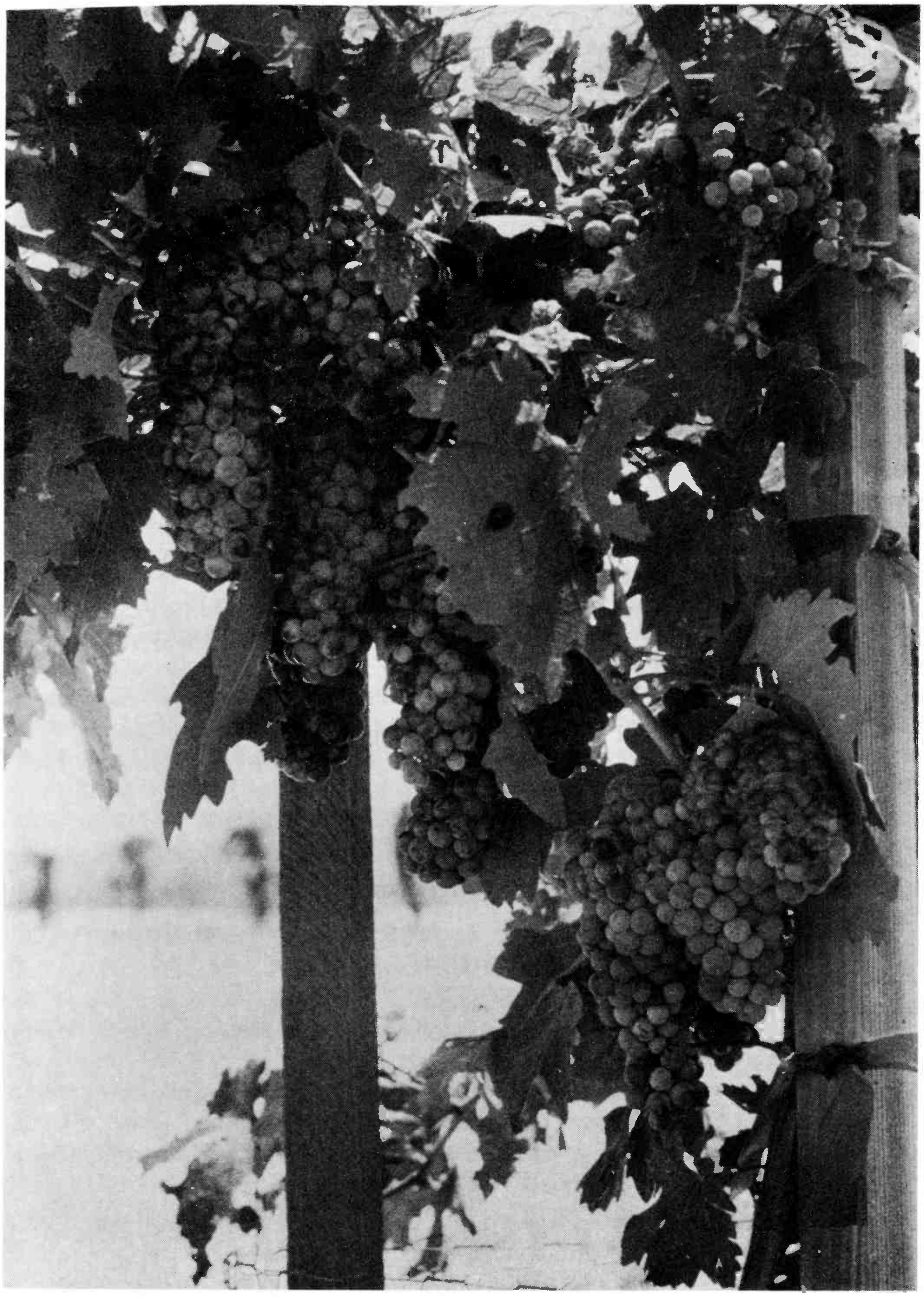
Trellising Costs

Table 17 presents more detailed figures on the cost of developing different trellising systems.

Table 17. Detailed trellising costs. Per acre costs, based on a 40 acre planting with a 7′ x 12′ spacing, 522 vines per acre (6 rows of 87 vines). Wire lengths: 11 ga., 26 ft/lb.; 12 ga., 34 ft/lb.; 14 ga., 59 ft/lb.

I.	Head-trained:		
	Stakes, 2″ x 2″ x 6′, 522 @ $.85		$ 443.70
		Total	$ 443.70
II.	Standard one-wire trellis:		
	Stakes, 2″ x 2″ x 6′, 522 @ $1.00		522.00
	End Posts, 12 @ $4.65		55.80
	Deadmen, 12 @ $1.25		15.00
	Wire, 14 ga., 63 lb. @ $.26/lb.		16.38
	Staples, #14, 3 lb. @ $.53/lb.		1.59
		Total	$ 610.77
III.	Standard two-wire trellis:		
	Stakes, 2″ x 2″ x 7′, 522 @ $1.00		$ 522.00
	End Posts, 12 @ $4.65		55.80
	Deadmen, 12 @ $1.25		15.00
	Wire, 14 ga., 126 lb. @ $.26/lb.		32.76
	Staples, #14, 6 lb. @ $.53/lb.		3.18
		Total	$ 626.74
IV.	Three-wire sloping-top trellis:		
	Stakes, 2″ x 2″ x 7′, 522 @ $1.00		$ 522.00
	End Posts, 12 @ $4.65		55.80
	Deadmen, 12 @ $1.25		15.00
	Crossarms, 2″ x 2″ x 40″, 522 @ $.19		91.18
	Braces, 522 @ $.04		20.88
	Nails, 12d, 5 lb. @ $.45/lb.		2.25
	Staples, #14, 9 lb. @ $.53/lb.		4.47
	Wire, 14 ga., 189 lb. @ $.26/lb.		49.14
	Additional for 4th wire		(17.97)
		Total	$ 751.03
		Four-wire Total	$ 769.00
V.	Three-wire "T" trellis:		
	Stakes, 2″ x 2″ x 7′, 522 @ $1.00		$ 522.00
	End Posts, 522 @ $4.65		55.80
	Deadmen, 522 @ $1.25		15.00
	Crossarms, 2″ x 2″ x 30″, 522 @ $.19		91.18
	Braces, 522 @ $.04		20.88
	Nails, 12d, 5 lb. @ $.45/lb.		2.25
	Staples, #14, 9 lb. @ $.53/lb.		4.47
	Wire, 12 ga., 109 lb. @ $.26/lb.		28.34
	Wire, 14 ga., 126 lb. @ $.26/lb.		32.76
	Wire, 12 ga., 327 lb. @ $.26/lb. (mechanical harvest)		(85.02)
		Total	$ 772.98
		Mechanical Harvest Total	$ 796.90
VI.	Geneva Double Curtain:		
	Posts, 180 @ $4.65		837.00
	Deadmen, 12 @ $1.25		15.00
	Crossarms, 2″ x 4″ x 3′, 180 @ $.46		82.80
	Braces, 360 @ $.47		169.20
	Nails, 16d, 7 lb. @ $.45/lb.		3.15
	Wire, 12 ga., 327 lb. @ $.26/lb.		85.02
	Staples, #14, 9 lb. @ $.53/lb.		4.77
		Total	$1196.94

Adapted from: Winkler, A. J. and A. N. Kasimatis, 1959. Supports for grapevines. Univ. California Coop. Ext. Ser. Leaf. 119.



Zinfandel Vine from Page Ranch, Arizona

The Plan

Any new potential winery should set forth a concise plan to follow for its product. The ability to anticipate future needs will only facilitate the winemaking process and expenses. The type of wine desired is often determined for the winery owner by several factors such as: the quality of grapes that can be harvested, the various winemaking equipment employed and the marketing outlook for the wine. This review of winemaking procedures will hopefully present some of the options faced by the winery operator.

Most table wines are advertised as either a competitively priced, generic wine or a premium, vintage wine. Both styles of wines have their merits and disadvantages in terms of costs. This review will attempt to demonstrate their various qualities. The following is a list of the various categories of wines:

1. Table wine
2. Dessert wine
3. Sparkling wine
4. Others

The weight of this report will concern itself with table wines and a general overview of the winemaking operation.

ECONOMICS

As with any new business a winery must incur capital, inflation and production costs. The following is a short summary of some of these expenses.

Capital costs can be divided between fixed and working costs. Fixed costs for a winery include the land, equipment and construction; while working capital comprises winery materials such as fining agents, and bottles. It also includes operating cash, salaries and storage costs. According to recent studies, risks are kept to a minimum when working capital is between 10% to 20% of fixed costs.

A winery should also become conscious of inflation. One method to estimate current cost from any previous listing is to use the current inflation index with the past inflation index with the formula.

$$\text{Present cost} = \frac{\text{Cost then} \times \text{Current inflation index}}{\text{past inflation index}}$$

One can now estimate the possible cost of certain major items, such as: crushers, presses, fermenters and centrifuges.

Net profit is simply total production costs from total income. Total production costs include:

1. Manufacturing,
2. Fixed costs,
3. Interest on investments,
4. Taxation.

Figure 70 shows a graph of a winery's operation to establish a favorable economic balance, based on a rise in income and steady fixed costs. The break-even point can be achieved quicker by reducing production and fixed costs.

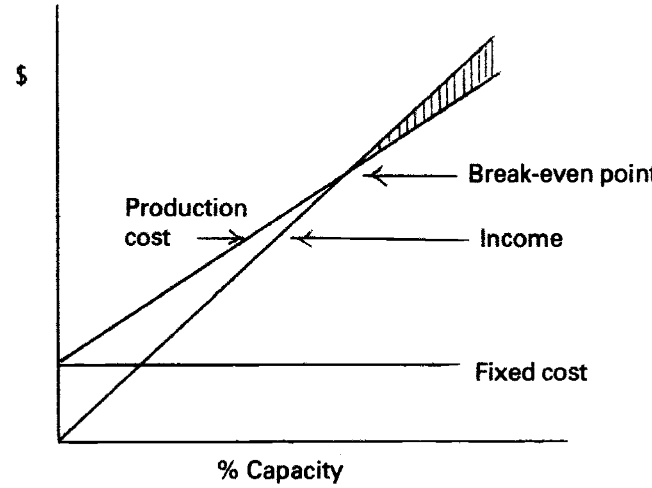


Figure 70. The economic balance.

The new winery owner will also be faced with variations of production and fixed costs depending upon his decision to produce either a premium or generic style of wine.

Added expenses for a premium winery would include:

1. Added cost of quality fruit,
2. Storage expenses,
3. Oak casks.

Added expenses for a generic winery as opposed to a premium one might include:

1. The purchase of equipment that can handle larger loads,
2. Access to greater tonnage of fruit and the trucks to carry the load,
3. The ability to market the wine over a wider spectrum.

The premium winery has the advantage of marketing the product at a higher price but the product must reflect the cost to the purchaser. The generic wine hopes to present a suitable wine with minimal costs to the winery and to the customer.

PLANNING A NEW WINERY

Production of wine in California has nearly doubled over the past 10 years as the figure approaches nearly 400 million gallons. Much of the total has been reached by expansion and construction of new wineries. In planning a new winery the owner should establish a reasonable goal and plan in detail around that goal. The winery should be located near a source of grapes that will satisfy its crushing needs. The winery should also contemplate the style of wine it wishes to produce, in regards to a generic or premium wine.

The winery needs to consider a multitude of other factors for its location. Prior to construction the winery may

Table 18. Sample Costs of Table Wine Wineries[1].

Style	**Generic**	**Generic**	**Premium**	**Premium**
Production in Gallons	24,000	2,400,000	24,000	3,000,000
Site Work	$ 46,000	$ 500,000	$ 50,000	$ 651,000
Water Development	21,000	200,000	23,000	249,000
Buildings	300,000	3,900,000	600,000	6,264,000
Fire Protection	16,000	210,000	22,000	235,000
Equipment	250,000	3,450,000	666,000	5,596,000
Landscape	7,000	135,000	18,000	80,000
Contingencies	125,000	1,565,000	257,000	2,433,000
Waste Treatment	21,000	300,000	23,000	342,000
Total Cost	$786,000	$9,983,000	$1,659,000	$15,850,000
Cost/Gallon	$33	$4	$70	$5

[1]Cooke, G. M., A. D. Reed, R. L. Keith. 1977. Sample costs for construction of table wine wineries in California. Univ. of Calif., Leaf. 2972.

need to consult as many as 24 different governmental agencies. Such agencies include county zoning and tax boards; food and health agencies and finally the Bureau of Alcohol, Tobacco and Firearms (BATF). Also, an Environmental Impact Report may be required to cover areas of pollution, noise, animal habitat endangerment and any economic influences. With regard to the goal the winery should develop a short and long range plan in shaping itself. In constructing the present winery, the owner should not restrict or limit room for expansion in the future. The winery owner should follow rules set forth by county building codes and OSHA. Such rules often cover the height of the building and different safety features to establish in the building.

Besides locating near a vineyard, a new winery might wish to locate near a populated area to attract visitors. Also, one might locate near highways or shipping lines for ease of delivery.

Costs for a new winery might include architect's fees, any site work, construction costs and permit fees. The following table lists several categories in relation to the style of wine produced and the amount bottled.

It can be seen that the price per gallon is indeed lower as the winery prepares for a larger crush. The winery might be faced with operating at a loss for a few years in order to sell at a competitive price. The cost per gallon does not include added costs expected from fruit harvest or marketing expenses.

Figures 71, 72, 73, 74 reflect expenses to the winery in terms of labor, oak barrels, presses, and fermenters.

Labor costs can be reflected in the work engaged in hauling of lines, operating machinery, any repair activity and delivery of goods throughout the winery. A number of skilled people are needed to insure a properly run winery. Such expenses relate to the minimum level of hours needed to prepare and clean all of the equipment with some variability with time of manufacturing.

Oak barrel prices reflect labor, transportation costs and present demand for the product. Demand for quality oak, especially French casks, which are used in premium wine production, has always been high and the price

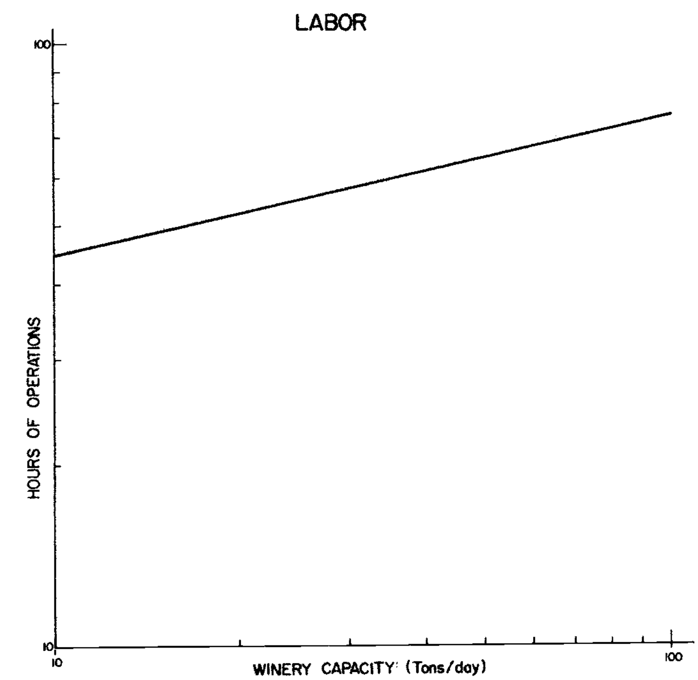


Figure 71. Labor.

does represent the demand. Yugoslavian oak has lately become common in many wineries, and American oak is often used in the production of sherries and other wines.

Presses and other operating equipment, such as centrifuges, show a rather large initial expense due to the engineering design and manufacturing costs. The added cost of more material becomes only a fraction of the total costs.

The expenses for fermenters are similar to presses in terms of initial design and construction costs, but prices are also porportional to surface area of the tank over the volume. As the diameter of the tank is increased, the volume expands at a greater rate. So cost per gallon decreases for each enlargement of the tank.

The graphs were compiled from data collected by Prof. Roger Boulton of the University of California, Davis.

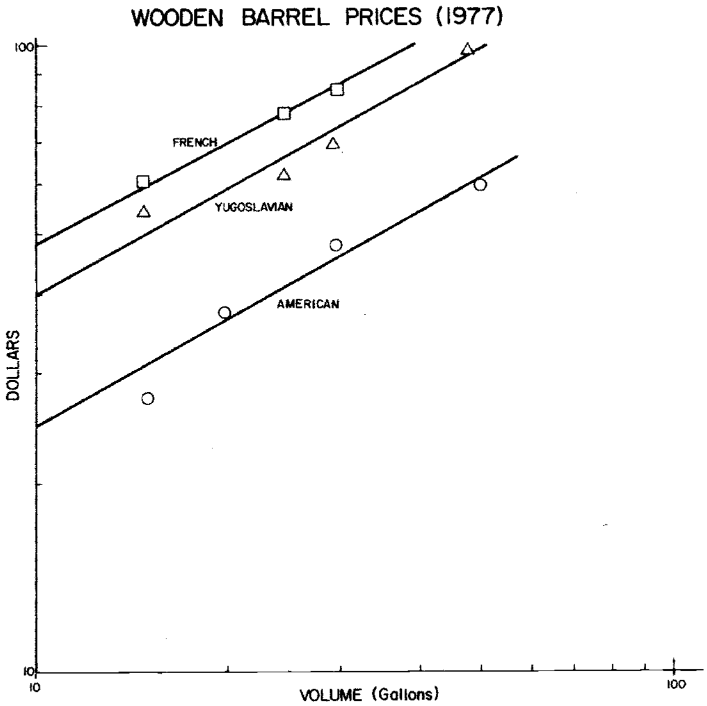


Figure 72. Wooden barrel prices.

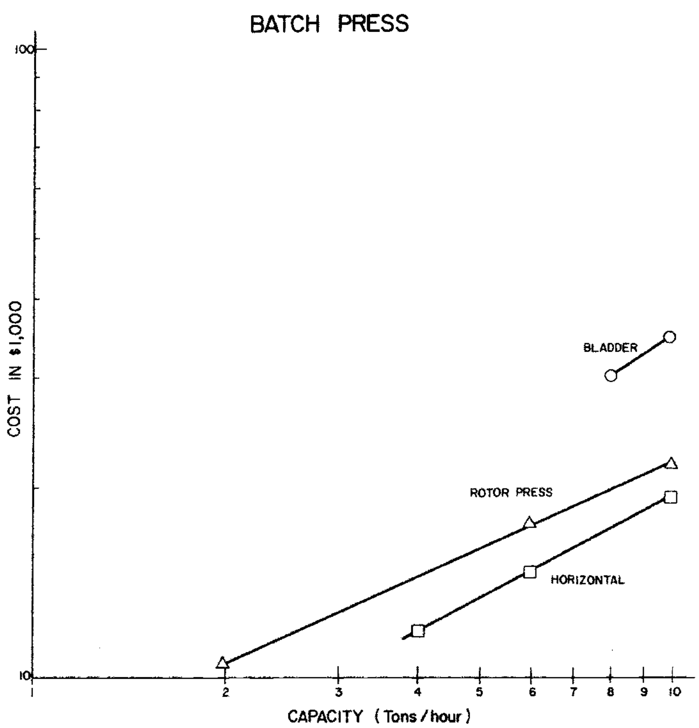


Figure 73. Batch press.

WINERY DESIGN

The design or layout of the winery should include a convenient delivery system for incoming grapes and an ease of passage for the wine throughout its production. A large winery, especially, would desire as smooth a system as possible to eliminate delays which would only add to production costs.

At the start of production the delivery frequency should reflect crushing capacity for it would be unfortu-

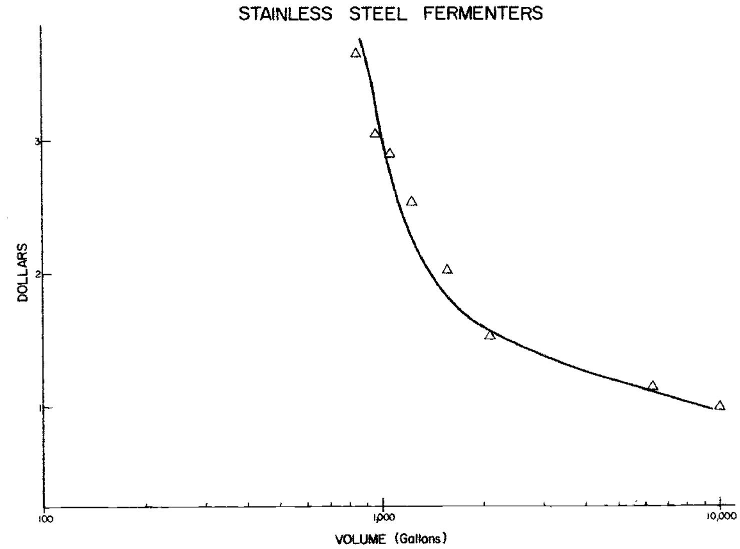


Figure 74. Stainless steel fermenters.

nate to have a bottleneck develop whereby delivery trucks must wait under the sun because of a small operating crusher. Also, both presses and tanks should correspond to maximum harvest loads, and they should be situated so that pumping distance is reduced.

The winery should install a system for ease of pomace removal. This should include tanks that allow for a quick release of the pomace, sloped flooring for ease of cleaning and enough water outlets and drains to insure a clean winery. The rapid removal of unwanted material prevents any unsanitary buildup and allows for speedy entry of new production. The winery should have an adequate wastewater treatment operation. A discussion of such treatments will follow.

There should be an arrangement for storage of wine in casks or those ready for shipment so there is no interference in current production. Overall the design should concentrate on the ease of flow in every phase of production from crushing through delivery.

The design may also reflect the type of production produced. A premium winery may desire more storage space for aging than a generic one. The production of white wines will require greater cooling during fermentation and so there may be a number of jacketed, cooling tanks to plan. The ceiling of the winery should be high enough to insure adequate ventilation and cooling. In terms of space the winery should allow sufficient area for extra tanks and possible expansion in the future. One should also be cautious of safety in any design and follow standards compiled by OSHA since corrections may have to be incorporated following an OSHA inspection.

The design may include separate rooms for a laboratory and bottling operation. A bottling room that can be easily cleaned will be helpful in reducing any bottle contamination that might lead to wine spoilage.

Equipment

A winery should use materials that are resistant to corrosion and not liable to release any residues into the wine. The equipment should be easily understood by those operating them and should be near available sources of supply for spare parts. Also, winery equipment should be accessible for cleaning.

A practical method to determine the capacity of various equipment is to ascertain the maximum load of grapes expected at one time during the crushing season. A winery hoping to crush 800 tons of one variety when it matures in the vineyard will require larger sized equipment, such as fermenters, to produce that wine than a winery crushing the same 800 tons, but from grapes that mature over widely-spaced intervals. A winery should allow itself enough capacity for its crushers, presses, fermenters and storage tanks during those peak periods.

Crushers

The most common type of crusher used in California is the Garolla type crusher-stemmer which uses speeding metal paddles to knock the grapes through openings in the revolving cylinder. As the grapes are knocked into a waiting basket or conveyor, the stems are driven out through the open end of the cylinder. Another type is the roller-crusher which uses two grooved metal rollers to crush the grapes by revolving in opposite directions.

Crushing relates to a winery in at least three points.

1. A winery may desire to have two different crushers either to handle both red and white varieties or to have one for backup in case the other one breaks down.
2. Maintenance of the crusher should be in the scope of the winery crew to make emergency repairs, to procure needed spare parts in time and to clean easily.
3. The crusher should be large enough to handle any peak load period to prevent any bottlenecks.

Most crushers will operate most efficiently at about 75% capacity from the manufacturer's stated maximum. So one may wish to purchase a crusher that has a higher maximum load than is required.

The position of the crusher is an important point. One position is to place the crusher in a pit to facilitate dumping of the grapes, but the pit would increase the load on the must pump and would make cleaning somewhat more difficult. A crusher that is above the ground would surely ease the strain of the must pump and of cleaning, but the winery would need to have either a conveyor system to feed the grapes into the crusher or build a ramp for the truck.

Presses

Following separation of free-run juice or fermented wine, the residual juice or wine may be extracted by pressing the pomace. Presses can be separated into two major categories, the batch and continuous presses. The batch press will operate only on individual loads and will require cleaning following each load. For smaller operations the basket press can best typify the style of the batch press, but larger wineries may be using more sophisticated presses. Such batch presses include the Willmes or bladder press, which uses an inflatable rubber bladder inside of a cylinder tank to press against the pomace. A pan is used beneath the tank which is dotted with numerous holes to collect the liquid. Another type is the horizontal-moving head. This press operates by using one or two heads acting as pistons pressing against the pomace in a cylinder. This action forces the pomace into a plug and releases the liquid through slits in the cylinder.

The second category of presses is the continuous press. the winemaker may continue to add pomace to the press without stopping as is necessary with a batch press. The continuous press uses a helical screw to drive the pomace towards one end of the tube in order to buildup a plug of the pomace. From this plug the liquid will flow from holes below the screw and collect in the pan. One disadvantage is the press must build a sizeable plug to initiate compression and so may not be very practical for a small winery.

Fermentation Tanks

Wines are currently fermented in various types of containers. These include oak, redwood, stainless steel, concrete and glass-lined containers. The vinter should also note that following fermentation some of these same tanks may be reused as storage tanks. At the present time steel tanks are more popular than wood or concrete because they are easily insulated for cooling and are easier to clean for switching from white to red wine for fermenting or storage. It has also been reported that cleaning and maintenance expenses for wooden tanks are about twice that of concrete or steel tanks. Wooden tanks may also have to be recoopered every few years. Concrete tanks are often specially lined for ease of cleaning.

Tanks can also be designed to allow for ease of discharge of pomace and lees as in a cone shape in which the bottom or cone can be quickly dropped and the pomace collected into a pan below. Otherwise, the tank would have to be entered and the pomace would be shoveled out. Finally, the total capacity of these tanks should reflect the peak periods, and the winery should have extra tanks to relieve possible emergencies.

Filters

Filters are used as an aid in the clarification of juice and wine. In general, filters are designed to allow the liquid to pass through a collector which picks up any solid material that it is designed to collect. The degree of clarification takes into account various factors which include the size and character of the pores of the filter medium and the rate of filtration. There are three main categories of filtration: bulk, fine and sterile.

One of the most common equipment for bulk filtration is the plate-and-frame filter. Bulk filtration is used to speed up the racking or settling process. With this filter the wine is forced through a series of screened plates coated with an absorbent material called filter aid, such as diatomaceous earth. Filter aids come in various particle sizes which are employed depending upon the purity of the wine. A normal amount of pressure for the plate-and-frame is about 60 psi.

Fine or polish filtration methods use pads or finer sized filter aid. The cartridge filter is an example of a pad which uses tubes made of cellulose positioned in a vertical manner to trap any solid material. These cartridges are often designed for only a single use and then must be discarded. Again, the winery can use the plate-and-frame apparatus with finer sized filter aid.

Sterile filtration involves the removal of yeast and bacteria from wine to prevent spoilage. This procedure is especially useful in the production of sweet wines which otherwise would allow sufficient carbohydrates for microbes to metabolize and so would alter the wine. For this procedure to be effective it must rely upon other factors, such as sterile bottling, satisfactory corks and an organized system to monitor the presence of any spoilage organisms in the filtration to bottling operation. The pore size of sterile filtration must collect yeast which measure from 1.2 to 11 microns and bacteria which are from 0.5 to 2 microns to give the proper insurance.

The Centrifuge

The centrifuge is often used to speed clarification of wines and to remove fining material and grape solids quickly to save more wine. The centrifuge operates on the principle that solids or materials of greater density than the liquid fraction will fall out in the operation. One disadvantage is that wine or juice may become overaerated. In the actual operation of clarification the length of time the liquid needs to be centrifuged is a function of the volume of the bowl and the flow rate. So as one increases the volume of wine into the centrifuge, the flow rate should be decreased or the time for clarification should be increased. Centrifuges are expensive and the winemaker should study whether or not the wine that is saved by this equipment warrants the initial cost.

Pumps

Different types of pumps are needed for various circumstances in the winery. In the transfer of must and wine the centrigfugal type is often used while in moving lees the piston pump may be employed. The winery needs to insure that the pumps are resistant to corrosion, are easily maintained and the cost is relative to their use.

Location

There are various factors in selecting the proper site for a new winery. The winemaker would probably desire to be close to a source of grapes for crushing. If shipping is a major necessity, the proximity to major roads or rail lines would facilitate transportation. Locating near a major city has proven valuable in attracting visitors and a convenient source of supplies. A large enough parcel of land should be sought for possible expansion.

The location of a winery may also depend upon various laws and county ordinances. Assorted governmental agencies will have to be consulted and permission received in order for construction to begin. There may be several local labor agreements to abide with and safety standards to follow.

Finally, the winery should insure the various traffic routes around the winery property allow access for all and are free from any congestion. For a large winery there might be separate routes for incoming trucks and visitors.

Water

Having an ample supply of water for the winery is a necessity. Water is principally used in sanitation for cleaning tanks, equipment and floors. In some cases water purification may be required.

Waste Disposal

Waste is accumulated in the winery during crushing, fermentation and aging. The rapid disposal of these wastes is essential to sanitation and a smooth operation in the winery. Wastes can be separated into solid and liquid types. Solids comprise grape stems, pomace and wine lees. Liquids include wastes from wash water from tanks and equipment, detergents and liquids that tend to be high in organic material.

The amount of pressed pomace is from 300 to 500 lb. per ton of grapes. Some wineries are able to utilize this pomace for distillation purposes by extracting more of the liquid fraction or to use it as a fertilizer for the vineyard. Some of the liquid wastes might be toxic to the vines if applied to the vineyard. For the processing of liquid wastes many wineries have had to construct treatment ponds to abide by local clean water standards.

Wine Production

Type and Quality Desired

There are various factors that may convince the winemaker to develop a certain type of wine. One important factor is the quality of the grapes to be crushed. It can be stated that good wines require decent grapes. In order to produce wines with an excellent distinct varietal character, the quality of the grapes at harvest needs to be high. Another factor may be the financial condition of the winery. The cost of wooden cooperage and storage needed in the development of some fine wines are not inexpensive. There have been wineries that had to wait up to 10 years before they were able to realize a profit.

A winery in a large viticultural region may have the liberty to purchase the varieties needed, but in new or isolated areas the vinter may be restricted in his choice. So it appears that the vinter and grower should come to agreement on what varieties would do well in that area in terms of fruit and wine that will be accepted commercially.

The winemaker in a new region may want to anticipate the desires of his customers. For one example, it has been demonstrated that new wine drinkers will favor white wines initially and then proceed later to red wines as their knowledge and appreciation of wines increase.

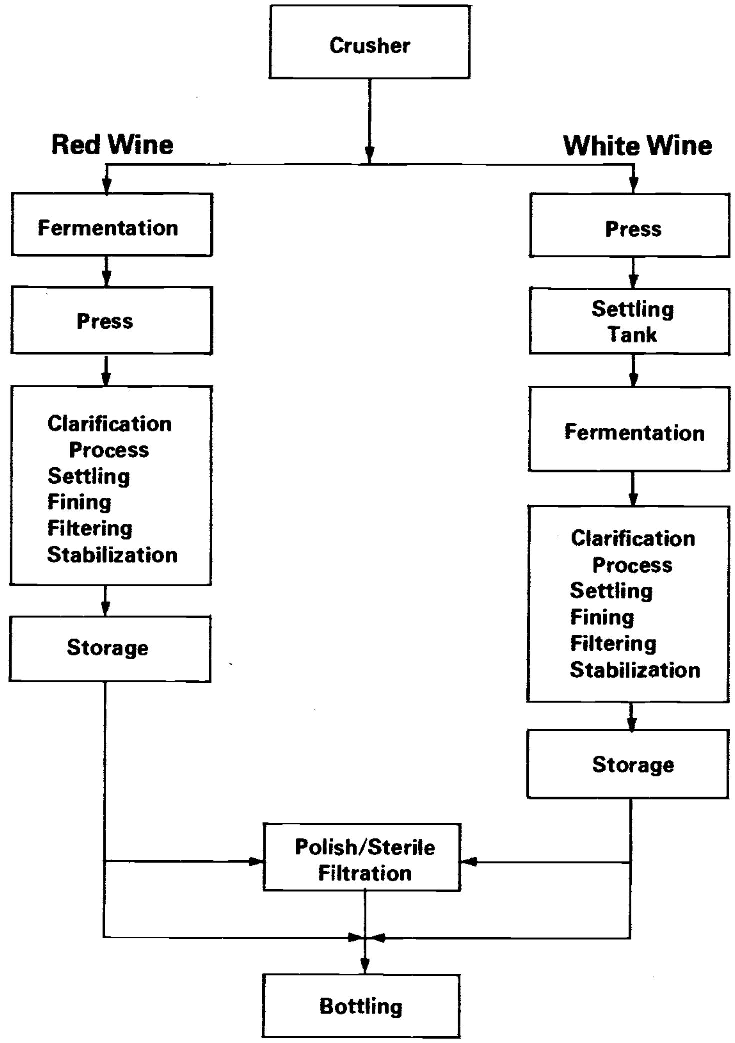
Fruit Harvest

The ideal situation is to have a perfectly balanced analysis of the grape in regards to Brix or sugar level, level of total acid and pH, proper coloring and absence of undesirable molds at harvest. The general quality of the grape is influenced by the climate and soils of the region, the particular variety and any viticultural practices that may contribute to the general quality of the grape.

Temperature, in regards to climate, affects sugar levels, total acid and color. It has been shown that in warmer temperatures the grower should expect higher sugar levels, but lower acids than in cooler climates as a general rule. In the hyperthermic region it has been found that for many varieties it may be difficult to raise the sugar level to the desired point. Many of the varieties have shown a tendency to level off and refuse to gain in sugar before shriveling due to the heat. Correct viticultural practices should be practiced by proper pruning, irrigation, weed and insect control and any possible fertilizing to produce the best quality grape.

As harvest approaches, the vinter, in agreement with the grower, may desire to check the fruit on a daily basis for sugar and acid levels to insure the correct timing of the harvest. To encourage the grower, the vinter may establish a bonus system to insure a high-quality crop. The winery and grower should anticipate the harvest date to insure enough pickers and trucks to remove all of the mature fruit.

The Winery Operation



White Wines

White varieties require great care from havesting to the crusher to prevent damage that might result in early oxidation or browning. At some locations refrigeration units have been added to trucks to cool the grapes and so reduce oxidation.

The grapes should be crushed quickly following the harvest. It would be preferable to complete this step in the morning while temperatures are still cool. For varieties that tend to brown quickly, the winemaker should add sulfur dioxide as quickly as possible to control oxidation. The common recommendation is for approximately 100 parts per million (ppm) of sulfur dioxide be added to juice from healthy appearing grapes while greater amounts should be added for injured or moldy grapes.

Pressing

The length of time prior to pressing is often a judgement of the winemaker. By allowing continued juice and skin contact, more compounds may be released from the skins into the juice. These compounds may include different flavor elements, tannins, colors, but there may be a danger of introducing excessive amounts of pectins, gums and tannins into the juice. When the juice is ready for pressing, the initial release of juice is referred to as the free-run, which has been considered the more desirable in making of fine white wines. Pressing will extract more juice but will carry with it more pectins and tannins to add to the juice.

Acid Adjustment

The next step is to allow the juice to settle for approximately 24 hr for some of the coarser material to fall out and yield a clearer product. At this time the winemaker may desire to adjust the acid content. One could add enough green fruit or acids, like tartaric or citric, to the juice. *Table Wines* recommends that white juices carry between 0.7 to 0.8 gm/100ml of acid prior to fermentation.

Grapes may also need a reduction in acid which may occur with some varieties to achieve the correct balance. At the present common methods to adjust excess acidity are calcium carbonate, calcium double salt, ion exchange and malo-lactic fermentation.

Calcium carbonate, $CACO_3$, method forms salts of calcium tartrate to precipitate out as crystals and reduce the amount of acid in wine. In the traditional method only a portion of the wine will receive this treatment and then be blended into the remaining lot of wine to adjust the acid.

Calcium double salt treatment is to reduce acidity in juice prior to fermentation. $CaCO_3$ complex (Acidex) is added to about 10 to 20% of the juice. At a pH of 4.5 the malate and tartrate combine with calcium to form the double salt crystal of Ca_2MT and following filtration, the juice can be blended back with the main body for fermentation.

For the ion exchange method, anion exchange is employed by passing the wine through a resin column to exchange tartrate ions with hydroxyl ions. Then malo-lactic fermentation involves bacterial conversion of malate to lactic acid in wines and so causes a reduction in titratable acids.

After the juice has been allowed to settle and racked off, it should now be ready for fermentation. Usually from 1 to 3% yeast or starter culture is added. The common wine yeast, *Saccharomyces cerevisiae*, is most frequently used. The juice should be placed in closed containers fitted with airlocks from 70 to 90% capacity. Some wineries may add carbon dioxide or nitrogen gas to the container to control oxygen contact as a gas blanket.

Fermentation

When fermentation has been initiated, many wineries will lower the temperature to 55 degrees to 66 degrees F (13 degrees to 19 degrees C). There are even some wineries that use lower temperatures in hopes of preserving more fruit quality. It has been shown that by controlling the temperature there is an enhancement of color, aroma and flavor. The lower temperature will lengthen the fermentation time as compared to red wine production, and may require aeration for some dry wines to complete firmentation.

Following fermentation the wine should be racked off the lees to prevent pick up of undesirable flavors and odors. There is the possibility with decomposition of yeast in the lees that some hydrogen sulfide could be produced. According to *Table Wines*, early racking along with cool temperatures is essential in maintaining a balanced, fruity wine.

Clarification

Fining may be required to aid in clarifying of cloudy wines. Any cloudiness in the wine may be due to instability of proteins, yeast material, pectins or metallic substances. The prompt removal of these elements helps to stabilize, clarify, remove microbial contaminants and hastens the aging process. It should be pointed out that excesses of fining agents should be avoided due to possible clouding or bleaching of color. Leading agents are bentonite, tannin, gelatin, casein and egg white.

Bentonite is a montmorillonite clay known for its swelling and cation-exchange capacity. The major advantages for bentonite are protein removal and adsorption of different metals, such as copper and iron. Two disadvantages are possible exchange of sodium into the wine and the buildup of sediment which may be difficult to filter out.

Gelatin is often used with tannin to clarify wines. The two substances will flocculate together and trap other suspended material, and may also remove some color from the wine. Fining with gelatin in this manner is aided by lowering the temperature. Settling occurs when the positively charged gelatin combines with negatively charged particles like tannin. The winemaker should use only pure grades of gelatin to prevent any off-odors. As with all fining agents, a series of samples should be run to prevent over-fining and then well mixed in the wine.

Casein is similar to gelatin in that it also causes flocculation and then settling to occur. It combines with tannin and is often used with bentonite during fining. Casein may also be used to remove color from the wine.

Other fining agents include egg albumen, which has little influence on color, isinglass, an organic agent which also has little effect on color and a number of synthetic compounds, such as nylon paste and polyvinylpyrrolidone (PVP).

Fining agents require care in determining the correct amount and are dependent upon the temperature of the wine for proper flocculation.

In most cases wines of high acid and low pH should require the minimum of filtering and fining to become brilliantly clear. Those wines that tend to be less than perfectly balanced may be more likely to develop cloudiness and so require more efforts to clarify. One simple method to aid in clarification is simply to lower the temperature to about 50 degrees F (10 degrees C) for settling prior to fermentation and then during the clarification process.

The three different stages of filtration may also be employed to speed the rate of clarification. Filters are more expensive than fining agents, but they usually require less time. However, the process of sending the wine through filtration apparatus may tend to overrate some white wines. The rate of filtration is influenced by the pore size of the filter medium, the capacity of the pump and the characteristics of the wine. An example for wines is that the flow of sweet wines may be influenced by low temperatures as such temperatures may cause the wine to become too viscous and, therefore, too slow. For both bulk and fine filtrations the best results when using the plate-and-frame filter is to mix filter aid with the wine and to run through at a slow rate to minimize clogging. Fine filtration should be used on only relatively clear wines.

Most modern wineries sterile-filter their wines prior to bottling to insure stability. This is particularly true for those wines with residual sugar which would provide a satisfactory growth medium for microorganisms. Filters should be easily cleaned and serviced and should be left dry while not in use.

Centrifuging has some uses in clarifying wines, but may tend to overaerate some white wines. This instrument removes fining agents to recover more wine, but some skill is required to monitor the rate of wine to achieve the desired clarification.

Stabilization

Cold stabilization occurs to remove tartaric acid from the wine in a short period of time. In newly-finished wines tartaric acid is found in a supersaturated condition and precipitates out over a period of time appearing as small crystals in the bottom of the wine bottle. Most of the excess tartrate can be removed by cooling the wine to 26 degrees to 28 degrees F (−3.3 degrees to −2.2 degrees C) for at least 10 days. After chilling is completed, the wine is usually rough filtered or carefully racked to prevent possible redissolving of the tartrates.

Another form of wine stabilization is with heat, called pasteurization. This process is one method to preserve wines that are susceptible to microbial attack. The winemaker should seek a desirable temperature and time length which would do minimal damage or interference to the characteristics of the wine. One method is to heat the wine to 140 degrees F (60 degrees C) for a short period and then filter before bottling. For wines that may not throw any precipitate, they can be bottled immediately following the pasteurization process.

There are many white wines that do not require any lengthy aging as compared to some red wines. Many white wines are sold only 6 months after crushing. Still the length of aging is relative to the wine and its characteristics. According to *Table Wines*, if the wine is bottled too soon, it may mature too slowly and if bottled too late, the wine may be over-oxidized.

Some white wines, like Chardonnay, lend themselves well to oak aging. The length of time for such aging will depend upon the size of the cask, amount of free sulfur dioxide, tannin content and cellar temperatures. The size of the cask determines the surface area in contact with the wine. A smaller cask would provide a greater surface contact and so would hasten aeration and aging. Then new wood casks have a tendency to release more of their compounds into the wine over a period of time than used casks. So the winemaker needs to carefully monitor his wine and to insure that his wines are topped off periodically to reduce unnecessary oxidation or spoilage.

Free sulfur dioxide tends to protect the wine from over oxidation by inhibiting several chemical browning steps. So wines with large amounts of free sulfur dioxide do lengthen the aging process. Free sulfur dioxide can be described as a sulfur form not bound to another compound in the wine.

Wines with high tannin or other phenolic material may require longer aging to develop a smooth taste. The degree of pressing and previous skin contact may determine the degree of phenolic and other grape constituents in the wine. Also, lower temperatures may slow the aging process.

For many winemakers it has been desirable to age their white wines in stainless steel to preserve the varietal fruitiness and by controlling oxidation to a greater degree.

Bottling

Wines that have been properly clarified and aged are now ready for bottling. Some wineries practice a test bottling by storing a sample of the wine after bottling at different temperatures to inspect for any changes in it. If no changes are observed over a period of time, the wine may be considered stable enough to bottle. Most large wineries situate their bottling operation in a separate room to insure sanitation. The bottles used should be thoroughly cleaned by blowing air into them or washing with steam. In filling the bottles, the winery has to guard against infection, over aeration and other contaminants. The fillers are usually rinsed with the wine before use. Often the greatest oxygen pickup will occur when the wine is in the filling machine. Many winemakers attempt to control oxygen entrance into the wine by purging the bottles or fillers with carbon dioxide or nitrogen.

For dry table wines the preferred closure has been the cork. Proper sealing of the bottle requires corks of high quality, sufficient length for aging and suitable equipment for driving the cork in satisfactorily. An improper seal would only increase aeration and mold growth around the cork.

Red Wine

The production of red wines depends upon the condition and maturity of the fruit and the proper release of flavor and color from the skins of the grapes into the wine during fermentation. A thorough crushing is desirable to insure sufficient exchange of flavors and color compounds. The addition of sulfur dioxide should occur soon after the crush to control undesirable yeast and bacteria. The amount may vary with the condition of the grapes and the acid-pH level of the must as grapes which appear to be injured or of a high pH reading would require a heavier dosage. Normal amounts of sulfur dioxide may range from 50 to 150 mg per liter of juice and, following a few hours, the addition of yeast is completed. It has been the practice of the American wine industry to use selected, single yeast strains of *Saccharomyces cerevisiae* to initiate fermentation. It has been discovered that different strains or species of this yeast fermenting the same fruit would produce a different compound and so vary the flavor and aroma of the wine. Therefore, by using single strains, the winemaker would hopefully produce more consistent results. Fermentation is usually activated quickly by the addition of starter cultures, which contain actively growing yeast. Only 1% by volume of the active starter is necessary to initiate fermentation. Too much starter may initiate a violent fermentation which would cause higher than acceptable temperatures.

Color Extraction

Proper color extraction requires the presence of the skins and sufficient mixing of skins and juice for color. Only a few varieties, such as Royalty and Salvador, contain red juice so the bulk of red varieties require proper extraction methods. Red wine is fermented in most California wineries in the temperature range of 65 degrees to 85 degrees F (18 degrees to 29 degrees C). The higher temperature range, as opposed to white wines, should enhance color extraction from the skins. Normally, fermentation needs only to continue on the skins until sufficient color, flavor and tannins have been extracted. Using a Brix hydrometer and a thermometer to judge the sugar reading, the normal range for pressing off the wine is from 15 degrees to 5 degrees Brix. The overall time for producing red wines on the skins is from 3 to 5 days.

During fermentation the skins are forced to the top by gas being produced and so form a cap. The control of the cap is essential to prevent spoilage and to properly release color into the wine. Control is achieved by pumping the juice over the skins or punching the skins down at least twice daily. Excessive pumping may tend to overaerate the wine and cause some loss of alcohol. If the cap were not controlled, high temperatures would result and the wine would probably suffer from noticeable off-flavors and be deficient in color.

Pressing

When the winemaker is satisfied with the color and flavor of the wine, the free run is drawn off and the rest may be extracted by pressing. For most table wines a hydraulic press is preferred over the continuous press due to extracting less of the pulp material. According to *Table Wines*, the press wine needs to be kept separate from the free run due to its slower aging and longer clarification.

Secondary Frementation

Secondary or malo-lactic fermentation occurs in some wines due to the bacterial conversion of malic to lactic acid with the release of carbon dioxide. This process may occur during the initial yeast fermentation or afterwards during aging. The winemaker would certainly desire the fermentation to be completed prior to bottling, especially among those wines which are susceptible to malo-lactic conversion. The bacteria involved do have some necessary requirements to function. They require a favorable pH reading, temperature range and necessary nutrient factors. Wines that are above a pH of 3.2 and have sufficient amounts of malic acid are susceptible to secondary fermentation. Also, the bacteria grow in the temperature range of 50 degrees to 98 degrees F (10 degrees to 37 degrees C) with sufficient nutrients drawn from residual sugars for energy. Malo-lactic fermentation may be inhibited by increasing the sulfur dioxide content. Wines with high alcoholic concentrations or wines that have been racked off the lees immediately after primary fermentation are less likely to go through a malo-lactic fermentation. The lees may provide a source of amino acids and other nutrients to encourage growth. Many wineries may inoculate with bacterial cultures, composed of strains of *Leuconostoc* or *Lactobacillus* to hopefully insure a desired fermentation. A convenient time for inoculation is at pressing while there is still residual sugar and nutrients.

Clarification

In terms of clarification the wine should begin to clear within a month following fermentation. The young wine can be racked to prevent any unfavorable contact with the lees without too much concern over over oxidation. At this time, the winemaker may want to test for any malo-lactic fermentation and to insure proper levels of sulfur dioxide.

Wines that fail to clarify properly may have problems due to yeast or bacteria suspension, protein colloids of yeast or grape tissue, or metal colloids of iron or copper salts. The removal of such particles by bentonite is based on mutual flocculation and specific absorption between the two. To prepare the fining agent the winemaker must make a slurry of about 1 lb. of bentonite with 2 gallons of water. The water amount should not exceed 1% of the volume of wine. Gelatin is frequently used by winemakers to lower the tannin level. In both cases fining is improved with lower temperatures. Other flocculation fining agents are isinglass, egg white, casein and certain synthetic compounds.

Wines may also undergo chilling to hasten removal of excess tartrates. The conditions may resemble those for white wine stabilization or the winemaker may decide to age his wine for a few years at low cellar temperatures.

Aging

Red wines that lend themselves to any extended aging are those of heavy body and taste. Such wines should be properly balanced in terms of acid content and pH and enough sulfur dioxide to insure stability during the aging process. Also, to reduce the danger of oxidation, the winemaker should be aware of topping the wine off in order to insure that the container is full. This last case is especially important in wood casks which experience a constant amount of loss through them. The degree or length of aging can be based upon the size of the container, temperature and any properties of the container or of the wine. The size of the container determines the surface area which is related to the air-wine contact. A smaller cask will certainly aerate or age the wine quicker than a larger cask, which would reduce the surface area contact. A popular cellar temperature range of 50 degrees to 60 degrees F (10 degrees to 15 degrees C) is often recommended for aging of fine wines. The length of aging, especially for wood, depends upon the age and the nature of the cask. Wooden casks are usually made of oak from the United States, France or Yugoslavia, and each has their own special properties that may be introduced into the wine. New wood has a tendency to readily transfer its particular compounds with those of the wine and so would possibly reduce the length of wood aging compared with used wood. The length is also based upon the tannin level, which helps to determine the astringency of the wine and sulfur dioxide levels which control oxidation.

Bottle or secondary aging is an important part in the preparation of the wine. Bottle aging results in slower oxidation and greater complexity.

Prior to bottling the winemaker will probably wish to filter the wine. Most large wineries use a separate room for the bottling process to preserve a place safe from spoilage organisms.

Rosé Wines

Rosé or pink wines are made in a similar method as red wines, but the fermentation is either curtailed on the skins or completed with low-colored red grapes. Blends can also be made from combining red and white wines to achieve the proper color.

In most cases pink wines are designed to be consumed early. Warm regions have been known for their pink wine production, simply because coloring for many varieties is often difficult to achieve. In studies Winkler and Amerine of the University of California have shown that temperature has a distinct influence on coloring as pigmentation is inhibited by the warm days and nights for many varieties. This case is especially true for the hyperthermic region of Arizona, where the grapes may appear dark to the eye, but in reality produce in most cases a low-colored wine. Also, extended fermentation on the skins to extract more color has only increased the bitterness of the wine with very little increase in color. In such warm regions of the Southwest, varieties such as Zinfandel, Gamay and Corignane usually produce a satisfactory pink to light red wine.

Dessert Wines

By definition dessert wines are made from grapes with an alcoholic content over 14% but not over 24% by volume. Most American dessert wines are lower than 21% due to a heavier tax imposed. The table below shows the tax schedule levied by the Federal government on various wines.

Wine	Alcohol Content	Federal Tax
Still Wine	not over 14%	$0.17 per gallon
Dessert Wine	between 14 and 21	0.67
Dessert Wine	between 21 and 24	2.25
Sparkling Wine		3.40
Artificially Carbonated Wine		2.40

To market these wines as dessert wines, the Federal government requires a minimum alcoholic standard of 17% for sherry and 18% for other such wines. The production of dessert wines is considered a process of preserving the wine by fortifying it with wine spirits or brandy to inhibit microbial activity. In the winery the type of spirits used is regulated by the Federal government and is referred to as neutral brandy with an alcoholic content of 170 degrees to 190 degrees proof (85 to 95% by volume). Federal law required that the wine be placed in a special fortifying tank for the brandy addition. The necessary amount of spirits required is carefully measured as the wine is brought up to its final percentage of alcohol.

The addition of brandy to fermenting wine should halt the fermentation and so preserve the grape sugar. In checking fermentation the brandy needs to be thoroughly mixed. It has been recommended that wine be fortified to at least 17% alcohol to prevent fermentation. There are some strains of yeast that have been known, however, to continue to ferment above this point. Most California dessert wines, according to *Dessert, Appetizer and Related Flavored Wines*, are fortified to 20% alcohol.

Some of the common white dessert wines are muscatel, Angelica, white port and sherry. Red dessert wines are commonly referred to as port. Sherry is produced by either a baking process of white dessert wine or the more traditional solera method. In the solera method the wine is blended with wines from different years in oak casks for a period of years to develop the proper flavor and aroma.

Sparkling Wine

Wines that retain carbon dioxide at one atmosphere of pressure at 50 degrees F (10 degrees C) are referred to as sparkling. The wine is produced under conditions for secondary fermentation of a sweetened wine where the carbon dioxide is trapped.

The preparation of sparkling wine begins with a still wine base. The wine used should be low in volatile acidity and relatively high in acid. In France and California white wines from Pinot noir and Chardonnay are often recommended, while other varieties, such as Folle blanche and French Colombard, have done well. In most cases the wine to be used will be young and should be brilliant, which might require some fining. The wine should be checked for the exact sugar content. Also, the alcohol level is important because wines with 10% or lower have a poor holding capacity for carbon dioxide while wines with 13% or greater are difficult to initiate fermentation. The wine should be low in sulfur dioxide, which otherwise might inhibit microbial activity. The wine should be rendered stable for malo-lactic activity and tartrate crystallization.

To establish secondary fermentation desired amounts of sugar and yeast are added to mixing vats. The amount of sugar to add, which is referred to as the tirage liquor, is based upon a table by Weinman.

Percent Alcohol	Quantity of Sugar to add in grams per litre to obtain 5 atm (75 psi)
10	20
11	21
12	22

The tirage liquor is a sugar-wine mixture of invert sugar reaching a Brix of 77 degrees. A pure culture of champagne-type yeast is needed to produce the firm sediment. About 2% by volume of yeast is added. Following a thorough mixing of the sugar and yeast with the base wine, the wine or cuvee is now ready for bottling. Bottles in this case should be strong enough to handle high pressures and defective ones should be discarded. Special caps are used to seal the bottle.

The fermentation takes place in relatively cool rooms 60 degrees F (15 degrees C) or lower for several weeks with the bottles turned on their sides. Following fermentation the wine is allowed to age on the sediment. At first the bottles are shaken to break up the sediment and then restacked. In France the wine is often left to age for 4 years. The next step is to work the sediment toward the cork, which entails twirling the bottle rapidly to the right and left and bringing the room temperature down to 25 degrees F (4 degrees C). The clarification procedure usually takes 2 to 6 weeks. This process of disgorging now takes place whereby the bottle neck is frozen in liquid at 5 degrees F (−15 degrees C). The cap and the frozen plug of sediment are removed. Some pressure and wine may also be lost.

After disgorging, the addition of a final dosage may be added and the bottle is finally corked. The bottle should be stored on its side to retain its full pressure.

Secondary fermentation may also be completed in tanks. Less labor and time for clarification are two advantages of this process, but the quality may differ somewhat from the bottle method. The tank fermentation method usually ferments at the same temperatures as the bottle style, but aging time on the sediment is reduced. This is considered a disadvantage of this process.

Artifically carbonated wines are made by charging the base wine with carbon dioxide in a suitable tank. One disadvantage of this method is that these wines tend to throw sediment and so must be marketed quickly.

Other Wines

Other wines can be classified as special natural, fruit and agricultural wines. Special natural wines are flavored wines made from natural herbs, spices or fruit juices additions. Prior to production the winemaker must receive permission from the Federal government for his recipe. Fruit wines are very common and include berry, peach or apple wine. Another class is termed agricultural wines which include raisin wine, honey wine or sake, a rice wine.

Sensory Evaluation

Wines were evaluated by a tasting panel from the University of Arizona. The panel followed the University of California at Davis Scorecard to judge the wines. The scorecard consists of different categories with point values assigned to them. Point values are related to the quality of the wine pertaining to that category. Categories include color, aroma, acid balance, flavor and six other points. Each panel member was also asked to describe the merits or faults of the wine to improve the description of that wine. In describing wines judges refrained from stating purely subjective remarks of "liking" the wine or pointing out how "common or great" the wine may be. The words should have some recognizable meaning to all in attendance. In the description of the recommended wines on page 103 for the Region the following list gives some of the terms used by the wine judges.

Wine Descriptions

Acetic- **An odor of vinegar.**
Alcoholic- **A wine that is high in alcohol and has a hot sensation.**
Aroma- **A distinct odor of fruit.**
Balance- **Pertaining to acid levels relative to the wine. An unbalanced wine is either too sour or flat.**
Bitter- **A harsh or piercing taste.**
Body- **Related to the "weight" of the wine.**
Complex- **Several aromas and flavors combining together.**
Flat- **Lack of acid.**
Mature- **A balanced or properly aged wine.**
Oxidized- **Wine that has turned from its original quality.**
Ripe- **Mature fruit.**
Smooth- **May relate to the effects of tannin or sugar in the wine.**
Tannin- **Related to the astringency in the wine. Young red wines may have levels of tannin.**

At the University of Arizona approximately nine wines of the same or similar variety were evaluated by the judges during one season. In the session the wines were judged in pairs or in a group of three and then discussed at the end of each set. During the judging a minimum of six judges were convened for recording of any scores.

VARIETAL RECOMMENDATION

A score of 13 is considered the minimal accepted mark for varietal recommendation. The number is arrived at by two sources. The first source is derived from the University of California at Davis Scorecard which lists 13 as a "standard wine with neither an outstanding character nor defect." The second source is an average scoring of 13.1 compiled from several commercial wines of California which were included with the wines from the Four Corners Region in scheduled blind testings. The wines from California included:

E & J Gallo
Christian Brothers
Inglenook
Paul Masson
Charles Krug
L. Martini
Sebastiani
Wente Brothers

Wines with lower scores failed due to environmental conditions, improper viticultural practices or lack of proper winemaking techniques.

Experimental or Small Lot Wine Production

A brief outline for experimental or small quantity production is described below.

A. White wine

1. Harvest grapes at 20– 22 degrees Brix
2. Crush, add SO_2 to 100 ppm and press.

3. Place juice in a closed container and settle for 12 hours in a cold room (40 degrees F). Rack off juice into a container for fermentation.
4. Inoculate juice with yeast culture (1–3% by volume). Hold at 70 degrees F for 24 hours to initiate fermentation.
5. Continue fermentation at 50–60 degrees F. Monitor with a hydrometer. Rack near dryness to stimulate fermentation. At end of fermentation rack again. Add 50 ppm SO_2 and store in cool room.
6. Rack again at 1 and 3 months following fermentation. May need to use clarifying agents.
7. Cold stabilize at 26 degrees F for 1 to 3 weeks. Rack while cold and return to cool room.
8. Bottle and evaluate.

B. Red Wine

1. Harvest grapes at 21–23 degrees Brix
2. Crush, add 100 ppm SO_2, place contents in fermenter.
3. Inoculate with 1–3% active yeast culture and ferment at 70–80 degrees F.
4. Press down on cap (skins) 2–3 times daily. Monitor fermentation. At sufficient color level or near dryness, press and transfer to another container with an airlock to continue any fermentation.
5. 1–2 days rack off sediment to reduce H_2S formation. Complete fermentation, rack, add 50 ppm of SO_2, and store in cool room.
6. Rack again at 1 and 3 months following fermentation. Fine, if necessary.
7. Cold stabilize at 26 degrees F for 1 to 3 weeks. Rack while cold and return to cool room.
8. Bottle and evaluate.

C. Rosé

1. Follow treatment of red wine, except a shorter fermentation time on the skins.

Methods of Chemical Analyses

The following chemical determinations were made on the wines produced at the University of Arizona:

1. Free Sulfur Dioxide
2. Volatile Acidity
3. Percent Alcohol
4. pH
5. Total Acidity
6. Residual Sugar
7. Extract
8. Tannin
9. Color
10. Malo-lactic conversion

The following procedures are in outline form from *Wine and Must Analysis* by M. A. Amerine and C. S. Ough, John Wiley and Sons, New York.

1. Free SO_2

1. Pipet 50 ml of wine into a flask
2. Add 5 ml of starch indicator solution
3. Add 5 ml of 1:3 sulfuric acid
4. Quickly titrate with 0.02 N iodine solution
5. End point is determined by a bluish color which lasts for one minute.
6. May need yellow light source for titrating red wines.
7. Use formula

$$\text{Free } SO_2\text{, mg/l} = \frac{(\text{ml of } I_2)(\text{N of } I_2)(32)(1000)}{\text{ml of wine}}$$

2. Volatile Acidity

1. Requires the use of a cash Still or a Sellier tube fitted in a 500 ml Erlenmeyer flask.
2. Pipet 10 ml of wine into central tube of the Cask Still or the Sellier apparatus.
3. Generate steam by heating water through a central tube
4. Steam should be forced through the wine sample and the distillate collected and then add 3 drops of 1% phenolphtholein solution and titrate with 0.1 N sodium hydroxide to reach a pink color.
5. Use formula.

$$\text{Acetic acid, g/100 ml} = \frac{(\text{ml of NaOH})(\text{N of NaOH})(60)(100)}{1000\ (\text{ml of wine})}$$

3. Percent Alcohol

1. Macrodistillation method is practiced.
2. Use 50 ml wine sample, measured in a volumetric flask.
3. Place wine sample into distillation flask and rinse volumetric flask out with 150 ml of water in three equal portions. Add boiling chips.
4. Distill out about 90% of original sample amount. Cool distillate and dilute to volume with water.
5. Determine percent with a refractive index refractometer.

pH

1. Use a pH meter

Total Acidity

1. 10 ml of wine sample is titrated with 0.1 NaOH to a pH of 8.2

Residual Sugar

1. Determined colormetrically with clinitest reagent tablets for urinalysis from Ames Company, Division of Miles Laboratory. This is an acceptable procedure up to 2% sugar in wine.

Extract

1. Measure the specific gravity of the wine with a hydrometer. Called Dw
2. Determine alcohol content and change figure to specific gravity reading. Called Da
3. Use formula
   g/100 ml Extract =
   Dw − Da + 1.00

Tannin

1. Follow the Folin-Coicalteu method.
2. Dissolve 0.5 g of tannin in 100 ml of water in a volumetric flask.
3. Establish a series of standards using 0,1,2,3,5 and 10 ml aliquots of the tannin solution. Concentration will equal 0,50,100,150,250 and 500 mg/l.
4. From each solution pipet 1 ml into a separate 100 ml volumetric flask, add 60 ml of water, add 5 ml of Folin-Coicalteu reagent, mix; then add between 1 and 8 minutes 15 ml of 20% sodium carbonate solution, mix and bring to volume with water.
5. Place in hot water bath 105 degrees F (75 degrees C) for 2 hours.
6. Determine absorbance of each solution at 765 nm with a colorinmeter and plot absorbance vs. concentration
7. For white wines use 1 ml aliquot
8. For red wines dilute 10 ml to 100 ml with water and use a 1 ml sample.

Color

1. Use a colorimeter at 420 for whites and 420 nm and 520 nm for reds. One cm cell for white and one mm cell for reds were used.

Malo-lactic conversion[1]

1. Prepare solvent with:
   100 ml n-butanol
   100 ml water
   10.7 ml formic acid
   15 ml bromocresol green solution. Mix thoroughly and discard lower layer. Place solvent in a 1 gallon jar.
2. Place a spot of wine sample on chromatographic paper 2.5 cm from edge.
3. Place paper in jar with solvent and allow solvent to ascend paper and drive the wine sample upwards.
4. After solvent has reached the top of the paper, remove and allow to dry.
5. Yellow spots will appear to indicate different organic acids. From top of the paper down acids will appear as:
   lactic acid
   malic acid
   citric acid
   tartaric acid
6. Prepare a set of standard acid solutions and place on the paper and compare with the wine sample.
7. Wines that show malic acid may be liable to undergo malo-lactic formentation.

RECOMMENDED GRAPE VARIETIES FOR THE FOUR CORNERS

Hyperthermic, HT

Emerald Riesling
French Colombard
Malvasia bianca
Petite Sirah

[1]Kunkee, R. E., Simplified Chromatographic Procedure for Detection of Malo-lactic Formentation. Wines and Vines 49(3):23–24 (1968).

Thermic low, T_l

Barbera
Carignane
Emerald Riesling
French Colombard
Malvasia bianca
Petite Sirah

Thermic medium T_m

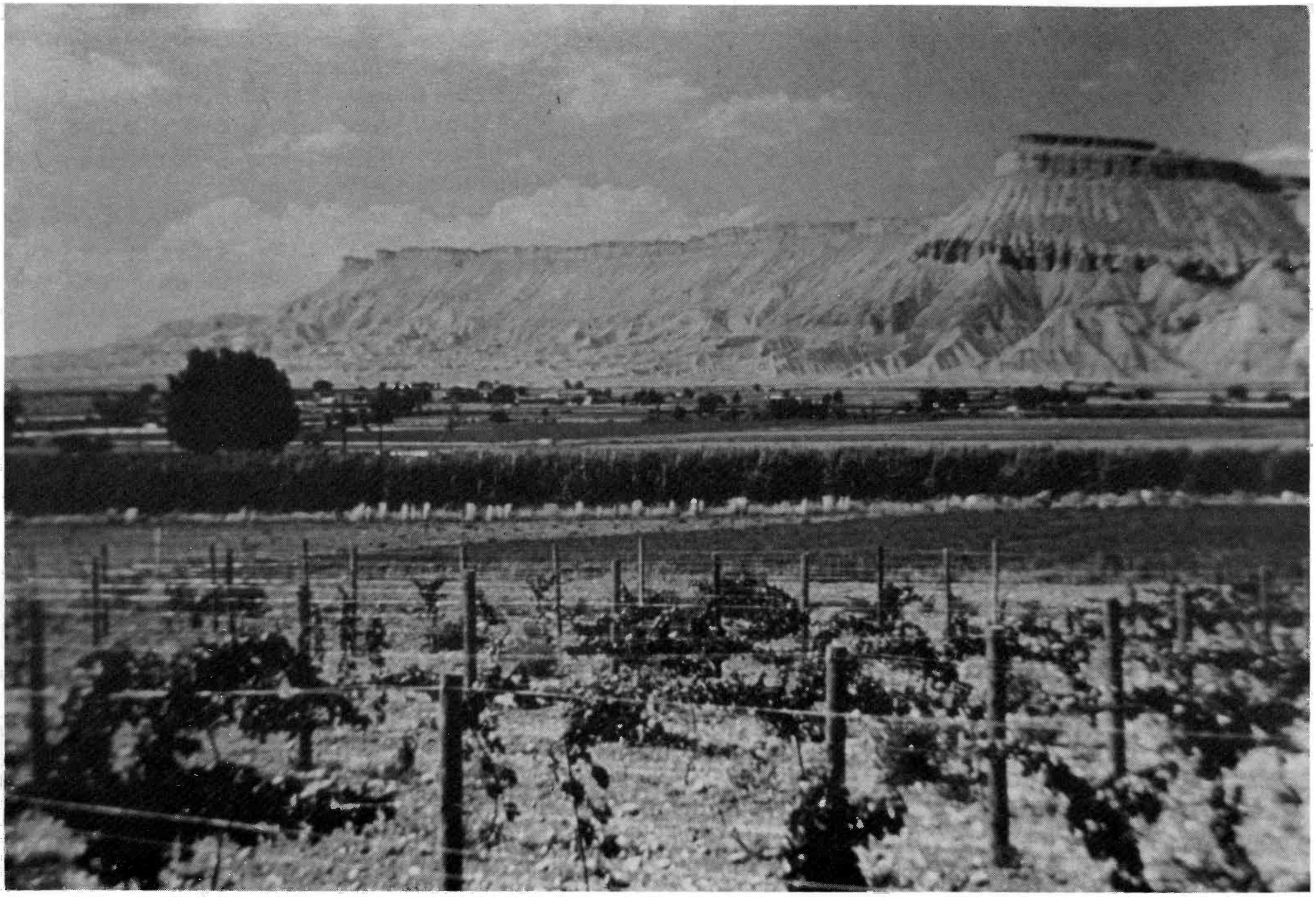
Barbera	Sylvaner
Cabernet Sauvignon	White Riesling
Chardonnay	Zinfandel
Chenin blanc	
French Colombard	
Gamay	
Ruby Cabernet	
Sauvignon blanc	

Thermic-high, T_h

Barbera	Sauvignon blanc
Cabernet Sauvignon	Semillon
Chardonnay	Sylvaner
Chenin blanc	White Riesling
Pinot noir	Zinfandel
Ruby Cabernet	
French hybrids	Foch
	Seyval blanc
	Villard blanc

Mesic, M

White Riesling	
French hybrids	Cascade
	Foch
American hybrids	Delaware
	Himrod



Vineyard in Grand Junction, Colorado

DISCUSSION OF VITICULTURAL AND ENOLOGICAL CHARACTERISTICS OF VARIETIES RECOMMENDED FOR THE FOUR CORNERS REGION

The varieties are discussed in terms of their viticultural and enological characteristics in relation to the data provided from the various plots in the Four Corners. The viticultural report covers a short description of the sugar, acid and color potential of the fruit in the various regions. The enological report states the general impression of the wine by the tasting panel and comments upon the data compiled by chemical analysis of the wine. At the end of each discussion a table is presented to list the particular regions where the variety is recommended and the average juice analysis corresponding to that region.

The varieties are separated into three sections for discussion. The three sections include *vinifera,* French hybrids and American hybrids.

Vinifera

Vinifera is a species of grapes with its origin in the Middle East and found throughout the great viticultural areas of Europe.

1. Barbera

Vit.—Barbera is a dark grape from Italy that does well in the thermic regions: T_l, T_m, and T_h (See description of regions on page 28.) The variety is grown for its high acid and pigmentation. The variety tends to mature later and may develop very high Brix readings, 24 degrees or 25 degrees, while still holding a very satisfactory acid content. Coloring also improves with maturity. The vine is a vigorous grower on mid thermic (Tm) sites. Clusters are medium in size and compact. It is recommended for regions T_l, T_m and T_h.

Eno.—The wines from region T_m have consistently received high scores for acid balance, aroma, flavor and color. When the grape is allowed to mature, the wine develops a distinctly, varietal character that requires only a moderate amount of aging to smooth the rich tannin contents of this full body wine. Coloring is enhanced in this temperate region T_m. Wines from warmer regions, HT and T_l, may lack some coloring and fruity character while cooler locations, T_h and M, may develop wines that are lacking in fruitiness, color and body.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_l	20.8	3.4	0.70	13.4
T_m	22.5	3.2	1.00	14.2
T_h	21.6	3.1	1.05	13.2

2. Cabernet Sauvignon

Vit.—A premium, red varietal from France that is sought for its flavor as well as for its renown throughout the world. Suitable locations appear to be in the thermic soil zones at higher altitudes where satisfactory flavor and color can develop and sufficient vine growth is seen. According to the data regions T_m and T_h can be recommended. The variety is a late ripener with sufficient sugar and moderate acid. In warmer locations (T_l) the fruit tends to lose its acid or may fail to mature at all. In cooler regions maturity may be delayed and may produce a smaller crop, which may be due to winter damage in comparison to thermic areas. Cabernet appears susceptible to winter injury in places where temperatures reach 0 degrees F (−18 degrees C). Clusters are loose with small berries.

Eno.—The wines from Regions T_m and T_h have shown a distinct, cabernet aroma and flavor with excellent coloration. Young wines are full of fruitiness and rich in tannin, with an excellent promise for improvement with age. Wines from the mesic soils are lower in body and fruitiness than the thermic areas. Wines from T_l are slightly reduced in color and tend to be bitter and flat tasting.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	21.2	3.4	0.76	13.4
T_h	22.3	3.4	0.75	13.0

3. Carignane

Vit.—Carignane is a dark grape that is common to the Mediterranean and is the leading red varietal in terms of acreage in California. In our Tucson plot (T_l) the variety developed a satisfactory Brix reading and is slightly low in acid with a dark red color. Wine is vigorous and productive. It ripens in midseason. Clusters are large in size and compact. Carignane can be recommended for region T_l.

Eno.—The wine from Tucson was fruity, smooth on the palate but slightly low in acid. Color was dark. Wine seems to require little aging and probably would produce an acceptable light red and fruity wine when harvested at an earlier date to preserve more acid.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_l	22.4	3.9	0.50	13.5

4. Chardonnay

Vit.—Chardonnay is a famous white variety from the Chablis region of France. In California the acreage has expanded from under 1,000 in 1970 to 11,500 by

1975. The variety matures early in the season with a high acid content in Regions T_m and T_h. Vines are less than moderate in vigor. It may suffer damage in regions of late frost, which might discourage planting in some mesic soil areas due to early bud break. More data is needed for evaluation of the variety in Grand Junction or other mesic sites. Variety is probably best suited to thermic soils of higher altitudes which show little or no frost in the early season. Clusters are small and loose to well filled. Chardonnay can be recommended in regions T_m and T_h.

Eno.—Wines from the mid thermic region (T_m) develop a rich fruity aroma and characteristic flavor. The wine is not very acidic. Wines from T_h are crisp, more acidic and light straw in color.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	21.4	3.4	1.00	13.0
T_h	20.9	3.4	1.06	13.6

5. Chenin blanc

Vit.—Chenin blanc is a leading white variety from France that is also widely grown in California (19,800 acres, 1975). The variety seems suited to thermic soils at higher elevations. It can be recommended in regions T_m and T_h. The variety develops satisfactory sugar and acid readings at these locations, but T_m was higher in pH. The vine is moderately productive and is an early to midseason ripener. Clusters are large and compact.

Eno.—Wines from the recommended regions release a crisp, fruity character with very little color. The wines seem to carry just enough acid and body which makes this a very pleasant young wine. Wines from warmer regions seem flat with little fruitiness.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	22.7	3.6	0.72	13.1
T_h	21.0	3.3	0.66	13.1

6. Emerald Riesling

Vit.—A white hybrid, produced by the University of California, is adapted to the warm regions. The variety may not develop high sugar readings but does hold its acid in warm regions. The vine is a vigorous grower and quite productive. The variety matures mid to late season. Clusters are large and compact. Emerald Riesling is recommended for regions HT and T_1.

Eno.—Wine develops into a clear white wine with a slight Riesling character. The wine from Tucson (T_1) has enough acid where some residual sugar could improve the flavor. Wine is made to be consumed quickly.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
HT	18.6	3.7	0.54	13.7
T_1	17.2	3.5	0.79	13.0

7. French Colombard

Vit.—A white grape that is from France and a very popular variety in California (28,900 acres, 1978). The variety in Arizona's warmer regions has been very productive and high in acid. It matures in midseason. Data for Region T_1 is very limited, but due to the success in the HT and T_m regions it should do well. Clusters are of medium size and well filled. French Colombard can be recommended for regions HT and T_m.

Eno.—The wines from the recommended regions have a neutral to peppermint flavor with a clear, crisp nose. The wine is very light in color. The wines from T_h are very acidic and impart a tart taste.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
HT	19.9	3.8	0.64	14.8
T_m	21.2	3.2	0.85	14.9

8. Gamay

Vit.—Gamay is a red grape originating from France. In the Region of T_m the fruit is high in acid and sugar. In warmer regions (T_1 or HT) color is difficult to achieve. In the mesic zone the acids are very high and proves to ripen very late. In T_m it is midseason ripener with moderate vigor and production. Clusters are medium and well filled. Gamay is recommended in region T_m.

Eno.—The variety has scored higher when the wine was fermented on the skins for only a short period. It appears that the wines develop a strong tannic taste which overwhelms any fruitiness when fermented to dryness. In general the wine leads itself to a fruity, light red wine that can be served with a minimum of aging.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	22.8	3.2	0.88	13.6

9. Malvasia bianca

Vit.—This is one white variety that has done well in the warmer regions (HT and T_1) of Arizona. The wine is vigorous and productive. It matures in midseason. During ripening the berry advances to a golden color and distinct, spicy flavor. Clusters are large and well filled. Malvasia bianca can be recommended in region HT and T_1.

Eno.—The wine develops into a fresh, fruity wine and appears to be suited to leaving some residual sugar for sweetness. It has been noticed that the wine may have a tendency to develop hazes during the initial production stages. When clarified, the wine is light in color and very aromatic.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
HT	19.1	3.8	0.54	13.7
T_l	20.2	3.8	0.49	13.0

10. Petite sirah

Vit.—Petite sirah is a dark grape that is from France and popular in California. The grape develops adequate coloring and flavor even in the warmest region. Acids are not high. The variety was only tested on HT and T_1 sites, but would probably do well on T_m locations. The vine is vigorous and productive. Clusters are medium and compact. It is recommended for regions HT and T_1.

Eno.—The wine is characterized as dark, red, fruity, tannic and full-bodied. Some acid may need to be added to balance the must prior to fermentation.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
HT	20.3	3.9	0.51	13.2
T_1	21.2	4.0	0.48	13.5

11. Pinot noir

Vit.—Pinot noir is a premium red from France that is popular throughout the world. Generally in the Four Corners Region vine growth is not too vigorous and production is low. Color is poor in warmer regions. In cooler regions the variety develops high sugars and moderate acids. Clusters are small and well filled. It can be recommended in regions T_h.

Eno.—The wines are often difficult to achieve proper coloring. Only one region T_h demonstrated fruit with proper coloring and vines with a satisfactory crop load. Wines from Grand Junction offer flavor and color, but the vine may be susceptible to winter damage. Warmer regions (HT and T_1) are likely to produce lightly-colored wines with some bitterness.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_h	21.4	3.4	0.72	15.2

12. Ruby Cabernet

Vit.—Ruby Cabernet is a *vinifera* hybrid produced in California that is designed to produce a cabernet-type wine. The variety has done well in Regions T_m and T_h. At these locations sugars and acids are moderate. The vine is vigorous and productive. In warmer plots the acid content is too low. Clusters large and well filled. It is recommended for regions T_m and T_h.

Eno.—The wine produced from this variety is very intense in color and tannin. This is especially true for wines from Region T_h. The wines do not have a complete cabernet aroma or flavor potential but do possess their own unique fruitiness. Quality does drop in Region T_1, where the wine is flat and bitter.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	21.7	3.5	0.69	13.9
T_h	22.7	3.5	0.71	13.8

13. Sauvignon blanc

Vit.—Sauvignon blanc is a white variety from France that had done well in this region. The variety seems best suited to the higher elevations of the thermic zones (T_m and T_h). It ripens in early midseason. The variety produces moderate sugar and acid levels. The vines are vigorous and productive. Clusters are small and loose. It can be recommended for regions T_m and T_h.

Eno.—The variety produces a very fruity wine, light straw in color, with more body than most white wines produced by the project. Even with the low acid content of the wine, some residual sugar does improve the taste. The wine easily oxidizes when made from grapes grown in warmer regions.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	20.4	3.4	0.70	13.7
T_h	20.5	3.3	0.70	13.4

14. Semillon

Vit.—Semillon is a premium white from France that has had some success at the upper elevations of the thermic soils and can be recommended for region T_h. The variety produces a low to moderate acid with moderate sugar content. It ripens in midseason. The vine is moderately vigorous and productive. As the variety matures, the berry turns gold in color. Clusters are medium and well filled.

Eno.—The variety produces a fruity, medium body and straw colored wine. The wine from warmer regions tends to oxidize easily. Semillon is often a low to moderate acid wine with some residual sugar. Semillon may be aged longer than many other white wines.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_h	21.4	3.4	0.61	13.4

15. Sylvaner

Vit.—Sylvaner is a white variety from Germany that has done well on the upper thermic soils (T_m and T_h). It ripens in early midseason. The grape produces satisfactory acid and sugar levels. The vine is not extremely productive, which may improve the acid levels. In warmer locations the grape tends to sunburn easily. Clusters are small and compact. It can be recommended for regions T_m and T_h.

Eno.—The wine is clean and fruity. The wine from Region T_h is crisp and aromatic. It has been one of the highest scoring white wines judged by the tasting panel. Wines from warmer locations tend to oxidize.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	21.1	3.5	0.75	13.7
T_h	22.5	3.4	0.88	14.4

16. White Riesling

Vit.—White Riesling is a premium white varietal from Germany that is also popular in California (8,300 acres). This variety when grown in the upper thermic to mesic zones produces a moderate to high acid must level. It can be recommended for regions T_m, T_h and M. Sugar levels are apparently sensitive to periods of rainfall which reduces sugar uptake and so delays maturity. This variety has proven to be winter hardy and would be acceptable to some mesic areas. The vine is vigorous and productive. Clusters are small and compact.

Eno.—There are two basic styles of wines produced from this variety depending upon the region or environment grown in during the year. Region T_m produces a higher alcohol and lower acid wine with a more subtle Riesling flavor during nonrainy seasons. Mesic soils produce higher acid and, possibly, lower alcohol wines with a more pronounced Riesling character. In warmer regions (T_l and HT) the wines are flat due to low acid levels.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	20.9	3.3	0.82	13.8
T_h	21.7	3.2	0.90	13.1
M	20.6	3.2	0.92	13.3

17. Zinfandel

Vit.—Zinfandel is one of the leading red varietals of California (29,900 acres). The variety produces adequate sugar and acid levels. Color levels are moderate. Zinfandel has had intermittent success at the T_m level. Periods of rainfall will suppress sugar and color. Zinfandel grown in many mesic areas fails to mature satisfactory. The vine is vigorous and productive. Clusters are medium and compact. It can be recommended for regions T_m and T_h.

Eno.—The variety may have difficulty developing the proper color. In warmer regions (T_l) only a light red color will be obtained. Acid levels are above moderate. In proper warm weather Regions (T_m) it can produce a high alcohol and tannic red wine. Wines from mesic soils show their lack of maturity.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_m	21.6	3.5	0.85	13.0
T_h	22.3	3.3	0.89	15.0

Hybrid Varieties

These varieties are of interest to the region because they possess some tolerance to low winter temperatures and may be appropriate to areas of a limited growing season.

French hybrids

These varieties were obtained by crossing *vinifera* varieties with grapes species from America. These crosses give growers varieties resistant to phylloxera without grafting or adaptable to a wider range of soils than *vinifera* while producing acceptable wine.

Recommended varieties

1. Cascade (S. 13053)

Vit.—An early-ripening dark grape that produces very high sugar readings with high acidity. The vine is moderate in growth and production. It is recommended for the mesic region.

Eno.—Cascade produces a dark red wine with a moderate tannic taste.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
M	25.6	3.2	0.86	13.7

2. Foch

Vit.—Foch is a red varietal that is popular in the North Central states. It has a tendency to develop high sugar readings while holding an adequate acid content. The vine is moderately vigorous and productive. Clusters are medium and well-filled. It can be recommended for region T_h and M.

Eno.—The variety produces a fine red wine that is very aromatic and full-bodied in taste. Acid levels are moderate from the recommended regions. The overall impression is a light cabernet style of wine with decent red color.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_h	21.4	3.6	0.75	13.2
M	24.8	3.3	1.00	13.8

3. Seyval blanc (S.V. 5276)

Vit.—A white variety that appears to be somewhat hardier than White Riesling to winter temperatures. It is a moderate in growth and production. Ripens in midseason. Clusters are medium and compact. Seyval blanc can be recommended for region T_h.

Eno.—This variety produced a very fruity and smooth wine with a slight taste of sugar.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_h	22.6	3.4	0.64	13.6

4. Villard blanc (S.V. 12375)

Vit.—A white variety that has been a moderate producer in Albuquerque. Sugar and acid levels are moderate. Clusters are medium to large and loose. Villard blanc is recommended for region T_h.

Eno.—This wine has been very fruity wine and has received the highest sensory score for hybrid grapes. Acids are low. More data are needed for evaluation in mesic soils.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
T_h	21.1	3.3	0.77	13.7

Other French hybrids that may do well in the four Corners Region, include:

White Grape	**Red Grape**
Aurora	Baco Noir
	Chancellor
	De Chaunac
	Leon Millot

At the present time more information is needed before these varieties can be recommended.

American hybrids

American or *Vitis labrusca* varieties have long been used for production of grape juice and sweet Kosher-type wines. These wines possess a strong native aroma, which is referred to as "foxy." These varieties usually bloom and ripen early which might make them susceptible to late spring frost in several thermic areas, but could ripen in the short growing seasons of many higher altitudes of the mesic regions.

1. Delaware

Vit.—A red variety that is popular in the East. This variety is moderate in vigor. It produces small compact clusters and may be susceptible to cracking during rainfall. Delaware is recommended for the mesic region.

Eno.—Delaware produces a light red wine and may, instead, produce a better white wine when pressed following the crush. The variety is very fruity and aromatic.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
M	24.7	3.2	0.55	13.1

2. Himrod

Vit.—Himrod is a seedless white grape that is known to ripen very early. It produces grapes of moderate sugar and acid. The grape turns gold as it begins to ripen. Clusters are medium sized with large berries, which make them suitable for table fruit. The vine is a vigorous grower. Himrod is recommended in the mesic region.

Eno.—A wine that is very fruity and shows some gold coloration. Acids are moderate.

Average Must Analysis

Region	Brix	pH	Acid	Wine Score
M	22.8	3.2	0.69	13.5

Table Grapes

Table grapes are currently a major crop in central and western Arizona, and include varieties:

Thompson seedless
Perlette
Cardinal
Beauty seedless

APPENDIX

Analytical & sensory data for evaluation of wine grapes from the Four Corners Area.—ARIZONA.

Babocomari

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average °Brix	Must Average pH	Must Average Total Acid g H_2Ta per 100 ml	Must Average B/A	Wine Average Ethanol percent volume	Wine Average pH	Wine Average Total Acid g H_2Ta per 100 ml	Wine Average Extract g per 100g	Wine Average Tannin mg per L	Absorbance 420 nm	Absorbance 520 nm	Sensory Score
Barbera	2	Sept. 10	2.3	21.6	3.1	1.05	20.6	12.7	3.4	0.70	1.6	1840	.174	.232	13.2
Cabernet Sauvignon	2	Sept. 4	3.9	22.3	3.4	0.75	29.7	*12.2	3.8	0.51	2.0	1950	.239	.297	13.0
Chardonnay	1	Aug. 21	1.1	20.9	3.4	1.06	19.7	11.0	3.5	0.91	1.0	410	.027		13.6
Clairette blanche	1	Oct. 4	1.1	22.2	3.5	0.44	50.5	11.9	3.5	0.39	0.3	380	.027		12.3
Chenin blanc	2	Aug. 22	4.2	21.0	3.3	0.66	31.8	13.1	3.2	0.52	1.8	310	.027		13.1
Gamay	2	Sept. 14	3.4	20.6	3.2	0.78	26.4	10.6	3.1	0.65	0.8	880	.134	.190	12.7
Gewürztraminer	1	Aug. 21	0.6	22.0	3.7	0.55	40.0	12.4	3.7	0.38	1.5	520	.020		11.8
Helena	1	Aug. 19	3.2	21.0	3.3	1.08	19.4	13.0	3.1	0.83	1.3	425	.016		13.2
Mission	1	Sept. 14	2.4	23.0	3.4	0.66	34.8	13.5	3.7	0.50	3.1	1160	.115	.127	13.8
Palomino	1	Sept. 14	2.5	22.0	3.6	0.41	53.6	12.8	3.8	0.40	1.0	360	.020		12.8
Pinot noir	2	Aug. 22	2.4	23.4	3.6	0.74	31.6	*13.1	3.7	0.51	2.1	2460	.130	.152	15.2
Ruby Cabernet	2	Sept. 10	4.9	22.7	3.5	0.71	32.0	12.4	3.7	0.60	2.1	2260	.285	.377	13.8
Sauvignon blanc	2	Aug. 17	6.1	20.5	3.3	0.70	29.3	12.0	3.2	0.56	1.0	530	.020		13.4
Semillon	1	Aug. 25	2.1	21.4	3.4	0.61	35.1	12.2	3.5	0.54	1.8	420	.036		13.4
Sylvaner	1	Aug. 19	1.0	22.5	3.4	0.88	25.6	13.0	3.2	0.72	0.8	320	.020		14.4
White Riesling	2	Sept. 3	2.8	21.7	3.2	0.90	24.1	12.5	3.0	0.65	1.8	360	.030		13.1
Zinfandel	2	Sept. 7	3.2	22.3	3.3	0.89	24.9	*12.0	3.4	0.68	1.0	1740	.134	.198	15.0
French Colombard	1	Aug. 19	1.5	21.4	3.1	1.10	19.5	12.9	2.9	0.90	1.3	395	.016		12.2

*Wine was tested for only one year.

Page Ranch

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average °Brix	Must Average pH	Must Average Total Acid g H_2Ta per 100 ml	Must Average B/A	Wine Average Ethanol percent volume	Wine Average pH	Wine Average Total Acid g H_2Ta per 100 ml	Wine Average Extract g per 100g	Wine Average Tannin mg per L	Wine Average Absorbance 420 nm	Wine Average Absorbance 520 nm	Wine Average Sensory Score
Barbera	4	Aug. 25	5.7	22.5	3.1	1.10	20.5	12.7	3.2	0.71	1.8	2840	.229	.318	14.2
Cabernet Sauvignon	4	Aug. 23	2.7	20.9	3.4	0.81	25.8	11.6	3.7	0.58	1.8	2130	.206	.234	13.4
Chardonnay	4	Aug. 3	2.7	21.4	3.4	1.00	21.4	12.1	3.3	0.55	1.8	238	.032		13.0
Chenin blanc	4	Aug. 14	4.2	22.7	3.6	0.72	31.5	12.8	3.3	0.57	0.5	344	.020		13.1
Clairette blanche	1	Oct. 4	11.2	22.2	3.5	0.44	50.5	12.8	3.8	0.38	1.5	480	.036		12.3
French Colombard	4	Aug. 19	2.3	21.2	3.2	0.85	24.9	12.2	3.1	0.73	0.8	288	.016		14.9
Gamay	4	Aug. 23	2.7	22.8	3.2	0.88	25.9	12.9	3.2	0.75	3.1	1510	.195	.288	13.1
Nebbiolo	1	Sept. 11	7.8	22.2	3.2	0.70	31.7	12.1	3.5	0.55	1.5	1100	.053	.062	13.1
Pinot noir	4	Aug. 7	1.8	21.4	3.4	0.72	29.7	12.1	3.5	0.64	2.1	1480	.146	.207	13.4
Ruby Cabernet	4	Aug. 21	2.6	22.1	3.4	0.74	29.9	11.9	3.6	0.66	1.1	2120	.188	.220	14.3
Sauvignon blanc	4	Aug. 7	6.1	20.4	3.4	0.70	29.1	11.0	3.3	0.62	1.1	238	.032		13.7
Sylvaner	3	Aug. 12	2.1	21.1	3.5	0.75	28.1	11.2	3.5	0.52	1.8	320	.020		13.7
White Riesling	4	Aug. 21	6.0	20.9	3.3	0.82	25.5	11.3	3.3	0.65	1.8	460	.020		13.8
Zinfandel	4	Aug. 20	4.3	23.0	3.5	0.79	29.1	12.5	3.5	0.68	1.1	1840	.168	.226	12.6

Tucson

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average °Brix	Must Average pH	Must Average Total Acid g H_2Ta per 100 ml	Must Average B/A	Wine Average Ethanol percent volume	Wine Average pH	Wine Average Total Acid g H_2Ta per 100 ml	Wine Average Extract g per 100g	Wine Average Tannin mg per L	Wine Average Absorbance 420 nm	Wine Average Absorbance 520 nm	Wine Average Sensory Score
Barbera	1	Aug. 16	3.8	20.8	3.4	0.70	29.7	12.2	3.6	0.64	1.5	1520	.151	.173	13.4
Cabernet Sauvignon	1	Sept. 11	3.1	23.2	3.7	0.56	41.1	11.5	4.3	0.49	2.1	1620	.156	.198	12.3
Carignane	1	Aug. 31	6.3	22.4	3.9	0.50	44.8	11.8	4.0	0.51	1.5	1460	.129	.130	13.5
Chardonnay	1	Aug. 1	4.3	20.0	3.9	0.58	34.5	11.1	4.0	0.52	1.5	420	.034		12.1
Clairette blanche	1	Sept. 4	7.3	20.6	4.0	0.43	47.9	12.1	4.1	0.32	1.5	316	.020		11.9
Emerald Riesling	1	Aug. 10	6.1	17.2	3.5	0.79	2.18	11.2	3.6	0.68	1.8	360	.020		13.0
Gamay	1	Sept. 1	3.8	21.4	3.5	0.70	30.6	10.9	3.7	0.45	1.3	1100	.083	.088	11.9
Gray Riesling	1	July 24	5.5	22.3	3.6	0.53	42.1	10.6	3.8	0.45	0.8	384	.036		12.1
Green Hungarian	1	Aug. 10	6.0	16 8	3.8	0.67	25.1	NO WINE MADE							
Mission	1	Sept. 5	3.6	21.4	3.8	0.38	56.3	12.6	4.3	0.36	2.3	880	.077	.048	8.9
Nebbiolo	1	Sept. 10	2.3	22.2	3.7	0.61	36.4	11.8	4.1	0.52	1.8	1740	.068	.071	12.5
Palomino	1	Aug. 10	3.2	18.4	3.9	0.41	44.9	11.8	3.4	0.64	0.5	310	.024		12.4
Petite Sirah	1	Aug. 30	4.1	21.2	4.0	0.48	44.2	10.4	3.9	0.51	2.1	2280	.191	.216	13.5
Pinot blanc	1	Aug. 1	5.5	19.1	3.9	0.50	38.2	12.4	3.6	0.45	0.8	466	.024		11.6
Pinot noir	1	Aug. 30	5.9	20.8	4.1	0.48	43.3	12.6	4.1	0.38	2.1	880	.136	.162	10.8
Ruby Cabernet	1	Sept. 10	2.3	22.2	4.0	0.47	47.2	12.6	4.1	0.49	2.1	1680	.208	.232	12.6
Sangiovese	1	Sept. 4	2.4	21.2	3.6	0.57	37.2	11.1	4.0	0.56	1.8	1520	.120	.096	13.1
Semillon	1	Aug. 10	3.9	20.6	4.1	0.47	43.8	11.8	3.7	0.43	0.8	284	.028		12.7
Tinta Madeira	1	Aug. 10	4.5	21.2	4.1	0.47	45.1	11.9	3.6	0.64	1.5	1280	.117	.127	12.8
Trebbiano	1	Sept. 2	7.8	22.0	4.0	0.57	38.6	13.1	4.1	0.41	1.3	422	.020		10.7
White Riesling	1	Aug. 10	3.1	20.0	3.7	0.64	31.3	11.8	3.7	0.47	1.3	348	.020		12.2
Zinfandel	1	Aug. 16	2.1	18.8	3.6	0.56	33.6	10.8	3.7	0.52	1.0	1740	.148	.186	13.1
Malvasia bianca	1	Aug. 16	5.2	20.2	3.8	0.49	41.2	11.2	3.9	0.48	1.8	410	.030		13.0
Sauvignon blanc	1	Aug. 7	1.9	20.2	3.9	0.52	38.8	12.0	3.8	0.59	2.3	510	.040		12.4

Whitewing

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average °Brix	Must Average pH	Must Average Total Acid g H_2Ta per 100 ml	Must Average B/A	Wine Average Ethanol percent volume	Wine Average pH	Wine Average Total Acid g H_2Ta per 100 ml	Wine Average Extract g per 100g	Wine Average Tannin mg per L	Wine Average Absorbance 420 nm	Wine Average Absorbance 520 nm	Wine Average Sensory Score
Barbera	3	July 24	9.3	21.3	3.5	0.70	30.4	11.8	3.6	0.62	3.1	1980	.086	.116	10.1
Chardonnay	3	July 19	8.0	22.0	3.7	0.68	32.4	12.0	3.3	0.66	1.0	278	.024		12.8
Chenin blanc	2	July 19	12.2	20.9	3.7	0.62	33.7	12.9	3.8	0.54	0.9				12.5
Emerald Riesling	3	Aug. 2	15.2	18.6	3.7	0.54	34.4	10.9	3.4	0.47	0.8	230	.032		13.7
French Colombard	2	July 29	13.9	19.9	3.8	0.64	31.1	10.9	3.4	0.63	1.1	420			14.8
Gamay	2	July 22	17.5	18.9	3.3	0.66	28.6	12.1	3.2	0.63	1.5	1820	.098	.103	12.1
Gewurztraminer	2	July 15	7.3	20.3	3.7	0.50	40.6	11.4	3.1	0.65	1.8	408	.026		13.3
Green Hungarian	1	July 23	7.5	17.4	4.0	0.38	45.8	9.1	3.1	0.54	0.5				12.8
Gray Riesling	3	July 9	10.7	21.5	3.8	0.54	39.8	11.9	3.6	0.43	0.8	306	.026		12.8
Malvasia bianca	3	July 22	13.7	19.1	3.8	0.55	34.7	10.9	3.4	0.56	1.2	533	.018		13.7
Mission (*)	3	July 26	13.5	18.4	3.6	0.49	37.6	11.7	3.5	0.50	1.5	715r 405w	.066 .044	.025	7.7r 12.5w
Muscat of Alexandria	1	July 28	5.2	17.0	3.6	0.55	30.9	9.1	3.2	0.52	0.5				13.7
Palomino	3	July 26	22.6	21.2	3.8	0.33	64.2	12.6	3.5	0.36	1.0	310	.016		11.7
Petite Sirah	3	Aug. 1	8.6	20.3	3.9	0.51	39.8	11.6	3.9	0.61	1.7	3300	.215	.229	13.2
Pinot blanc	3	July 15	8.2	22.3	3.9	0.46	48.5	12.1	3.3	0.54	2.0	496	.026		10.3
Pinot noir	3	July 15	13.3	21.1	3.9	0.56	37.7	11.4	3.7	0.53	2.0	1710	.121	.152	11.4
Pinot noir GB	3	Aug. 1	12.5	19.8	3.9	0.65	30.9	10.5	3.8	0.59	1.3	1980	.114	.156	11.5
Salvador	3	July 28	17.7	21.1	3.7	0.64	33.0	12.5	3.5	0.64	2.1	1950	.252	.298	11.3
Sauvignon blanc	3	July 24	9.2	19.3	3.8	0.63	30.6	11.3	3.5	0.51	1.3	420	.044		11.3
Semillon	3	July 22	19.2	21.2	3.8	0.59	35.9	11.8	3.4	0.45	1.7	410	.052		11.8
Souzao	2	Aug. 5	8.2	19.2	3.8	0.75	25.6	11.1	3.8	0.57	2.1	1320	.210	.235	12.6
Sylvaner	2	July 18	9.2	19.3	4.0	0.52	37.1	11.5	3.6	0.52	1.3	362	.052		10.5
Tinta Madeira	3	July 20	20.4	21.4	4.1	0.63	33.9	12.3	4.2	0.49	2.1	1780	.088	.106	10.3
White Riesling	1	July 16	7.8	18.9	3.4	0.57	33.2	10.6	3.0	0.54	0.8		.055		12.4
Zinfandel	3	Aug. 1	13.1	20.5	3.9	0.57	36.0	12.7	3.8	0.58	1.5	1310	.104	.128	11.4

*First year was a red wine only

APPENDIX B:

Analytical & sensory data for evaluation of wine grapes from the Four Corners Area.—COLORADO

Grand Junction

				Must Average				Wine Average							
Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	°Brix	pH	Total Acid g H_2Ta per 100 ml	B/A	Ethanol per-cent volume	pH	Total Acid g H_2Ta per 100 ml	Extract g per 100g	Tannin mg per L	Absorbance 420 nm	Absorbance 520 nm	Sensory Score
Baco noir (CAR)[a]	1	Sept. 15	7.5	21.7	3.0	1.42	15.3	12.1	2.9	1.20	2.3	1500	.155	.145	12.0
Cabernet Sauvignon (BRA)	2	Sept. 21	2.2	22.0	3.2	0.85	25.9	12.3	3.2	0.75	1.7	1860	.201	.294	13.3
Cabernet Sauvignon (ZIM)	1	Sept. 9		21.2	3.4	0.88	24.1	12.1	3.4	0.68	0.8	2150	.302	.293	13.9
Chardonnay (BLA)	1	Sept. 9	8.5	23.2	3.6	0.64	36.3	13.5	3.4	0.52	1.3				12.9
Chardonnay (BRA)	1	Aug. 30	1.3	21.7	3.2	0.93	23.3	12.0	3.1	0.66	1.8				12.0
Chardonnay (TAL)	1	Sept. 7	2.8	22.8	3.5	0.95	24.0	12.2	3.1	1.04	1.3	395			13.3
Foch (CAR)	1	Sept. 15	5.2	24.8	3.3	1.00	24.8	13.9	3.4	0.74	2.3	2050	.260	.270	13.8
Gamay (BRA)	2	Sept. 24	3.2	21.0	3.1	1.14	18.4	12.7	3.1	0.91	2.0	2900	.236	.365	12.7
Gamay (GIG)	3	Sept. 23	7.9	20.7	3.2	0.91	22.7	11.2	3.2	0.75	1.3	2540	.126	.242	13.4
Leon Millot (CAR)	2	Sept. 15	2.1	26.2	3.1	1.40	18.7	13.8	3.2	1.20	4.3	2260	.398	.442	12.8
Pinot noir (TAL)	1	Sept. 7	3.2	22.0	3.4	0.78	28.2	12.9	4.0	0.46	1.8	1520	.138	.168	15.1
White Riesling (GIG)	3	Sept. 10	7.9	21.0	3.2	0.86	24.4	13.1	3.1	0.71	1.5	550	.020		13.3
White Riesling (GOB)	1	Sept. 22	7.5	20.6	3.2	1.09	18.9	13.4	3.0	0.73	1.5				12.0
White Riesling (SCH)	2	Sept. 26	5.0	19.3	3.3	0.93	20.8	10.6	3.2	0.72	1.0	311	.024		12.4

[a] BLA—Blatnick, BRA—Bracken, CAR—Carruthers, GOB—Gobbo, SCH—Schmitt, TAL—Talley, ZIM—Zimmerman

APPENDIX C:

Analytical & sensory data for evaluation of wine grapes from the Four Corners Area.—NEW MEXICO

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average: °Brix	Must Average: pH	Must Average: Total Acid g H_2Ta per 100 ml	Must Average: B/A	Wine Average: Ethanol percent volume	Wine Average: pH	Wine Average: Total Acid g H_2Ta per 100 ml	Wine Average: Extract g per 100g	Wine Average: Tannin mg per L	Wine Average: Absorbance 420 nm	Wine Average: Absorbance 520 nm	Wine Average: Sensory Score
Lincoln															
Chardonnay	2	Oct. 4		22.8	3.4	0.76	30.0	*15.6	3.5	0.60	3.1				13.0
Melon	1	Sept. 29		19.9	3.2	0.83	24.0	10.4	3.0	0.70	1.3	310	.045		13.5
Pinot noir	1	Sept. 29		21.0	3.2	0.83	25.3	10.5	3.6	0.73	1.3	950	.078	.043	12.4
White Riesling	2	Oct. 4		21.5	3.1	0.80	26.9	12.5	2.9	0.61	1.7	620	.040		11.7
Zinfandel	2	Oct. 10	3.4	22.0	3.4	0.94	23.4	12.8	3.3	0.88	1.7	1380	.136	.188	13.0
Roswell															
Barbera	1	Aug. 19		19.3	3.5	0.87	22.2	9.5	3.5	0.71	2.1	1200	.086	.096	10.9
Chardonnay	1	Aug. 19		21.4	3.5	0.63	34.0	12.0	3.8	0.40	1.0	505	.058		12.6
Cabernet Sauvignon	1	Aug. 24	1.3	21.4	3.5	0.68	31.5	12.6	3.6	0.59	2.1	2560	.245	.354	13.3
Gamay	1	Aug. 24	10.6	21.8	3.4	0.85	25.6	12.6	3.2	0.79	1.8	740	.117	.173	14.2
Palomino	1	Aug. 24	9.1	19.9	3.6	0.49	40.6	12.6	3.5	0.39	0.5	210	.020		12.6
Ruby Cabernet	2	Aug. 22	6.1	21.2	3.6	0.64	33.1	12.5	3.8	0.62	2.2	2810	.278	.341	13.6
Zinfandel	2	Aug. 22	3.9	20.1	3.5	0.92	21.8	11.4	3.4	0.70	2.1	2110	.133	.180	13.4
Albuquerque															
Baco noir	2	Aug. 12	8.1	22.2	3.7	1.01	22.0	13.1	3.7	0.72	1.8	1560	.315	.236	11.8
Black Malvosie	3	Aug. 12	7.6	20.5	3.4	0.69	29.7	12.2	3.4	0.60	1.6	1420	.074	.094	12.3
Cascade	3	Sept. 14	3.2	21.5	3.1	1.32	16.3	12.8	3.2	1.02	3.3	4140	.520	.540	11.1
Chancellor	3	Sept. 18	5.9	22.1	3.3	0.79	27.9	13.3	3.7	0.63	2.3	2580	.318	.327	12.7
Foch	3	Aug. 23	6.0	21.4	3.6	0.75	28.5	12.4	3.7	0.66	2.8	2640	.248	.226	13.2
Seyval blanc	1	Sept. 8		22.6	3.4	0.64	35.3	9.0	3.3	0.54	1.0	350			13.6
Villard blanc	2	Sept. 4	5.5	21.1	3.3	0.77	27.4	12.6	3.2	0.58	1.5		.034		13.7

Farmington

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average: °Brix	Must Average: pH	Must Average: Total Acid g H_2Ta per 100 ml	Must Average: B/A	Wine Average: Ethanol percent volume	Wine Average: pH	Wine Average: Total Acid g H_2Ta per 100 ml	Wine Average: Extract g per 100g	Wine Average: Tannin mg per L	Wine Average: Absorbance 420 nm	Wine Average: Absorbance 520 nm	Wine Average: Sensory Score
Agawam	1	Sept. 12		24.8	3.1	1.31	18.9	13.1	3.1	0.95	2.6	850	.279	.296	11.4
Baco noir	1	Sept. 13		21.4	3.1	0.64	32.9	11.4	3.2	0.74	1.0	840	.045	.025	10.8
Bath	1	Sept. 20		21.3	3.1	0.45	47.3	NO WINE MADE							
Cascade	1	Sept. 20	6.0	25.6	3.2	0.86	29.8	11.3	2.8	0.75	2.1	1450	.145	.241	13.7
Chelois	2	Sept. 19	17.5	23.2	3.2	1.05	22.1	13.4	3.2	0.86	2.1	2110	.310	.410	12.8
Delaware	1	Sept. 15	6.1	24.7	3.2	0.55	44.9	15.6	3.2	0.50		600	.043		13.1
Dutchess	1	Sept. 13		19.6	3.2	0.66	29.7	11.4	3.1	0.72	2.1	288	.032		11.3
Rosette	2	Sept. 15	13.5	22.7	3.2	0.74	30.7	12.7	3.1	0.64	1.1	1410	.150	.210	12.1
Rougeon	2	Sept. 16	30.0	20.2	3.3	0.88	22.9	12.0	3.4	0.71	1.8	2420	.196	.215	12.8
Royality	1	Sept. 13		19.6	3.1	1.19	16.5	10.9	3.2	0.89	2.1	4360	.379	.431	12.9
Zinfandel	1	Sept. 13		20.0	3.1	1.06	18.9	11.0	3.1	0.92	1.3	1160	.098	.188	13.4

Placitas

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average: °Brix	Must Average: pH	Must Average: Total Acid g H_2Ta per 100 ml	Must Average: B/A	Wine Average: Ethanol percent volume	Wine Average: pH	Wine Average: Total Acid g H_2Ta per 100 ml	Wine Average: Extract g per 100g	Wine Average: Tannin mg per L	Wine Average: Absorbance 420 nm	Wine Average: Absorbance 520 nm	Wine Average: Sensory Score
Alicante Bouschet	1	Sept. 27	7.2	16.8	3.2	0.92	18.3	9.9	3.2	0.83	1.8	1780	.278	.388	11.6
Muscat of Alexandria	1	Sept. 27	5.3	15.8	3.3	0.81	19.5	12.6	3.2	0.65	1.5	232	.038		11.9
Zinfandel	1	Sept. 27	7.5	15.0	3.1	1.30	11.5	10.7	3.1	1.15	1.8	1460	.138	.184	11.6

APPENDIX D:

Analytical & sensory data for evaluation of wine grapes from the Four Corners Area.—UTAH

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average: °Brix	Must Average: pH	Must Average: Total Acid g H_2Ta per 100 ml	Must Average: B/A	Wine Average: Ethanol percent volume	Wine Average: pH	Wine Average: Total Acid g H_2Ta per 100 ml	Wine Average: Extract g per 100g	Wine Average: Tannin mg per L	Wine Average: Absorbance 420 nm	Wine Average: Absorbance 520 nm	Wine Average: Sensory Score
Blanding															
Interlaken	1	Aug. 9	1.0	25.2	3.8	0.58		NO WINE MADE							
Bluff Bench															
Himrod	1	Sept. 7	4.0	23.0	3.3	0.74	31.1	13.1	3.4	0.69	2.1	440	.024		12.4
Interlaken	1	Aug. 9	2.6	18.8	3.4	0.66	28.5	NO WINE MADE							
Schuyler	1	Aug. 9	2.9	20.4	3.2	0.61	33.4	NO WINE MADE							
Unknown White	2	Sept. 8	3.8	22.0	3.3	0.73	30.1	12.6	3.3	0.60	1.8	215	.020		11.8
Moab															
Aurore	1	Aug. 9	3.1	21.9	3.5	0.77	28.4	12.0	3.4	0.60	2.6	467	.026		12.8
Himrod	2	Aug. 21	19.9	22.7	3.2	0.63	13.5	12.7	3.0	0.65	1.0	210	.030		13.5
Gew¨urztraminer	1	Sept. 7	3.8	25.4	3.7	0.45	56.4	14.2	3.8	0.48	3.1	380	.030	.121	
Pinot noir	1	Aug. 16	1.0	21.2	3.4	0.83	25.5	13.2	3.1	0.92	2.9	1850	.135	.132	13.0
Schuyler	3	Aug. 10	7.7	22.7	3.5	0.65	34.9	13.5	3.6	0.66	4.1	2085	.131	.190	9.8
Unknown Black #1	2	Aug. 11	3.9	23.5	3.2	1.30	18.1	13.6	3.5	0.72	2.7	1700	.180	.180	12.0
Unknown Black #2	1	Sept. 7	3.5	25.2	3.8	0.55	45.8	13.8	3.9	0.62	2.8	1860	.180	.180	14.1
Unknown White	2	Sept. 1	11.6	20.8	3.3	0.75	27.7	12.1	3.3	0.62	1.8	310	.034		12.9
Montezuma Canyon															
Schuyler (white)	1	Aug. 18	9.9	16.2	3.2	0.88	18.4	10.5	2.9	0.71	1.0	360	.038		11.4
Utah Black	1	Sept. 9	5.0	23.0	3.2	1.21	19.0	11.4	3.0	0.92	2.9	1150	.271	.291	13.6
Zinfandel	2	Sept. 21	7.4	17.8	3.2	1.14	15.6	9.9	3.1	1.04	1.8	1160	.130	.161	11.8

St. George

Variety	Number of Years Tested	Avg. date of Harvest	Max Yield T/HA	Must Average °Brix	Must Average pH	Must Average Total Acid g H_2Ta per 100 ml	B/A	Wine Average Ethanol percent volume	Wine Average pH	Wine Average Total Acid g H_2Ta per 100 ml	Extract g per 100g	Tannin mg per L	Absorbance 420 nm	Absorbance 520 nm	Sensory Score
Cabernet Sauvignon	1	Sept. 8	3.1	21.2	3.4	0.60	35.3	11.7	3.8	0.50	1.8	2070	.188	.250	13.6
Gewurztraminer	1	Sept. 8	1.5	24.0	3.6	0.55	43.6	13.4	3.5	0.47	1.0	205	.030		12.3
Gray Riesling	1	Aug. 18	1.3	23.0	3.6	0.62	37.0	12.4	3.5	0.61	1.3	305	.018		12.3
Meunier	1	Sept. 8	3.1	24.0	3.6	0.52	46.2	13.5	3.8	0.61	1.0	2360	.099	.215	11.9
Pinot noir	1	Sept. 8	3.4	22.0	3.7	0.53	41.5	11.8	3.7	0.51	1.0	1300	.061	.068	12.9
Pinot noir GB	1	Sept. 8	7.0	23.2	3.8	0.53	43.8	12.6	3.9	0.49	1.0	1420	.120	.138	12.3
Royality	1	Sept. 8	5.6	23.8	3.4	0.58	41.0	13.5	3.7	0.56	1.0	5580	.352	.402	12.1
Thompson Seedless	1	Aug. 18	6.6	18.7	3.4	0.75	23.7	12.1	3.4	0.52	3.6	544	.024		12.0

Disclaimer

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