



VITICULTURE



A manual prepared by Todd Rosenstock of the
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Department of Agriculture and Natural Resources

University of California, Davis
One Shields Avenue
Davis, CA 95616

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1. WHY THIS MANUAL?

Table grape and raisin production is a scientifically specific and labor-intensive process. To achieve optimal yields of both quality and quantity, the grower must utilize both site-specific knowledge and best management practices. Each cultural practice has the potential to significantly affect the outcome of the crop. This manual attempts to outline many of the physiological, environmental, and pathological considerations the grower might come across. It should serve as a reference for questions and a guide to determining future inquiries. The goal of this manual is to help Afghan Grape Farmers increase both the quantity and quality of their grapes.

2. ECOPHYSIOLOGY OF GRAPEVINES

Grapevine performance depends on the genotype, the environment, and the interaction between the genotype and the environment. Environments consist of many factors that affect vine growth and productivity. Several physical, chemical and vital activities of the vine and its parts are involved in the uptake of nutrients, the synthesis of metabolic substances, the processes of growth, and the development of flowers and fruit. The most essential activities that affect the physiological function of the vine include: transpiration, photosynthesis, respiration, water uptake, nutrient absorption, photosynthesis, and translocation.

The growth and production of a grapevine is the result of the coordination among all organs to provide the necessary mineral nutrients, carbohydrates, plant hormones and water.

2.1 Grapevine growth

Growth is a complex phenomenon. It occurs as a result of cell division, elongation and radial increase. The production of the vine's organs and increase shoot length occurs at the apical meristem. The increase in diameter of the shoots, trunk and roots is the result of new tissues arising from vascular cambium. The cells on the inner side enlarge and differentiate into xylem and wood tissues; those on the outer side enlarge and differentiate into phloem and bark tissues. Energy needed for vine growth is provided by the oxidation of carbohydrates produced during the process of photosynthesis.

2.2 Annual cycle of growth

Understanding the cycle of vine growth will improve the ability of viticulturists to manage and regulate the vine to produce high yields with optimum fruit quality.

The cycle of vine growth may be described as a series of phenological events, which occur during the growing seasons. Budbreak occurs in the spring followed by a period of rapid growth and canopy development. Flower clusters are first

visible on young shoots shortly after bud break and fruit development begins soon after antithesis in the spring. Fruit ripening begins in mid-summer and concludes when fruit reaches the proper maturity standard. Leaf senescence begins in the late fall and the onset of dormancy occurs with the first fall frost.

Grapevine growth may also be viewed as three distinct developmental cycles: the vegetative growth cycle, fruit growth and development cycle and fruit bud differentiation (cluster initiation) for the following season. The vegetative cycle development of the vine canopy is initiated and completed in the same season, while the reproductive cycle requires two years for completion. In the first season, flower cluster primordia develop in the primary or latent buds. The following growing season, the flower clusters enlarge and develop into fruit clusters. Thus, the potential number of flower clusters per vine, as well as their size, is determined during the previous growing season. Berry set and fruit development is determined during the current season.

2.3 Vine photosynthesis

Photosynthesis is the process by which solar energy is converted to chemical energy (ATP, NADPH) by chlorophyll in the presence of carbon dioxide and water. This chemical energy is utilized to produce carbohydrates within the plant.

Although, sugar is the primary plant food, the plant produces other carbohydrates, proteins and fats. Sugar, mainly sucrose, manufactured in the green cells undergoes many transformations. Some of it is oxidized to provide chemical energy for vine growth. Sugar that is not used immediately is translocated to storage tissues in the fruit, trunk, roots, canes, etc. It is then transformed into other carbohydrates such as glucose and fructose, which are the sugars of a mature grape. In addition, it can be converted to starch, the principal storage food of the vine, and hemicellulose and cellulose, the building materials of which the cells of the various parts of the vine are constructed. The sugar not used for food reserves or synthesis of other carbohydrates or synthesis of other carbohydrates may be synthesized into proteins, fats and other compounds.

2.4 Environmental factors affecting photosynthesis

Basic to our understanding the principles of vine training, pruning, trellising and canopy management is how environmental factors such as light intensity, temperature, carbon dioxide concentration and moisture influence the rate of photosynthesis in grapevines.

Light

Light is the most important factor influencing photosynthesis of all plants. Grape leaf photosynthesis increases with direct correlation to ambient light levels. At a

point, further increase in light intensity will not increase photosynthesis. This is known as the light saturation point.

The photosynthetic rate of the entire vine is probably never light saturated. This is due to the fact that not all leaves are fully exposed to sunlight at any time. Mutual leaf shading can become considerably significant in dense canopies. A single leaf can absorb 90% of the solar radiation in the visible range of the spectrum. Light intensities in the interior parts of vines are sometimes below the light compensation point. At full canopy, the amount of leaf area on the exterior of the canopy may be only 20 to 40% of the entire vine's leaf area, depending upon time of day, stage of vine growth and trellis configuration. This would mean that about 60 – 80% of the vine's leaf area might be shaded. It has been reported that 70% of all carbohydrates produced via photosynthesis is manufactured in the leaves located on the exterior of the vine's canopy and exposed to maximum light intensity. The remainders of carbohydrates are produced by shaded leaves. As mentioned earlier, light intensity maximizes stomatal opening, thus increasing gas exchange, indirectly affecting photosynthesis.

Temperature and Water

Temperature affects vine photosynthesis directly through its effects on the rates of enzymatic reactions involved in the process of photosynthesis. The optimum temperature for grapevine leaf photosynthesis is between 25°C and 30°C. Temperature below or above the optimum decreases the photosynthetic rate. At 10°C photosynthesis will decrease to zero. The rate of photosynthesis, at a leaf temperature of 40°C, will be reduced by 25 – 40%. High temperatures causes water stress; thus causing the stomata to close resulting in a decrease in gas exchange. Water is not only a primary reactant but also helps control stomatal opening and closing. Water deficits result in a drop in photosynthesis.

2.5 Cultural practices and vine photosynthesis

Cultural operations such as training, trellising, row orientation, canopy management, mineral nutrition, irrigation and water quality can affect whole vine photosynthesis. An east/west row direction intercepts less light than one in which the row direction is oriented north/south. The south side of the grapevine in an east/west oriented row will receive lower light intensity during early morning and late afternoon hours, while the north curtain in the same row may be in the shade much of the day, depending on the time of year.

The amount of solar radiation intercepted by the canopy surface of grapevines, as well as the light environment found within the canopy interior is largely determined by the training and trellis system employed and vine leaf area. Low light within the interior of grapevine canopies is one of the primary cultural problems associated with commercial production. 80 – 90% of the

photosynthetically active radiation (PAR) arriving at the surface of the exterior canopy leaves is absorbed, with the remainder either transmitted or reflected. The low levels of PAR commonly found in the interior of canopies are a result of this high degree of absorption. Vine training and trellising systems are designed to increase both canopy height and width for better light penetration.

Vines trained to a single wire trellis system will intercept less light than vines trained to a trellis system using a crossarm. The crossarm will extend the leaf surface area at the top so that more of the vine canopy has the opportunity to intercept more light.

Vine mineral nutrition is important for vine growth and productivity. Nitrogen and magnesium are structural components of the chlorophyll molecule. Nitrogen is also a component of the enzyme proteins needed to convert solar energy into chemical energy and carbon dioxide to carbohydrates during photosynthesis. Iron is required for the synthesis of chlorophyll. Potassium and zinc are needed as cofactors for enzyme activation and their deficiency will disrupt cellular metabolism.

Irrigation exerts considerable influence, affecting root growth, top growth, and yield of grapevines. It has also some effect on the microclimate in the vineyard. Water status must be maintained to maintain leaf area. Water quality is another important aspect of irrigation. Grapevines are sensitive to high salt concentration. High salt concentrations in the soil solution and/or irrigation water create high osmotic pressure, reducing the availability of soil water to the plant. This poses a threat of osmotic withdrawal of water from plant tissues. Specific ions such as sodium and chloride may prove toxic at high concentrations. Growth yield parameters are negatively correlated with increasing salinity for many crop plants.

2.6 Growth cycles

The cycle of vine growth is vital knowledge to be able to determine the best management and regulation aspects. Budbreak occurs in the spring, followed by a period of rapid shoot growth and canopy development. Flower clusters are first visible on young shoots shortly after budbreak and fruit development begins soon after flower opening or antithesis in the spring. Fruit ripening begins with the initiation of fruit softening in mid-summer, and concludes when fruit reaches the proper composition for harvest. Leaf drop begins in the late fall, and the onset of deep dormancy occurs with the first fall frost.

There are three distinct cycles: the vegetative growth cycle, the fruit growth and development cycle and the fruit bud differentiation or cluster initiation for the following growing season. The vegetative cycle is completed within one season while the other two begin in one season and are completed in the following.

2.7 Vegetative growth

Grapevines require exposure to chilling temperature during dormancy for optimum budbreak. They will remain dormant until the mean daily temperatures in the early spring reach approximately 10°C. As temperatures rise, shoot growth rate increases. About one month after budbreak, vines may grow as much as 10 – 12 inches per week. After the initial stages of berry growth, the rate begins to slow but continues as long as soil moisture and temperature are sufficient.

Energy to support budbreak and initial stages of shoot growth comes from stored carbohydrates in permanent parts of the vine.

Grapevine shoots have two types of nodes or buds, primary and lateral. The canopy consists of both primary and lateral shoots. Primary shoots originate from the primary bud, while lateral shoots grow from lateral buds borne on primary shoots. During the early stages of vine growth, the vine canopy mostly consists of the leaves from primary shoots.

2.8 Fruit-bud differentiation and cluster primordia development

The process begins in the developing primary dormant bud near the time the current crop is beginning bloom. The flower cluster primordia of grape are formed the year prior to their appearance and bloom. Flower cluster initiation or fruit bud differentiation begins near anthesis in the basal buds of the shoot, and continues along the cane through mid-summer. Temperature and light are important environmental characteristics that affect fruit bud differentiation.

3. GRAPEVINE WATER RELATIONS

Water is important to all living organisms. Water is a reagent in photosynthesis and in a number of other biochemical or biophysical processes. It is essential for the maintenance of turgidity (which in turn is necessary for cell enlargement, stomatal opening, and maintenance).

Water moves along gradients from decreasing water potential. This can sometimes be called mass flow, if some external agent produces the difference in water potential. The loss of water from leaves (evapotranspiration) and the resultant uptake of water through the roots is an example of mass flow. Diffusion results from the random motion of molecules. Osmosis is an example of diffusion caused by a difference in potential of water on two sides of a membrane.

3.1 Water movement and interactions, soil-vine-air

Evaporation of water from stomata, the microscopic pores located on the lower surface of the leaf, drives the uptake of water from the soil. Stomata are closed in the absence of light. The stomatal opening will result in the loss of water vapor from the leaf due to the large gradient in water potential between the atmosphere and the interior of the leaf. The vascular tissue contains specialized cells, called vessels that transport water from the roots to the leaves. Thus water is pulled up through the vine due to the strong cohesive properties of water molecules in these small water-conducting cells.

3.2 Daily and seasonal vine water relations and water use

The main driving force of vineyard water use or evapotranspiration, ET, is net radiation. Net radiation provides the energy to convert water in the liquid state to the vapor state. Net radiation and vine water use are highly correlated. Other environmental factors influencing ET are wind speed and vapor pressure deficit. Both of these factors facilitate the evaporation of water from the stomata into the air. Vineyard management systems might also affect water use. Trellis systems that spread the canopy or vines with more leaf area will use more water.

Vine water use will also vary throughout the growing season. Water use is low early in the season, from budbreak until one month later, as there is little leaf area during this time. Vine water use will plateau at full canopy.

3.3 Effects of irrigation on vine growth

Most studies on grapevines have demonstrated that water deficits affect vegetative growth to a greater degree than reproductive growth. A reduction in shoot growth is one of the first visible symptoms of vine water stress. A severe or rapid water stress can result in the shoot tip dying. Moderate water deficits will

decrease shoot elongation rate, internode length and diameter expansion. Leaf area per vine is reduced under water deficit conditions. Growth of lateral shoots is more reduced than that of the primary shoots under water stressed conditions.

Reproductive growth of grapevines is generally less sensitive to water stress than vegetative growth. However the most sensitive stage of berry growth is the 2 to 3 weeks of initiation of berries. While size is not greatly impacted by water deficits later in the season, the berry's solute concentration is affected by vine water status. Many times vines that are water stressed will have a higher concentration of sugar in the fruit. This may be due to 1) decreased yield, thus less competing sinks for carbohydrates, 2) berries lose water under stress and the concentration of sugars increase, and 3) shaded fruit by large amounts of vegetative growth might reduced rates of sugar accumulation. Water stress may delay maturity.

Unnatural color development in the fruit of red and black cultivars may be a problem for table grapes. Irrigation scheduling may be used to improve color as water deficits increase the production of pigments in the berries.

The ultimate effect of irrigation amounts on final yield are due to whether these amounts are affecting fruit development in the current growing season (i.e. the number of berries that set per cluster and/or berry growth) or cluster development for the next cropping season (i.e. the number of buds that will develop cluster primordial and the size of the cluster primordial which will determine the number of flowers that develop the following year). In Thompson Seedless, the most important effect the irrigation treatments had been on the vine's potential yield for next year (i.e. potential bud fruitfulness). Mild water deficits had a positive effect on bud fruitfulness and increased the number of clusters per vine.

4. NURSERY ESTABLISHMENT

4.1 Propagation

Seeds, cuttings, budding, grafting, layering and tissue culture may be used to propagate grapevines. The choice of the propagation method is governed by several factors: presence or absence of soil borne pathogens, location of the vineyard, climatic conditions, and skill of the grower or labor available.

Nearly all grapevines, whether for fruiting or rootstocks are propagated by cuttings. These are usually grown in a nursery for one year to produce rootlings. The cuttings may be grafted before being planted in the nursery to produce bench grafts. Layering propagates a few varieties whose cuttings are difficult to root.

Collection of Cuttings

The first stage in propagation of both own-rooted and grafted vines usually involves making budwood cuttings from dormant canes (i.e. last season's shoots). Cuttings may be taken at any time during the dormant period but are usually taken in early winter. Cuttings for own-rooted vines or scion wood are made 30-40 cm long. This length may vary slightly depending on the propagation method to be used.

Rootstock cuttings are usually made longer (40-45 cm) so that when planted the graft union remains above the soil level. Before a cutting is planted in the nursery, all buds except the one at the top should be removed. Such disbudding is essential to avoid suckering in the vineyard. If disbudding is not done before the cuttings are planted in the nursery, the rootlings must be disbudded before being placed in the vineyard. Failure to disbud may result in short-lived vineyard. Disbudding the rootlings is much more difficult and costly than disbudding the cuttings.

Selection of Cuttings

Dormant cuttings are best taken from healthy, true-to-type vigorous vines having well matured canes. They should have an ample supply of stored foods (carbohydrates) to nourish the developing roots and shoots until the new plant becomes self-sustaining. The choice of planting stock will have an enormous impact on the health and quality of the planting for the life of the vineyard. If virus-infected planting stock is used, no subsequent cultivation practices or treatments will improve the diseased condition, short of replacing the vines. It is also important to choose planting stock that is true to variety. If the vines are misidentified, they may be unsuitable for the product for which they were planted. Costly procedures such as replanting or grafting over are the only way to correct this kind of mistake.

Cuttings for own-rooted vines

Cutting for producing own-rooting vines should be about 8-12 mm in diameter and of medium internodes length (10-12 cm). Cuttings with long internodes from rapid growth often have low stored reserves. Canes that are flattened or immature or have dead sections are best avoided.

Cuttings for grafted vines

Similar qualities apply as for ungrafted vines, but size is more critical. Scion wood for bench grafting should be straight, 7-10 mm in diameter with internodes less than 7 cm, cuttings with longer internodes tend to be flattened in cross-section making them undesirable for bench grafting

4.2 Grafting and budding

Grafting is the process, which two plant parts are connected together to produce a continuous single united plant. Budding is similar to grafting except that the scion is reduced in size to usually contain only one bud. Any grafted plant consists of three essential parts: the stock, the scion and the graft union. The stock is the lower part of the graft, which develops in the root system. The scion consists of the shoot-aerial portion of the graft. The union is the region where the scion and stock are joined.

Purpose of grafting

Vines are grafted for any of the following purposes: a) to obtain vines of desired fruiting variety on roots resistant pests and diseases; b) to correct mixed varieties in established vineyard, c) to change the variety of an established vineyard; d) to increase supply of new or rare variety or e) to obtain vines on roots tolerant to adverse soil conditions.

Requirement for successful grafting

The most important factors governing success in grafting vines are: compatibility between stock and scion, favorable conditions of moisture, temperature and aeration, contact or close proximity of the cambium layers of stock and scion, youth of scion and stock and a healthy degree of vegetative activity in scion and stock. Compatibility refers to the capabilities of the stock and scion to exist together, involving structural and chemical similarity. There is no definite rule that can predict exactly the outcome of a particular graft combination. As a general rule, the more closely the plants are related botanically, the better the chances for the graft union to be successful. Thus, almost all vinifera grape varieties are easily inter-grafted. Generally, the younger the parts to be grafted together, the more successful the grafting, provided that favorable environmental conditions

are maintained. With dormant scions, results are best if the work is delayed until the stock starts growth, or near that time. The scions should be kept dormant by storing them in a cool place. Summer grafting or budding is most successful when the stocks are growing vigorously.

Bench Grafting

In the past bench grafting (indoor grafting) has been the most common method of producing grafted vines of desired fruiting varieties on roots resistant to pests. The work is carried out in a well-lighted place, usually indoors, during the late winter and early spring. The newly made grafts are stored or callused in sand or in a hot room and are grown for a year in the nursery before being planted in the vineyard. Single bud scions of the desired fruiting variety are grafted on either a rooted cutting or one-year-old rooting of the desired stock variety. Those grafted on rootings may be planted directly in the vineyard.

The canes for scion and those for stock cuttings are often made up in length of 76 cm to 115 cm or more. Then when grafting is done the long pieces are cut into the desired length. About 36 cm for the stocks and a single-bud piece for the scions.

4.3 Grafting methods

The most common method of grafting and budding are whip grafting and T-budding. Whip grafting is highly successful if done properly because there is considerable cambium contact. It heals quickly and makes a strong union. T budding (shield budding) is also widely used by nurserymen in propagating nursery stock of most fruit tree species, vines and ornamentals.

Performing a whip graft [Figures 2, 3, 4 (Hartmann et al, 1990)]

The stock

1. A long sloping cut 2.5-6.0 cm long is made at the top of the stock
2. A second downward cut is made starting one-third of the distance from the tip to the base of the first cut- pulled a part to form a tongue

The Scion

1. A long, sloping cut is made at the base of the scion the same length as the cut on the stock.
2. A second cut is made under the first, just as for the stock – pulled apart to form a tongue.

The Union

1. The stock and scion are slipped together, the tongues interlocking.
2. The graft is then tied and waxed (see the fig. below for whip grafting)

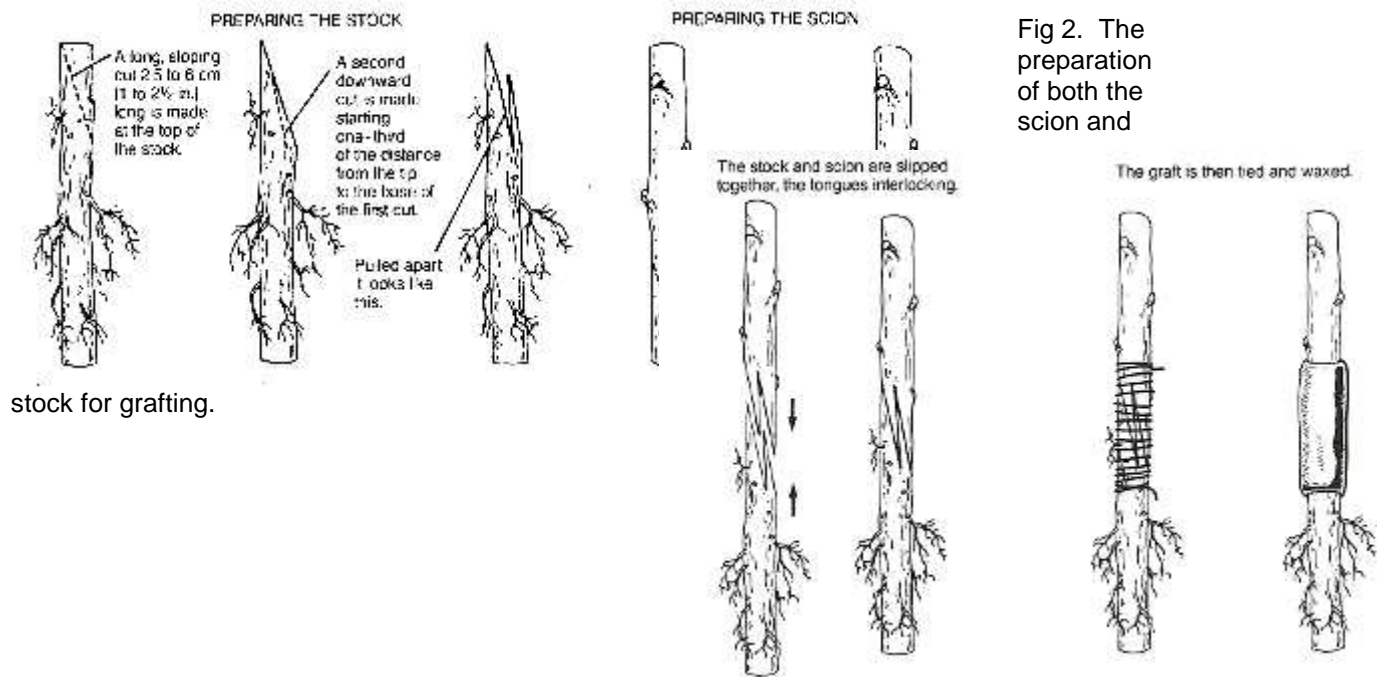


Fig 3. Fitting and tying the whip.

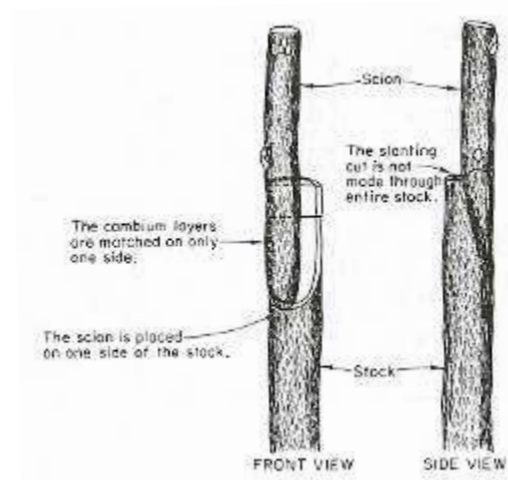


Fig 4. Fitting a smaller scion

into a larger stock.

Performing T-budding [Figure 5 (Hartman et al., 1990)]

The Stock

1. A vertical cut 2.5 cm long is made in the stock
2. A horizontal cut is made through the bark about one-third the distance around the stock. The knife is given slight twist to open the two flaps of bark.

The Scion

1. Starting about 1.2 cm below the bud, a slicing cut is made under and about 2.5 cm beyond the bud.
2. A bout 2 cm above the bud a horizontal cut is made through the bark and into the wood, permitting the removal of the bud

The Union

1. The shield piece is inserted by pushing it downward under the two flaps of the bark until the horizontal cuts on the shield and the stock are even.
2. The bud union is then tightly tied with some wrapping material such as tape, budding rubber and raffia to hold the two components firmly together until healing is completed (see the fig. below-for T-budding)

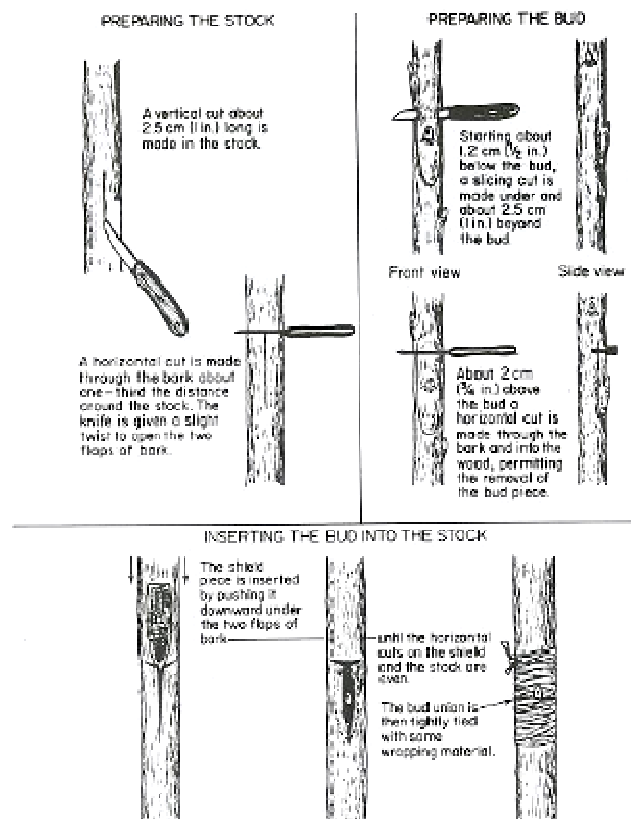


Figure 5. Preparation and insertion of a T-bud.

4.4 Nursery site selection

An ideal nursery soil is a deep, friable sandy loam, which is fertile, well drained and free of nematodes and pathogens. The site should be fairly level, protected from wind but not shaded and supplied with good quality irrigation water. Selection of a new site, which has been followed for several years, will reduce nematode and infertility problems.

Site Preparations

In developing countries, friable sandy loam soils, which are deep and well drained, are considered ideal for nursery establishment. The nursery site has to be ploughed well before planting. If possible, about 3-5 weeks later the soil is disked, harrowed to a fine tilth and then leveled using a leveling board drawn by a tractor. The land is then divided into planting rows. A furrow is then ripped along each row to facilitate irrigation of the nursery plants. Fencing and wind breaks have to be established when necessary.

Planting

This is usually done from early to mid spring. At least 25% more cuttings than the number of rootlings required should be planted. A row spacing of 120-150 cm is suitable. A furrow is ripped along each row, water is applied along full length of the furrow and the cuttings are pushed into the soil leaving atleast two nodes exposed. Cuttings can be planted 5 cm apart but a wider spacing may be preferable for infertile soils or where irrigation is limited. A heavy irrigation should be applied immediately afterwards to compact the soil around the cuttings. Different clones should be clearly separated by gaps and identified with labels so that mix-up does not occur when lifting. A plan (Figure 5) should be made of the nursery in case labels are lost.

Fig 6. Nursery Plan. Different varieties should be separated by gaps.

Variety # 1	Variety # 2	Variety # 3	Variety # 4
Variety # 5	Variety # 6	Variety # 7	Variety # 8
Variety # 9	Variety # 10	Variety # 11	Variety # 12
Variety # 13	Variety # 14	Variety # 15	Variety # 16

4.5 Nursery care

Irrigation

The provision of adequate, good quality water is probably the most crucial requirement during the growing season. The development of callus and adventitious roots are particularly sensitive to water stress. Soil should be maintained close to field capacity, but adequate soil aeration is also important.

Regular irrigations are needed during the early part of the growing season, especially if the weather is hot and dry.

Drip irrigation can be used, if available, but frequent applications are necessary for success. Furrow irrigation may be used provided that the length of furrows should not exceed 70m and slope should be about 0.4-0.5%; with clay loam soils, length of furrow should not exceed 130m and slope should be about 0.25%.

Weed control

In a vine nursery, weed control is essential as weeds compete for water, nutrients and sunlight and impede the lifting operation. If available, pre-emergence herbicides Devinol and Surflan can be used safely in vine nurseries provided that the soil is well prepared and a light irrigation is applied following herbicide application. In smaller nurseries weeds can be controlled by hand hoeing or by use of garden rotary hoe.

Nutrition

Grapevine nurseries may require little fertilizers if the soil is reasonably fertile. On less fertile soils, small quantity of urea or ammonium nitrate can be applied during the growing season, but applications should be stopped at the end of summer to allow shoots to harden.

Pest and diseases

Nurseries are subject to the same pests and diseases as are vineyards. In fact downy mildew and oidium infections are favored by the crowded conditions of the nursery. A protective copper-sulfur based spray should be applied soon after budburst and regularly thereafter, depending on weather conditions, to control downy mildew, oidium and bud mite. Control of vegetative growth by hedging up to three times per season can assist with disease control. Grape beetle and cutworm can cause problems in heavy soils in late spring by attacking the stems at or just below the soil level and ring-barking the vines. Carbaryl can be used to control these pests. Light brown apple moth and vine moth can be damaging and control by use of *Bacillus thuringiensis* (Dipel) or other suitable insecticides may be necessary.

4.6 Lifting, grading, storage of rootings

Lifting

Rootings are usually lifted (dugout) in the late winter. Roots should be cut prior to lifting, either shovels or a U-shaped digger fitted to a tractor can be used to cut the roots and lift the vines. The top may be pruned back, lightly, before lifting. To

avoid mixing clones in the nursery, each clone should be bundled and labeled before starting the next clone.

Grading

Ideally, rootlings should have several major roots spreading in different directions and several shoots, 4 to 5 cm thick and 20 cm long. Poor quality rootlings should be rejected

Bundling and labeling

Rootlings should be conveniently bundled in lots of 50; if bundles are made too large, rootlings in the center may dry out during storage. Each bundle should be tied with twine and labeled.

Roots and canes may be trimmed to aid bundling, but root pruning should not be excessive since it may reduce initial growth of rootlings in the vineyard. Canes can be pruned back to one or two well placed 2-node spurs so the rootlings are ready for planting.

Storage

It is best to plant rootlings in the vineyard immediately after lifting if possible. Rootlings may be kept for one or two days stacked in shade under a tarpaulin and roots sprinkled with water as necessary. To store for longer periods bundles can be heeled-in in a pit of moist sharp sand or in a sandy soil location; the sand is washed thoroughly between the roots and kept moist until the rootlings are removed for planting.

Treatment for nematodes

Freedom from nematodes is an important requirement of planting material. If pre-planting precautions have not been successful and rootlings have become infested, it is possible to disinfest them by treatment with hot water or nematicides. Submerging dormant rootlings in hot water at a temperature of 48 °C for 30 minutes, 52 °C for 5 minutes or 54 °C for 2 minutes destroys root-knot nematodes. Minimal reaction to hot water treatment was reported for several species of dagger nematodes. Cutting suspected of the presence of dragger nematodes are preferably treated with a nematicides in addition to hot water to be on the safe side. A nematicides dip (fenamiphos at 1000mg/L held at 24 °C for 30 minutes) is more effective than hot water treatment

5. VINEYARD ESTABLISHMENT

Planning the establishment of the vineyard is one of the most important aspects to getting started. Many of the foreseeable problems can be avoided with careful anticipation and attention to detail. The following is a list of strategies to consider when planning the establishment of a vineyard.

- 1) Choose a site. (See chapter entitled SOIL CONSIDERATIONS.)
- 2) Grade the site as best possible. Try to minimize any slopes or depressions to best handle irrigation and minimize compaction.
- 3) Mark out the spacing utilizing string and any available markers to better assess uniform planting.
- 4) Plant the vineyard.
- 5) Train the vines.
- 6) Producing the crop.

5.1 Vineyard design/layout

Ultimately, vineyard design must focus on the expected vine size as determined by the combination of site capacity, vine vigor, vineyard inputs and management practices.

Aspects of Site Selection

- Climatic factors: temperature, humidity, wind speed and solar radiation
- Soil conditions-topography, cost of cleaning, texture and composition
- Water supply and quality
- Prevailing pests and diseases
- Proximity to labor
- Proximity to market
- Community aspects

Row direction

Since light inception is one of the most important aspects of quality grape production it is necessary to know the piece of land you are working. Initially, you must determine the directions, which the sun raises and sets. This will help to maximize the amount of light energy captured. The vineyard should be planted in an east to west direction in warmer sites. A north-south direction facilitates direct sunlight to both sides of the canopy and should be planted in cooler areas.

Spacing (Table 1)

Vine spacing should be matched to site and vine capacity. Capacity is a function of soil type, depth, and fertility. This is the ability of a vineyard site to support

vine growth and fruit production. In low capacity sites, vines should be planted closer together and vice versa if the site is high capacity.

Between Rows: 12ft. (3.66m) spacing is standard. Low vigor varieties plant at 10 – 11 ft. (3-3.35 m.)

In Rows: Spacing can vary between 6-8 ft (1.8-2.4 m.) depending on the vigor of the cultivar planted.

Vine Spacing within row	Vines per acre		
	10 feet between rows	11 feet between rows	12 feet between rows
6 feet	726	660	605
7 feet	622	566	519
8 feet	544	495	454

Table 1. Vine spacing for in and between rows. Number of vines necessary.

Field Layout

The rows should have an adequate space at the end to allow for the movement of vehicles (approx. 12 ft or 3.66 m.). Rows longer than about 400 feet should be divided midway to allow picking access to the entire block.

5.2 Planting considerations

Initially, lines should be laid out to provide adequate direction when planting the vineyard. Along these lines dig a hole 18 to 20 inches (46-51 cm) deep. Place a vine in the hole, close to the stake or planting mark, spread the roots, and fill the hole two-thirds full with soil that is free from any chemical residues. Then raise the vine to the proper height. **Benchgrafts**, the graft union should be 3 to 4 inches (8 – 10 cm) above the soil line to prevent scion rooting. Rootings should be lifted so that 6 in. (15 cm) are above ground. Tamp the soil around the roots and then fill the hole. Be certain there are no air pockets around the roots. Planting holes should never be made with a pointed steel bar because the compacted sides of the hole will restrict root growth. **Attempt to keep planting stock moist.** If planted during April and May, mound soil around dormant rooting or benchgrafts to help protect against drying out. Pull soil back as the weather begins to heat up.

Green growing plants are best planted in April to early May when soil temperature reach 15.5°C. If plants come in small pots, leave them on at planting. Do not unnecessarily disturb the root systems by removing the container, as long as the roots have ability to grow through it. Plant the vines so that the top of the paper carton or planting media is a bout 1 in (2.5 cm.) below soil level. This helps irrigation water reach the planting media and roots.

Irrigation of a newly planted vineyard

Adequate irrigation is required to settle the soil around the newly planted vines and remove air pockets. After settling there should be no irrigation for 3 to 4 weeks, depending upon weather and soil texture. Over-watering after planting reduces root development by lowering the soil temperature and oxygen level.

Begin with furrows 6-8 in. (16-20 cm) away from each side of the vines. Then move them out to 12 in. (30cm) or more later in the summer after the vines are well established.

Fertilization of a newly planted vineyard

Some nitrogen fertilization may be needed during the first growing season, depending upon soil texture and previous cropping history.

5.3 Training and pruning grapes

The reasons to train grapes are simple:

1. Allow light penetration to fruiting sites.
2. To help induce fruiting as quickly as possible.

The reasons to prune vines are simple:

1. Invigorate new growth and fruiting sites.
2. Remove dead and diseased wood.
3. Increase light inception in canopy to increase yield.

There are two main principles of timing effect on pruning. Dormant training and pruning is the most invigorating. Summer training and pruning has the greatest dwarfing effect because it removes portions of the vine, which the vine has expended energy to produce.

Pruning and **training** of vineyards is done with two types of cuts. There are heading cuts, which stimulate lateral bud growth from directly below the cut. Second, there are thinning cuts, which stimulate re-growth throughout canopy.

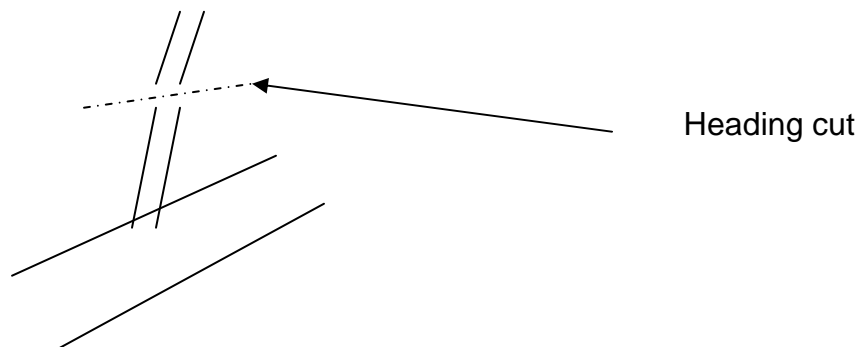
5.4 Types of pruning cuts

While there are two types of pruning cuts, heading and thinning, mainly heading cuts are used. Heading cuts are used to promote branching directly below the cut. Thinning cuts help to invigorate growth throughout the canopy.

When determining the type and severity of pruning cuts, one should consider: inherent vigor of the vine, anticipated regrowth response, fruiting sites needed for optimal yield, the location of the fruiting wood and the training system being used.

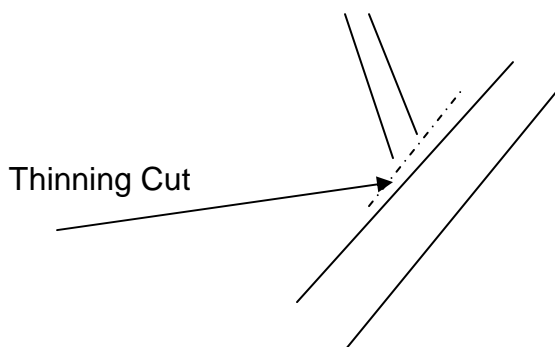
Heading Cuts (performed during training and pruning)

To perform a heading cut, cut branch somewhere along its length. Heading cuts are used to stimulate growth at a particular location.



Thinning Cuts (usually performed during training)

To perform a thinning cut, cut branch at its origin. Thinning cuts are used to remove unwanted limbs, either due to position, canopy thickness, disease, or death or to stimulate growth throughout the canopy.



There are many ways of training grapes. Each way is dependent upon the availability of support systems. If possible some type of support should be utilized to help facilitate light and air penetration. The methods covered are head training and cordon training.

5.5 Head training – establishment of vine (Figure 7, 8, 9)

Fig 7. Winter of first year.
Prune to two buds.

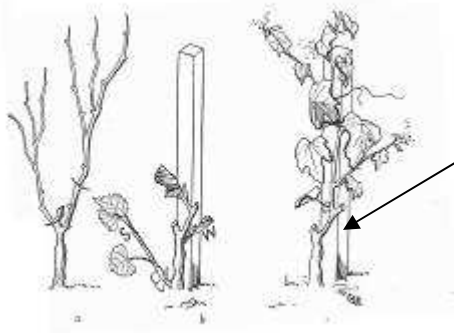
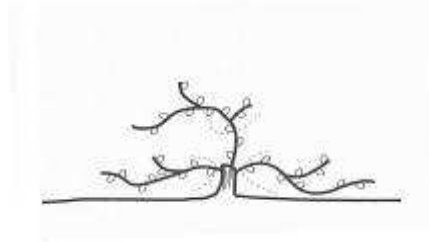


Fig 8. Second Season Pruning: Remove suckers and top (heading cut). Tie to support (if possible)

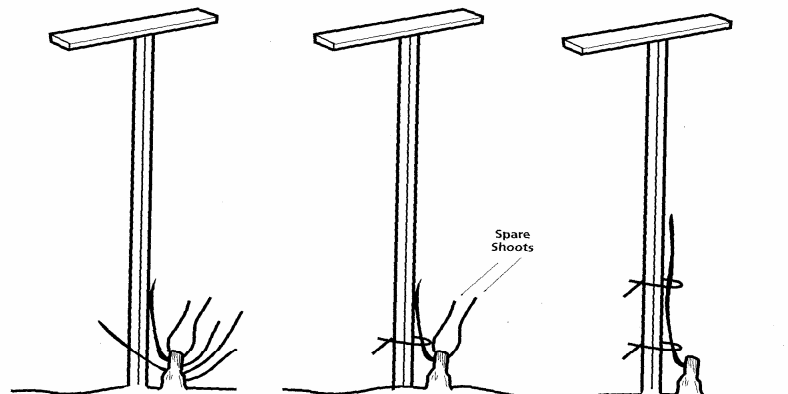
Fig 9. Prune to 1 cane. Remove suckers and lower shoots.



Cordon Training

This method is used when adequate “T” trellises are available. Cordon training provides increased light inception and increases yield. Do not use wire, which can be corroded by the weather.

Fig 10. Spring of second year. Select 1 main shoot (based on



vigor and proximity to staking apparatus)

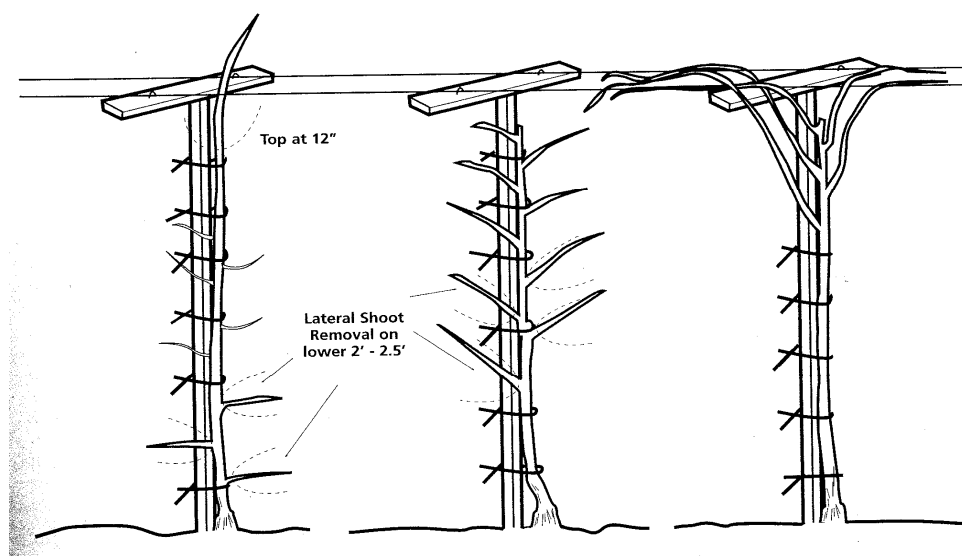


Fig 11. Let shoot grow 30 – 46cm beyond desired head height. Early summer remove lower lateral shoot and top the main shoot. Midsummer remove mid lateral shoots. Late summer secure upper laterals by wrapping around trellis wire. Use non-corrosive wire

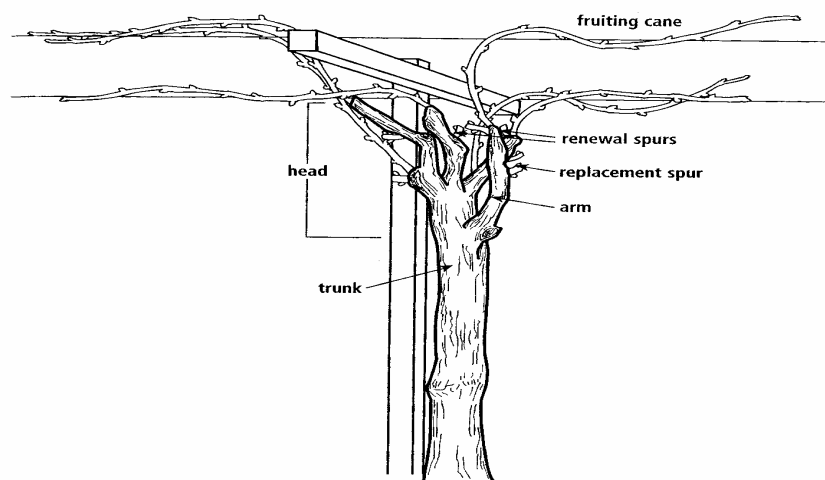


Fig 12. The ideal cordon trained vine.

5.6 Pruning

Grapes are one of the most technically demanding crops when it comes to pruning. They are pruned for three main reasons: to keep the vine in a shape that conforms to the trellis system and facilitates vineyard operations, to remove old wood and retain fruiting canes or spurs for the current season crop, plus spurs for future fruit wood placement and to select a quantity and quality of fruiting wood that is in balance with vine growth and capacity.

One must consider the vine characteristics when determining a pruning method including: inherent vigor, last year's production, desired characteristics (yield or quality), and availability of trellises.

There are two pruning techniques and two training techniques. By conjunction there are essential four types of general methodology of grape training and pruning. The two training techniques are referred to as head and cordon. The pruning techniques are spur and cane.

The general rule for grapes is to achieve balanced pruning. Thus, the numbers of fruiting buds left on the vine are proportional to bearing capacity and vine characteristics.

Head Pruning for rejuvenation Figure 12

With this method the vine will be cut back to 2 –3 spurs to facilitate the following years growth. In many cold climates, it might be advantageous to retain a few extra spurs in case of frost injury and dieback. This will allow the damaged buds to be removed the following spring. Attempt to support permanent part of vine with trellis: either berms, concrete or wood. This should only be used where vines have fruitful basal buds.

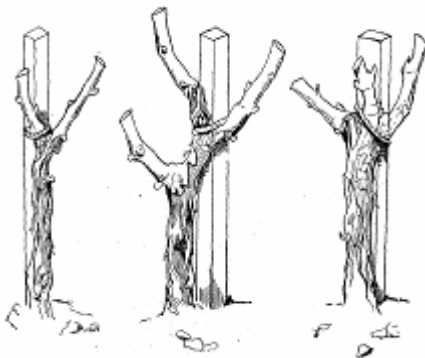


Fig 13. Cut spurs back to 2-3 spurs per vine.

6. SOIL MANAGEMENT & FERTILITY

6.1 Soil properties

Grapevines are grown in a wide variety of soils, with each of them holding a distinctive combination of properties that influence vine growth and produce quality. For appropriate vineyard soil management, the following soil properties will need to be considered:

- texture
- porosity
- pH
- structure
- drainage
- nutrients
- depth
- organic matter
- organisms

The texture of each soil is defined by the relative amounts of the three sizes of inorganic particles (sand, silt and clay) and is named using the soil texture triangle (Figure 13):

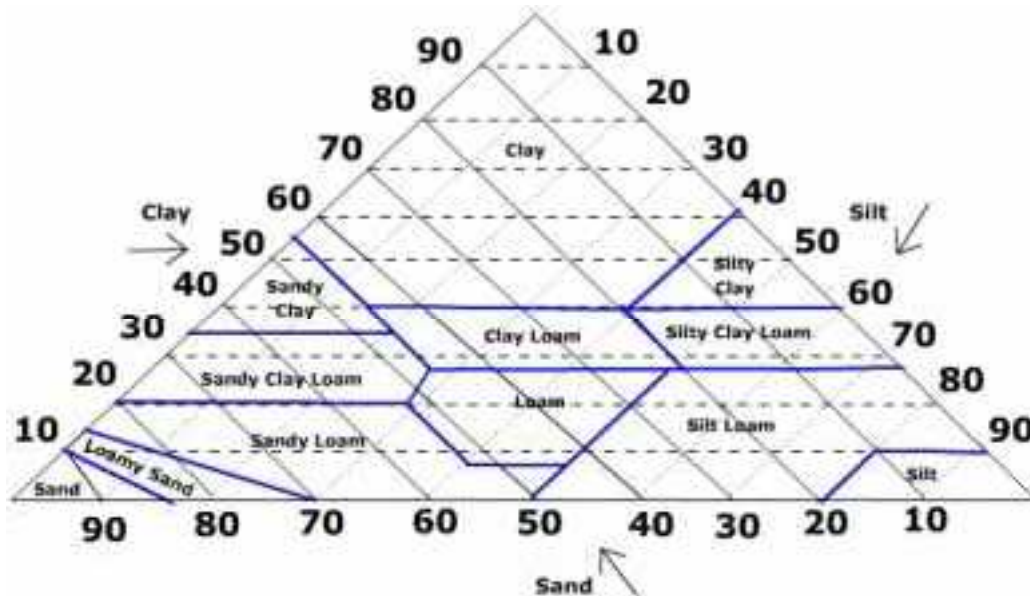


Fig 14. Soil Texture Triangle. Clay particles are the smallest in size, while sand ones are the largest. In the field, soil texture can be determined by rubbing a moist soil sample between the thumb and fingers. Formation of a continuous ribbon indicates high clay content. Grittiness indicates sand. A smooth feel, with little stickiness or grittiness indicates silt.

Deep, sandy soils are ideally suited to raisin production. Deep soils will sustain a large, healthy vine capable of producing both high tonnage and high sugar. Although many consider sandy loams and fine sandy loams to be the best for raisin grape growing, raisins are successfully grown on other soils as well.

Considering the range of soil textures that could be used for grape and raisin production, varying advantages and disadvantages should be considered:

Sands and loamy sands

ADVANTAGE
excellent infiltration and
percolation rates

DISADVANTAGES
low water holding capacity
low fertility
nematode problems

Clay and clay loams

ADVANTAGE
excellent water holding capacity
problems

DISADVANTAGES
infiltration and percolation

Soil surveys for the prospective site will either need to be found or carried out. Soil survey information should be augmented with your own physical examination of the site. Arrange to have enough deep pits dug to cover the range of soil types present. Examine the pits for textural layers such as sand or silt, and for the presence of clay, silt and hardpans. Make detailed notes about the depth and thickness of these layers. This will enable you to make intelligent decisions about the suitability of the site and what soil modification measures you will need to take. Different textural layers, for example, should be mixed prior to planting.

Grapes are sensitive to soil salinity, high pH, sodium, chloride and boron. In some cases these chemical problems can be corrected with soil amendments and large quantities of high-quality water, provided there is sufficient internal drainage. Soil amendments can change the soil pH and displace sodium if accompanied by good-quality water. Salts and boron can only be removed by leaching with high-quality water, and only if there is adequate drainage.

Water tables also need to be considered, especially if they are within 5.5 meters of the surface. A high water table can result in excess salts in the root zone. Another potential problem from a high water table is the continuing availability of soil moisture that may cause vines to keep growing into the fall and may delay fruit maturity.

Case 1 – Deep, Well-Drained, Coarse-Textured Soils

These have low water holding capacity (LWHC), requiring more frequent furrow irrigations at about 2-week intervals during the summer months. Irrigation cutoff before harvest should be no more than 2 to 3 weeks due to LWHC.

Nematodes prefer coarse-textured soils, and nematode-resistant rootstock may be needed. Because of low fertility and high leaching potential, nitrogen should be applied in small amounts two or more times a year. Regular potassium and zinc fertilization may be needed.

Case 2 – Moderately Deep to Deep, Medium- to Well-Drained, Medium-Textured Soils

These have medium water holding capacity (WHC), requiring furrow irrigation intervals of 2 to 4 weeks (typically 2.5 to 3 weeks) during the summer months. Preharvest irrigation cutoff is typically 2.5 to 4 weeks before projected harvest. Medium to low water infiltration rates require 0.2 to 0.4 km irrigation runs with minimal slope; from no slope to 0.10 percent maximum.

These soils can have high fertility, and require minimal inputs of fertilizer, including nitrogen. Sand streaks, land leveling cuts, and spots with high pH problems may require supplemental potassium and zinc applications.

Sandy loam soils can have nematode problems. *Phylloxera* can be a problem in loams and fine sandy loams. Resistant rootstocks will be needed if *Phylloxera* is present.

These soils are often improved by slip plowing prior to planting.

Case 3 – Shallow or Fine-Textured Soils

Shallow soils require careful, light irrigations at short intervals. Good surface drainage is required to prevent waterlogging in winter. Shallow soils will have a preharvest irrigation cut-off date of only 1 to 2 weeks. Deep, fine-textured soils will have a cutoff date of 3 to 4 weeks.

Fine-textured soils are difficult to terrace prior to harvest; they are ideal for *Phylloxera*, *Phytophthora* root rot, and citrus and dagger nematodes.

These soils are improved by deep ripping or slip plowing prior to planting.

6.2 Soil preparation

Furrow- or flood-irrigated vineyards must be properly leveled to ensure cost-effective water use. A site's graded slope should be based on its soil texture, the length of the irrigation run, and the head of water available. Lower slopes are desired in fine sandy loam to sandy loam soils (1 to 2.5 mm per 10 m) than in loamy sand and sandy soils (5 to 8 mm per 10 m).



Surface irrigation efficiency may be low enough in the coarser-textured soils to easily justify drip irrigation as an alternative.

The presence of stratification (distinct changes in texture in layers of soil profile) or hardpan (cementation in the soil profile) requires soil modification beyond simple chiseling in preplant preparations. The two most common modification methods are:

1. Deep ripping → fractures hardpan
particularly important when hardpan is within upper 4 feet of the profile
2. Slip plowing → mixes stratified soils

If soil surveys indicate the absence of stratification (distinct changes in texture in layers of soil profile) or hardpan (cementation in the soil profile), chiseling to a depth of 45 to 60 cm is sufficient preplant preparation. Chiseling only breaks up the compacted zones that have been created near the surface by past tillage practices. Chiseling after leveling breaks up surface compaction, and prevents both ponding of water during winter rains and slow infiltration after planting.

For these practices, the following guidelines should be taken into consideration:

- the soil should be as dry as possible, thus providing maximum fracturing in case of ripping and minimizing surface compaction from heavy equipment
- penetration into the soil should be 30 cm deeper than the depth of the targeted area
- the distance between passes should be equal to or less than the desired modification depth
- better modification is achieved by making more passes in one direction than by changing to right-angle or diagonal passes
- it is best to make sure one pass goes directly down planned vine rows by marking them prior to modification

After modification or chiseling, the vineyard site will need to be disked and irrigated before the final grade is established. Irrigation settles the disrupted soil and ensures that the desired slope is indeed achieved.

6.3 Fertility

The availability of nutrients in the soil is decisive for grape production levels and quality. However, ensuring an appropriate level of soil organic matter is certainly an initial consideration when it comes to the fertility of vineyard soils. Not only does organic matter improve the soil structure critically, but it also supplies significant quantities of needed nutrients, especially nitrogen.

This requires regular additions of organic matter to the soil, including on-site organic matter, such as prunings, leaves and cover crops, and also imported organic matter, such as straw, wood chips and composts.

Nitrogen

Common application rates for nitrogen in vineyards are 6-12 kg N/ha per year to maintain vigor and 12-35 kg N/ha per year to slightly increase vigor. When cover crops are being used, nitrogen is needed to support these as well as supply grapevines.

Farm manure, grape pomace and compost can be good sources of N. There is special value in utilizing these organic sources because of the gradual and extended availability of their N. This characteristic makes the N sources of greatest value in the more readily leached sandy soils. Apply larger amounts during the first year of use, since the N will be slow to mineralize and thus slow to become available to the vines. These rates can be diminished over years of continued use as a result of the gradual mineralization of residual organic N from previous years' application.

Cover crops can be good N sources and will extend N availability. A winter legume such as vetch or bur clover can contain from 22 to 140 kg N/ha, depending on the planted area and its level of growth and maturity. Research has shown that the N released from a disked-in, good stand of vetch cover crop can supply the equivalent N value of a 56 kg N/ha commercial N application. This would be sufficient for most vineyards except those of low vigor or those on very sandy soils.

Organic sources of N should be applied and/or during winter and spring, to allow for timely decomposition and release of nutrients.

7. Irrigation Rates & Scheduling

Adequate quantities of water are essential for rapid vineyard development and crop production. Water deficits early in the growing season reduce vegetative (shoot growth and can reduce crop yields. Slowed vegetative growth is detrimental to young vines, which need maximum growth to hasten the development of the vineyard canopy. Severe water deficits during the summer and after harvest may disrupt bud development and cause premature leaf drop. Too much water, not only can cause poor internode spacing and lack of winter hardiness, but can also damage roots by depriving them of oxygen and creating conditions that favor the development of soil-borne diseases.

Growers must determine the amount of irrigation water to apply, when to apply it, and the most efficient application method for a given set of conditions. It is important to understand that irrigations should be applied to meet the variable crop requirements over the season, should be distributed evenly to maximize irrigation efficiency and nutrient uptake, and should minimize the effects of soil conditions that could encourage disease.

7.1 Surface irrigation

Surface or gravity systems operate at almost zero pressure and include many systems, only furrow systems are discussed here. The chief advantages of gravity systems are their low capital input and low pumping cost. The chief disadvantages are large inputs of skilled labor are needed, and irrigation efficiency can be low. Adjustments, such as, pipelines can replace earthen ditches or concrete channels fitted with side outlets, as valves on risers allow easy control of the flow rate. Furrow irrigation is the most commonly used system of irrigation in most grapevine growing areas.

Efficient furrow irrigation requires medium to fine textured soils. Very fine textured soils with low infiltration rates need unrealistically low flow rates, while coarse textured soils need high flow rates, which cause erosion. Deep soils are preferred, because the interval between irrigations can be long. The water should reach the end of the field in about one half of the total irrigation time, and you can manipulate that time by controlling the outflow volume, slope, number and shape of furrows and field length.

7.2 Drip irrigation

Drip irrigation was developed to irrigate crops under unfavorable conditions such as harsh climate, poor soil and limited or marginal quality water supplies. Waste of water is minimized because of the low levels of flow. The advantages of drip irrigation over other systems are low labor requirement, efficient use of water, reduced weed growth, and high performance with saline water. Disadvantages

are high capital cost, attention to maintenance, such as, checking for blockages, damage to drippers and filters and pump performance.

The amount of water that can be applied in a single application depends upon the ability of the soil to absorb water. For minimum disease problems and maximum vineyard life, surface irrigation water should be absorbed by the soil within a maximum of 24 to 48 hours. If infiltration does not occur in this time frame, split applications should be used to facilitate percolation into the root zone. Many growers allow the root zone moisture to deplete to near 50 percent of the available soil moisture, and then irrigate with enough water to refill most or of the root zone.

With all strategies, the total water requirement is met through stored winter rainfall, irrigation, and in-season rainfall. The most effective way to use these water resources is to construct a water budget that includes estimates of crop consumptive water use.

7.3 Irrigation scheduling

The best way to discuss the principles of scheduling furrow irrigations is in terms of a water budget. The water budget balances vineyard water use with the size of the soil water reservoir. The grower should irrigate the vineyard when 30 to 50 percent of the soil water reservoir has been depleted by vine ET (evapotranspiration), and the irrigation should be sufficient to refill the reservoir. You can determine the soil water reservoir based on the soil's available water-holding capacity (which varies with soil texture), the depth of the root system, and allowable depletion.

Table 2: Approximate water use for a raisin vineyard during four seasonal irrigation stages

Irrigation stage	Phenological events	Approximate dates	Approximate irrigation stage	Days in canopy	Vineyard water use during irrigation stage (inches/acre)
					Large canopy
Stage one	Budbreak to bloom	April 1 to May 10	40	2.0	2.5
Stage two	Bloom to veraison	May 10 to July 1	51	5.6	7.5
Stage three	Veraison to harvest	July 1 to September 1	62	8.0	10.7

Stage four	Harvest to leaf fall	September 1 to November 1	61	3.8	5.1
Total vineyard water use of season				19.4	25.8

The water use of vines with similar canopy types is the same regardless of soil type. It is more difficult to furrow irrigate vineyards efficiently on sandy soil than on finer-textured soil: more water is lost below the root zone. This difference is irrigation efficiency. Typical irrigation efficiency, allowable depletion, amount of water applied at each irrigation, number of irrigations per season, and total water applied for different soil texture classes are given in the following table.

Table 3: Comparison of irrigation amounts for varying soil.

water Textural for Class year (in)	Irrigation efficiency (%)	Allowable	Irrigation	Irrigation	Number of	Total
		depletion (inches)	amount (inches)	amount (gallons/acre)	irrigations per year	applied
Sandy	40	1.4	3.5	94,500	14	49
Loam	70	2.6	3.7	99,900	7	26
Clay	80	4.4	5.5	148,500	4	

Scheduling Drip Irrigations

More frequent irrigations are necessary because there is less soil water storage. Drip irrigations should be frequent (every 1 – 4 days in the summer) and the amount of water should be sufficient to satisfy the vine's water use until the next irrigation. Drip irrigations should be cut back to 50 to 75 percent of schedule amounts beginning in late July or early August to slow shoot growth in vigorous vineyards.

7.4 Irrigation cutoff

Raisins

Irrigations must be cut off long enough before harvest to allow the soil surface to be sufficiently dry for preparation of a dry terrace by harvest. In sandy soils, cutoff should occur 2 to 4 weeks before harvest and for clayey soils it should occur 4 to 6 weeks. If irrigation is cutoff too early, the stress may impede sugar development, thus affecting quality. If extensive water stress occurs over many years at this time, it weakens the vineyard and will reduce production in the future. If in past years, vines have continued to grow vigorously at harvest, an

earlier cutoff date is recommended because extensive growth may cause delayed fruit maturity.

Postharvest Irrigation

A postharvest irrigation is recommended to reduce water stress and leech salts. The timing of this irrigation is based upon soil type. Finer textured soils have a greater water holding capacity, thus irrigation can be delayed. Sandy soils might need to be irrigated as soon as the crop is out of the fields.

7.5 Signs of water stress

Symptoms of water stress include: a decrease in the angle formed by the axis of the leaf petiole and the plane of the leaf blade, slowed shoot growth, and internode growth is inhibited. If pronounced stress, tendrils and shoot tips die. Lastly, leaves will fall.

8. MAJOR DISEASES

Grapes are susceptible to a number of diseases, four biological agents cause plant diseases: fungi, viruses, bacteria and nematodes fungal parasites cause the largest number of grape diseases. Viruses, such as fanleaf, are the most destructive and difficult to control. Care must be taken to plant virus free stock. Bacterial diseases are relatively unimportant in viticulture. Nematodes and insects are of critical importance as vectors transmitting diseases.

8.1 Fungal diseases

Although there are a numerous fungal diseases infecting the vine and its fruits, four fungi represent the most economically important fungal. These are the fungi that cause powdery mildew (*Oidium*); anthracnose, black rot and downy mildew (*Peronospora*)

8.1.1 Powdery mildew (*Oidium*)

Unlike most other fungal diseases of the grape, most of which are favored by moist conditions, powdery mildew flourishes in dry climates. It is probably present wherever grapes are grown. It is caused by the fungus *Umicinula necator* Burr. and attacks all succulent green parts of the vine.

Disease Cycle (plate 1)

Powdery mildew cannot grow on dead or dormant grape tissues. It survives the winter as a dormant mycelium under infected buds or dormant cleistothecia, which are washed off leaves and shoots onto the bark of upper trunks and cordons during fall rains. Ascospores are functional as primary inoculums in some grape production areas.

Germination

In the spring, ascospores are released during rains and sprinkler irrigation and water splashed and windblown to newly emerging shoots and leaves. The individual colonies appearing on lower surface of basal leaves are the first symptoms. Mildew colonies develop within 6-7 days following spring rainfall. Scarring located close to buds indicates that the bud may contain overwintering mycelium. Mycelium in infected buds grows over the emerging shoots, producing many spores. When temperatures are above 33 °C, fungal growth and infection are delayed. Spores germinate at leaf surface temperature between 6-33 °C (43-90°F), the optimum being 25 °C. Rapid germination and mycelial growth take place at 21-30 °C. At optimum temperatures, the germination time (time between spore germination and production of spores by new colony) is only 5days. Temperatures above 30°C kill spores and mildew colonies. Temperature plays a

larger role in disease development by conidia than does moisture. The disease normally develops over the full range of relative humidity, however, free water, such as rain, dew, or irrigation water can cause poor and abnormal germination of spores and may wash spores and mycelium from the host tissue (see diagram)

Symptoms (Plates 2-6)

The development of powdery mildew first becomes apparent as whitish patches of cobweb-like growth on the surfaces of the green parts of the vine. Soon the patches take on a grayish, powdery appearance, caused by the formation of numerous spores. Affected areas later darken to reddish brown or black, owing to injury of the vine tissues. These areas are particularly conspicuous on the fruit and dormant canes. Severely affected young leaves become distorted and discolored, sometimes giving the vine a wilted appearance. A badly affected vine emits a mildew odor.

Flowers may be attacked, resulting in failure to set fruits. Berries that are attacked when very small drop off. Large berries that are attacked develop irregularly into abnormal shapes; sometimes they crack or become badly scarred. Powdery mildew on the stems of clusters makes them weak and brittle.

Control

Control is divided into prevention and eradication. The most effective control practice is prevention. Sulfur dust gives excellent protection if properly applied throughout the season. The degree of protection will depend upon the timing and thoroughness of application. The sulfur particles prevent development of the fungus mainly by destroying the germinating spores. For sulfur to be effective, it must be present before the fungus develops. Begin dusting 7 to 14 days after bud break and repeat every 14 days. If growth is rapid, start applications when shoots are 7.5 cm long and repeat when shoots are 15 cm long and then continue every 10 days until fruit begins to ripen. Bayleton, a locally systemic fungicides proved to be extremely effective in controlling powdery mildew in years of less severe mildew occurrence. Bayleton is applied, before the on set of the disease, that is, as a protectant rather than as an eradicant. Spray intervals of 10 and 17 days are recommended for Bayleton.

Once the powdery mildew fungus becomes established on the vine and start producing spores, it is no longer susceptible to sulfur dust. An eradication spray is then necessary to eradicate the fungus. The eradicant spray solution consists of 1 to 2 pounds of wet table sulfur to 100 gallons of water and enough of a good wetting agent to ensure that leaves and berries are thoroughly covered by the spray. Average vines generally require from 200 -300 gallons of spray per acre early in the season and from 300-400-gallons in middle or late season. The wetting agent and water eradicate the fungus, and the sulfur forms a protective

coating over the foliage until the next dusting time. In cool areas up to 3 pounds per gallon may be used. All vinifera varieties are susceptible, in slight varying degrees to powdery mildew.

8.1.2 Downy mildew (Peronospora)

The fungus *Plasmopara viticola* that causes downy mildew is believed to be present in most grape-growing regions of the world. Its seriousness in any region or season depends on the humidity and frequency and duration of summer rains.

Symptoms

The first evidence of infection is the appearance of light yellow translucent spots on the upper leaf surface. Soon patches of white mildew form on the underside of the leaf. These patches are caused by spore producing organs of the fungus growing out through the stomata. The tissues of the affected portions are killed, later turning brown. Badly affected leaves finally become dry and drop from the vine. In wet seasons varieties that are poorly cared for may be completely defoliated by late summer or early fall. Defoliated vines cannot ripen their fruit or mature their canes. Flowers and young fruits may be attacked and killed and fall from clusters. Late infected berries wither, turn brown and finally shrivel into mummies that shatter easily from clusters. All varieties of vitis vinifera are very susceptible to downy mildew.

Control

The fungicide still most widely used for control of downy mildew has been Bordeaux mixture. A number of organic fungicides such as zineb, maneb and captan have been used with success against downy mildew in several countries. They may not be effective, but they appeal to the grower because they are less toxic than Bordeaux mixture to leaves, flowers and newly set berries.

8.1.3 Anthracnose

Anthracnose which is present in all grape growing regions having summer rains is caused by the fungus *Gloeosporium ampelophagum* which attacks all parts of the vine.

Symptoms

Cankers are produced on the shoots, tendrils, clusters, stems, leaf veins and berries. At first the lesions are pin point in size, brown or grayish-black, depressed in the center and raised at the border; as the spots become older they enlarge and elongate lengthwise of the vine part. The bark on the shoots is finally destroyed and the underlying wood turns grayish. Isolated leaf spots are pale gray, with reddish-brown or purple borders. On berries the spots are small and

dark brown at first, as they enlarge they remain circular, and becoming grayish in the center, with the border remaining dark. Severely affected berries finally dry into mummies.

Control

For control of anthracnose the vines are sprayed during the dormant season with commercial lime-sulfur solution diluted 1 to 8 parts water. During the growing season, the vines are sprayed five times with Bordeaux mixture or with copperoxychloride when the shoots are 7-8 inches long, just before bloom, immediately after bloom, seven to ten days later and when berries are about half grown.

8.1.4 Black Rot

Black rot is caused by the fungus *Guignardia bidwellii*. It is practically present in all grape growing regions that have frequent summer rains. This fungus grows best in hot moist weather; rains help disseminate the summer spores and droplets of water are necessary for spore germination. It is the most destructive disease in vineyards of the United States east of the Rocky Mountains, where it is virtually prevents success in growing vinifera varieties.

Symptoms

Black rot attacks all green parts of the vine and is particularly destructive to fruit. On the leaves it produces reddish-brown, irregularly-shaped spots with black fruiting bodies of the fungus sometimes forming more or less concentric rings within the spot. On the shoots, tendrils, cluster stems, petioles and large leaf veins it produces small elliptical, dark-colored cankers. The berries are usually attacked between the time they are half grown and the beginning of ripening. The infection spot which first appears as a small blanched area, soon changes to a whitish area having a brownish line around the margin, enlarges rapidly and becomes sunken. The affected berries shrivel and dry and in about a week become hard black mummies that cling to the cluster stem.

Control

An effective control material is ferbam. It is more effective than Bordeaux mixture and does not injure the vine. Three or four sprays are sufficient. Applications should be made when the shoots are 45-60 cm long, just before bloom, immediately after bloom and seven to fourteen days later. The fungus overwinters in mummified fruit, affected canes and tendrils. Control is assisted by burning the prunings and plowing the vineyard in the spring to turn under mummified fruits and other disease carrying material.

8.1.5 Gray Mould (Bunch Rot)

The most important fungal plant pathogen responsible for bunch rot of grape berries is *Botrytis cinerea*. The chemical enzymes produced by the fungus can destroy the integrity of grape berries within a few days.

Disease Cycle (Plate 7)

Overwintering: *Botrytis* survives winter by forming dormant structures called sclerotia, either on the surface or within colonized plant tissue. The sclerotia are hard, black structures about 3 mm in diameter. Because these sclerotia are hard, it is difficult for fungicides to penetrate them, thereby decreasing the effectiveness of dormant sprays.

After rains or irrigation in spring the sclerotia germinate and produce gray spores (conidia), which are spread by wind

Germination: To germinate, *Botrytis* spores require free water and nutrients. The spores require continuous free water for germination and growth. The free water can be from rain, fog, irrigation or dew. Periods as short as 15 minutes with no available water are sufficient to stop germination. However, even with water present, germination also requires nutrients that can come from grape berries

Symptoms (Plates 8-12)

Bunch rot (Gray mould) begins when individually infected berries within the cluster turn brown due to the enzymes produced by the fungus. Often this stage is known as “slipskin” because the enzymes break down the cutin in the epidermis and easily slips off the berry. If moisture is high and wind is low, cracks will form in which the mycelium and spores will produce the characteristic gray mould. The main nutrient required is a simple sugar such as fructose and glucose. When water is on a mature grape berry for 2 hours, enough sugars can accumulate in the water to stimulate spore germination and growth.

The dependency of spores for water and nutrients can be a factor in disease control. Often *Botrytis* bunch rot begins in clusters where the berries have been damaged, thus releasing juice and sugars needed for spore germination.

Warmer temperatures usually hasten drying of the berries and directly reduce germination. At 32 °C and above the fungus does not grow, but it will grow slowly even at 1 °C, which allow it to severely infect stored table grapes.

Control

Several fungicides are registered for controlling *Botrytis* bunch rot; most are contact materials. Only one, benomyl, has systemic properties in grape tissues. The fungicides differ in mode of action. By using combinations of fungicides with different mode of actions, it is often possible to delay development of resistance

of fungus to any specific fungicide. Some of the fungicides used for Botrytis control are captan, iprodione, and vinclozolin (dicarboximide fungicides). Spray programs may consist of sprays at bloom or multiple applications applied at bloom, veraison and at least 2 weeks before harvest.

Biological control of Botrytis bunch rot has been achieved in France with beneficial fungus *Trichoderma viride*. Apparently, the effectiveness of the fungus depends on matching particular strains with growing conditions.

8.2 Bacterial diseases

8.2.1 Crown Gall

Crown gall of grape, caused by *Agrobacterium Tumefaciens*, is a major problem throughout the world.

Crown gall is most severe in moist climates where frosts are common. Freeze damage cause wounds that enable the bacterium to inflict multiple sites on canes often producing a beaded appearance. Under these conditions, the disease can destroy a vineyard. The gall girdles the tissue, preventing flow of nutrients. They also offer sites for invasion by various fungal pathogens and some insects.

Symptoms (Plates 13-16)

Galls, up to 5 cm in diameter are found as outgrowth on roots, crowns and sometimes cane and stems. The galls are composed of relatively soft disorganized tissues. The galls are initially smooth on surface, but with age and increased size, they become rough looking, dark, brittle and cracked. If exposed, crown galls usually dry out.

Control

To avoid crown gall, it is essential to use indexed stock certified free of the bacterium.

8.3 Viral diseases

8.3.1 Fanleaf

Fanleaf disease is carried in the soil. The dagger nematode, *Xiphinema index* transmits the virus to healthy roots during the feeding process. Fanleaf occurs in most countries where vinifera grapes are grown

Disease Cycle

Grapevine fanleaf virus is rarely spread except by infected nursery stock. However, on-site spread can occur when the vector nematode is introduced into

a vineyard either with rooted plants or by the physical movement of nematode infected soil. Where diseased and healthy vines are side by side, spread takes place only when dagger nematode is present. The nematode vector plays an important role in perpetuating the disease at an infection site. When diseased vines are pulled, many of the roots and nearly all of the vector population remain in the soil. The roots die slowly, supporting a residual inoculative vector population for 6-10 years. If new vines are planted in such a site during this period the new vineyard will become infected as soon as roots grow into contact with inoculative vector population

Symptoms (Plates 17-21)

Affected vines are smaller than healthy ones. The canes and foliage appear clustered because of shortening and irregular spacing of internodes on the shoots. Three types of leaf symptoms commonly associated with affected vines:

- 1) Fanleaf deformation: leaves are asymmetric, with an open petiolar sinus. The main veins are drawn close together and teeth along the margin of the blade are elongated, giving the leaves the appearance of a fan and leading to the virus name.
- 2) Yellow mosaic: the leaf blade shows extensive patches of bright yellow diffusing into a yellow-green pattern. Such leaves may be fan-shaped, but they are often without distortion.
- 3) Vine banding: Bright yellow bands may develop only along the major veins starting in early or mid summer. The leaf shape is almost normal

Fanleaf virus greatly reduces fruit set (up to 80%). Such reduction, which varies with cultivar and season, results in severe economic loss.

Control

Control of fanleaf virus is primarily preventive: by selecting and planting certified virus free planting material.

Soil fumigation with nematocide methyl bromide has been used to kill nematode vector.

8.3.2 Leaf Roll

Leaf roll disease occurs wherever grapes are grown. The causal virus is readily transmitted from infected to healthy vines by budding and grafting. Leaf roll is characterized by a rolling downward of the leaf margins, reduced fruit color and marked lower sugar content at the normal time of harvest.

Disease Cycle

Leaf Roll is spread only by nursery stock material, particularly when nursery workers and growers do not pay close attention to selection of wood sources.

Symptoms (Plates 22-24)

On affected vines, the margins of the leaf blades roll down starting with basal leaf on the cane. Area between major veins turn yellow or red depending on whether the variety produces green or red-colored fruit. In either case, the area adjacent to major veins remain green until late fall. A diagnostic system is rolled yellow or red leaves with green vein banding. The entire vine takes on a yellowish or reddish cast at harvest time and into autumn. In few cultivars the red or yellow areas of the blade continue to degenerate so that the blade becomes necrotic as if it were burned.

In Thompson seedless variety, leaf burning without rolling is the principal leaf symptoms. In most cultivars fruit maturity is delayed so that fruit on the affected vine may be greenish or whitish at harvest when fruit on healthy vines ripe. Whether a selected vine is free of grafting buds of healthy indicator plant of Cabernet franc, which is very sensitive to the disease showing strong foliar symptoms within 18 months, can check leaf roll disease. If it remains without symptoms after this time, the indexed vine is a likely candidate of propagation of leaf roll- free nursery stock.

Control

The only effective control of leaf roll is to ensure that healthy propagating material from virus tested stock is used to plant vineyards.

8.3.3 Corky Bark

Corky bark is of worldwide occurrence with much the same distribution as leaf roll, but is less common. It has become widespread and serious in countries where nursery workers and growers do not pay close attention to selection of wood sources. The disease can exist in a latent state in many vinifera cultivars, showing only after infected buds are grafted onto a rootstocks. When this happens, the plant may initially appear normal, but gradually incompatibility will develop at the union. This causes the scion shoot to slowly decline and ultimately die.

Symptoms (Plates 25-27)

Corky bark symptoms resemble those of leaf roll, but their effect is more pronounced. Vigor of affected vines on rootstocks is greatly reduced. After several years the scion cultivars dies, leaving only the rootstock growing in space where the vine would be.

Reduced vigor (small, stunted plants) is often sufficient to suspect corky bark, and can be detected even during dormancy. Shoot growth is delayed in early spring. During summer the foliage becomes bright yellow. As the season

progress, leaves roll downward and turn red or bronze–yellow. Unlike leaf roll, the color spreads uniformly across the entire leaf blade, including along major veins. Fruit maturity is delayed and yield much reduced.

Many rootstock cultivars show no symptoms of infection. Other rootstocks develop deep pits in stem, especially near the graft union. LN-33 rootstock is especially sensitive to corky bark and healthy cuttings of it can be used to test for presence of the disease in vines selected for propagation. LN-33 plants inoculated by chip bud grafts from an infected source develop red leaves, proliferated secondary phloem tissues and deranged cambium and xylem layers; they soon die. Those inoculated plants that do not develop these symptoms within 18 months are presumed to have been inoculated from a source free of corky bark.

9. MAJOR PESTS

Various kinds of insects and mites attack grapes, some are specific to grape and cannot live on any other host; others, like cutworms and grasshopper, feed on many kinds of plants.

9.1 Branch and twig borer

Branch and twig borer, *Melanus confertus*, belongs to the family of wood-boring beetles. It is associated with many species of cultivated and native trees and shrubs.

Description

The adult is a dark brown beetle, cylindrical in shape, with the pronotum wider near the head than at the base. The adult female is 12-16 mm long; the adult male is 7-8 mm long. Adult females lay a single egg in cracks and crevice in rough bark, on cordons or on the trunk. After hatching, a larva bores into wood at an old pruning wound or at an injured area of the vine where it develops over a period of 10 months. The larva is white and covered with fine hair; the head is small and brown. Three pairs of legs are found on the pronotum near the head. The pupa is 10 mm long, white and cylindrical in shape.

Damage (Plates 28, 29)

Adult and larval stages of branch and twig borer can cause injury to grapevines. Adults burrow into the canes at the bud axil or into the crotch formed by shoot and spur. During bud swell, adults feed on buds and bore into canes directly through the bud. Feeding is often deep enough to completely conceal the adult in the hole. When shoots reach a length of 20-25 cm, a strong wind can cause infected canes to twist and break at the feeding site, resulting in significant loss of vine growth and yield. Damage by adults is more serious in cane-pruned vineyards where early-season loss of a portion of one cane may result in significant loss to an individual vine; generally 4 to 6 canes (12 to 16) are retained after pruning. Vigorous vines and cultivars may compensate for injury more readily than less vigorous ones.

Control

Cultural Control: To manage branch and twig borers in vineyards, prevent their invasion and establishment with cultural methods. Completely remove wood brush piles of any trees or shrubs from the vineyard or burn them before emergence of adult beetles. Remove and destroy dead or dying portions of vine by pruning that should not remain in the vineyard.

Chemical control: Chemical control is normally not necessary if good cultural controls are practiced. If a damaging population of borers is present in vineyard, chemical treatment may be needed. Carbaryl offers some control of adult branch and twig borers in spring.

9.2 Cutworms

Cutworms, one of the most injurious pests of crops worldwide injure grapes in early spring when their feeding destroys the developing buds. The most common species attacking grapes are the variegated cutworms (*Perideroma saucia*); the spotted cutworm (*Amathes c-nigrum*) and the brassy cutworm (*Orthodes rufula*)

Description

Cutworms are dull-colored caterpillars ranging in length from 25-50 cm when fully grown. Positive identification is important in controlling cutworms because of behavioral differences in activity. Some species climb on the vine to feed, returning to the soil during the day. Others remain on vines under the bark, or in crevices during the day.

Variegated Cutworm: The adult is grayish brown moth 25 mm long, with dark or dusty mottling on the fore wings and clear hind wings. It is found during the day in a folded, resting position under foliage or shaded parts of the plants. Mature larvae are about 40-50 mm long with smooth skin. Body color varies from pale gray to a dark mottled brown intermixed with red and yellow dots. The head is light brown.

Spotted Cutworm: The adult is 18 mm long and is reddish or brassy to tan color with a kidney- bean shaped brown spot near the middle of each fore wing. The Larvae are also reddish or brassy in appearance and 25- 30 mm long, with light, dust gray hind wings. Mature larvae are about 35 mm long and are generally a dull gray-brown.

Damage (Plates 30-32)

Cutworms have a broad host range including grapes. Damage to grapevines occurs from bud swell to when shoots are several inches long. Injured buds may fail to develop canes or clusters, which can cause significant yield reduction in some varieties.

Control

Natural enemies are very important. They include predaceous or parasitic insects, mammals, parasitic nematodes, birds, hymenopterous parasites and reptiles. Predaceous beetles (often found under bark) and tachinid flies are also important in biological control. When the natural controls fail, an effective control

can be obtained by applying a banded treatment around the vine trunk using a carbaryl-apple, pomace bait.

9.3 Grape Leafhopper

The grape leafhopper, *Erythroneura elegantula* is the most widely distributed of the grape insects.

Description

The adult leafhopper is about 3mm long. The hopper is purple yellow, with reddish and brown markings. Grape leafhopper eggs are laid singly in epidermal tissues of both upper and lower leaf surfaces, although the lower surface is preferred. Eggs can hardly be seen with the naked eye

Damage (Plates 33 - 37)

Both adults and larvae feed on leaves inserting the mouthparts into the leaves and sucking out liquid contents. Leafhopper damage first appear as a scattering of small white spots; with continued feeding, the spots become more and more numerous until a pale yellow or whitish-yellow blotching result from removal of the chlorophyll. The leaves may dry up and fall prematurely. The extent of the damage is in direct proportion to the number present.

Unless the over-wintering adults are exceedingly abundant, the injury they produce is unimportant, but offspring may cause defoliation. The defoliation, which increases as the season advances, frequently exposes the developing grapes to sun burn injury, causing heavy losses. Defoliation also retard sugar accumulation in the grapes, thereby delaying ripening and lowering the quality.

If numerous at harvest, the leafhoppers may be nuisance to the pickers. Swarms of leafhoppers emerge from vines when disturbed, flying into the eyes, ears and nostrils of the pickers. They may increase discomfort by attempting to pierce exposed skin of workers.

Control

The most important natural enemy of the grape leafhopper in commercial vineyards is the wasp called *Angrus epos*. Its progeny develop within eggs of grape leafhoppers, resulting in their death. These parasitic wasps have amazing ability to locate and attack grape leafhopper eggs.

Chemical control seemed to be ineffective because grape leafhoppers have the ability to develop resistance, resulting that every few years a new insecticide has been necessary. It is therefore useless to list control material. Should chemical

insecticides be necessary, the following are suggested: endosulfan 50% W, Careryl 50% W or ethion 25% W.

9.4 Grape Leaf Folder (leaf Roller)

Grape leaf folder, *Desmia funeralis* is a serious vineyard pest. In its larval stage, grape leaf folder rolls and feeds on leaves, reducing photosynthetic process. Under extreme population densities, it may feed on the fruit.

Description

The adult moths of this insect are dark-brown to black with a wingspan of about 2.5 mm. The forewings have oval white spots; the back wings of the male have one white spot, whereas those of the female have two such spots. Eggs are laid on the underside of the leaves, between the large veins and on the shoots.

Damage (Plate 38-40)

The rolls made by the larvae restrict exposed leaf surface to solar radiation and their feeding reduces leaf area necessary for photosynthetic process. When infestation is heavy, the vines are partially defoliated. Late in the season, heavy infestation larvae reduce the quality of table grapes by running over the clusters thereby removing the bloom, or by actually feeding on the clusters. The breaks they make in the skin of berries in feeding serve as ports of entry for rot organisms.

Control

Parasites often tend to keep the leaf folder population from building up or spreading. The most commonly observed parasite of grape leaf folder is the larval parasite, *Bracon cushmani*. This small wasp reproduces on leaf folder larvae. It lays one to several eggs on the body of the larva. Hatched wasp larvae feed externally on grape leaf folder larvae and pupate near the consumed bodies. Parasite per host average about eight but range from one to twenty, depending upon size of the parasitized larva. Two tachinid parasite flies *Nemorilla pyste* and *Erynnia tortricis* attack grape leaf folder. General predators such as spiders, wasps and birds reduce grape leaf folder populations as well. When chemical control becomes necessary, it is suggested to use the bacterial insecticide (*Bacillus thuringiensis*), carbaryl or cryolite.

9.5 Grape Mealy Bug

The grape meal bug can quickly destroy the marketability of a cluster of grape-particularly table grapes-by turning it into a sticky sooty mess. This insect, *Pseudococcus maritinus*, also feeds on many other plants. Mealy bugs may feed on leaves, stems and branches or under the shedding bark.

Description

Grape mealy bug has a soft, flattened, and distinctly segmented body. Mature mealy bugs are about 5 mm in length, oval and covered uniformly with fine, white mealy waxy secretion. Fine filaments of wax protrude from the margin of their flat bodies. There are longer filaments at the front and rear ends.

Grape mealy bugs over winter as eggs or as young on the trunk and arms of the vine. By June these forms have matured. Their eggs (about 600 eggs) are laid in the ovisac, a loose, cottony wax sac usually deposited on the rough bark. The second generation lays eggs during the fall. The young arise at this time over winter.

Damage (Plates 41-43)

Where it feeds, the mealy bug excretes honeydew that collects in drops. This may be found on the leaves, on the bark or on the cluster. When it collect in quantity, it may run or drip. Wherever it collects, it supports the growth of a black fungus that imparts sooty appearance to the leaves and clusters. Sooty, sticky grape clusters with whitish mealy bugs and their cottony wax masses are valueless on the basis of appearance alone, especially with table grapes.

Control

Natural enemies and hot weather help control the mealy bug. Natural enemies of grape mealy bug are assumed to be responsible for keeping populations at low levels. When parasites and predators originally present in large numbers are driven away by ants, poison baits to control ants will permit their enemies to control the meal bugs. Insecticides should be used sparingly, to avoid unnecessary reduction of predator populations.

Their waxy secretions prevent many insecticides, which might otherwise be effective from reaching the mealy bugs. This has not been the case with a spray of liquid lime-sulfur and either dormant emulsified oil or dormant oil emulsion in water. This spray is effective when applied just before bud swell. Good control may also be obtained with a dormant spray of emulsified Parathion. Thorough coverage is necessary with ether spray.

9.6 Thrips

Several species of thrips attack grapes with varying degrees of damage. These include grape or vine thrip, *Depanothrips reuteri*. There are about six generations each year, the first group of larvae appearing early April; thereafter a generation is produced every twenty to twenty-five days. The adults over-winter in the soil. The flower or grass thrips, *Franlliniella occidentalis* are more widely distributed.

They often come into the vineyards in the spring in large numbers, as grasses and weeds in the area become dry and largely disappear again from the vines by the time berries are one third grown. The bean thrip, *Hercothrips fasciatus*, sometimes damage vines like the flower thrips, particularly in irrigated areas. Occasionally the citrus thrips, *Scirtothrips citri*, also attack grapes, but only in hot dry areas where citrus trees are growing near the vineyard. All of these thrips are small about 5mm in length, elongated, narrow-bodied and active.

Damage (Plates 44 - 46)

The damage of thrips on grapes, which render table grapes unmarketable, consists of: (1) Halo spots as a result of egg deposition in the young fruit, (2) berry scarring on Thompson seedless (starfish) that can render them unmarketable, and (3) shoot stunting and foliage damage

Control

Chemical insecticides usually control the grape thrip: Endosulfan 50% W, Careryl 50% W or Ethion 25% W.

9.7 Nematodes

Nematodes are microscopic, multicellular, non-segmented roundworms commonly present in the soil and are adapted by structure of their mouthparts to derive nutrients from: (1) soil microorganisms such as fungi, bacteria and other nematodes or (2) plant roots. A typical vineyard soil contains nematodes feeding on grape roots or other biological components of the soil, and on other vineyard plants or weeds.

Plant parasitic nematodes reduce root efficiency. Vine damage is eventually manifested as reduced vigor and yield with slight yellowing of leaves. Roots of nematode-infected vines are unable to meet aboveground demands for nutrients and water, especially during peak demand periods, and are the first to show a nitrogen or water deficiency. On nematode tolerant grape varieties, vine stress can be minimized by regulating cropping loads with extensive pruning. Several species of nematodes that damage grapevines are found. Two of them will be considered:

9.8 Root-knot Nematode

The most widely distributed nematode pest of grapes is the root-knot nematode, *Meloidogyne incognita*

Description

The active juveniles are attracted to roots and usually penetrate and enter just behind the root tip. Once inside the root, they establish themselves in the conducting tissues, begin feeding and after two weeks of warm summer temperatures the females mature into egg-laying adults. Their development stimulates a cellular change in the plant tissue around the feeding site. This change results in the formation of “knot” or “gall” seen on the surface of the root. Internally, this results in disruption of conducting tissues.

The number of the females living in a single gall apparently influences its size. The adult female is pearly white, pear-shaped and barely visible to unaided eye. A single female may lay 500-1500 eggs and in warm climates there may be five to ten generations a year. Root knot nematode males, do not feed on grape roots and cause no direct concern to the grower.

Damage (47 - 49)

Root-knot nematodes interfere with plant growth and nutrient uptake. They create “sinks” in the root system that channel aboveground photosynthates to them. They further disrupt the orderly uptake of water and nutrients by their physical pressure within the root tissue and the calls they formed.

Control

Vines are severely damaged by root-knot nematodes only when grown on porous sandy or sandy loam soils. The more porous the soil, the greater the damage. The light sandy soils lend themselves readily to fumigation as the most direct control for nematodes. For effective fumigation the soil must be well prepared by deep cultivation and removal of as many as possible of the live roots. Dibromochloro-propane, an effective nematocide has been used safely around grapes at rates up to 10 gallons of active ingredients per acre. In porous light soils the best control is the use of nematode-resistance rootstocks.

9.9 Dagger Nematode

Several species of dagger nematodes occur on grapes worldwide. One species, *Xiphinema index*, is important because of its role as a vector of fanleaf, yellow mosaic and several other viruses. This nematode is responsible for the reinfection viruses of new grape plantings on old-grape land.

Control: The recommended control for *Xiphinema* nematodes is to apply a deeply placed soil fumigant. The old vines must be removed as completely as possible. Use of tolerant rootstocks are recommended for new plantings especially in light soils.

10. EFFECTS OF THINNING, GIRDLING AND GROWTH REGULATORS

Thinning, girdling and use of growth regulators are advanced horticultural techniques, which utilize knowledge of the ecophysiology of the vine to enhance desired attributes.

10.1 Thinning

Thinning is both the removal of flower clusters before blooming and of immature clusters or part of such clusters after fruit set. Thinning consists of the removal of living parts and thus concentrates the activities of the vine into the parts left; that is, thinning strengthens the vine by limiting the crop without diminishing the leaf area as in the case of pruning.

Fruits from thinned vines are less likely to decay. Also, properly thinned fruit is less costly to pick, because clusters are more uniformly colored and less time is required in selecting the clusters to be harvested.

Three methods of thinning, each adapted to a given type of fruit setting, were developed. These methods are: flower cluster thinning (for varieties that tend to set straggly clusters), cluster thinning (for those set near-perfect clusters), and berry thinning (for those that set over-compact clusters).

Flower-cluster thinning

Flower-cluster thinning is done between leafing-out and blooming, and reduces the number of flower clusters without changing the number of leaves, resulting in an increased leaf/cluster ratio. The retained clusters are, thus, better supplied with photosynthates synthesized in the leaves. As a result berry set and quality are improved. Flower-cluster thinning, done as early as possible, provides the retained clusters with the benefit of the large ratio of leaves to clusters over a long period of time.

Cluster thinning

In cluster thinning, entire clusters are removed after berry set. The method has no direct effect on the percentage set or cluster length. It is an essentially a grading and sorting of fruit clusters at an early stage. Undesirable clusters, e.g. undersized, oversized and misshapen are removed. Thus the early thinning provides more favorable conditions for nutrition of retained clusters, leading to larger berries

Cluster thinning is the easiest and best means of reducing crops on overloaded vines in order that the remainder of the crop may develop and mature properly. By leaving enough fruiting wood (spurs and canes) at pruning time to produce a

good crop in years of poor set, and then reducing the overload in years of good set by cluster thinning, large regular crops may be produced every year. However, cluster thinning is a time consuming and expensive operation and growers should not leave more fruiting wood than can be economically thinned.

Berry Thinning

Berry thinning consists of removing parts of the clusters after shatter of impotent flowers. The rachis (main stem) of the cluster is cut far enough back from the apex of the cluster to retain only the desired number of berries. Retention of 4 to 8 of the long branches at the base of the clusters, depending on their size, is usually ample. These branches are usually long enough to give way to each other as the berries grow, so that the cluster will not be over-compact. The branches farther out on the rachis, not only are shorter, but also arise near each other and have less space for spreading; it is here that clusters of some varieties become too compact,

10.2 Timing

Time of berry thinning has a great effect on berry size. In seeded varieties thinning is most effective when done immediately after set. With a delay of about a week or two the increase in berry size is greatly reduced.

Berry thinning is not an effective means of increasing the size of the berries of seedless varieties. Because the effect is slight, thinning is impractical for this purpose. It is however very important in the production of table fruit of seedless varieties for preventing over-compactness of clusters when berry size is increased either by girdling or use of growth regulators.

Since berry thinning has little effect on the berry size of seedless varieties, the time of thinning of these varieties is less important. It should, however, be done before the bloom to avoid rubbing this wax coating off grape berries.

10.3 Girdling

Girdling is the removal of a narrow ring of bark entirely around the trunk or canes of a grapevine. The common width is about three sixteenth of an inch (3/16in.). It is essential that the ring of bark be completely removed. If only small section of the ring of bark is left, there may be little or no response. The immediate effect for a complete girdle is to interrupt the normal flow of food materials so that the level of carbohydrates (sugars and starches) and plant hormones increase in the parts above the girdle.

Grapes are girdled to increase berry size and to advance maturity. Most seedless varieties, if girdled at berry set will increase berry weight from 40 to 60%, compared to those not girdle depending on how well the vines are thinned.

Seeded grapes girdled at fruit set will show only modest increase in weight, usually in the range of 5 to 10%, but occasionally up to 20%.

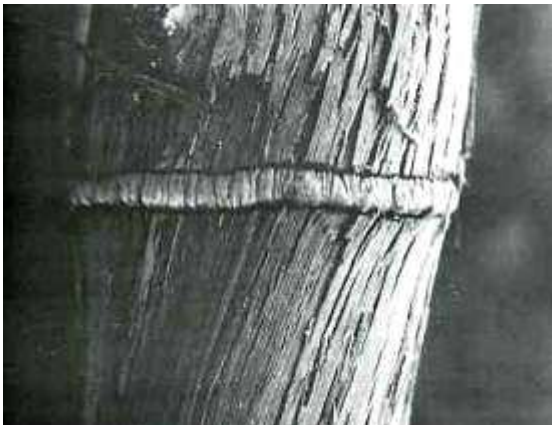
Vines girdled at the beginning of ripening phase (as indicated by development of color or softening of the berries) will accumulate sugar more rapidly and also develop more color (if colored varieties). This technique permits harvesting up to a week or so earlier than on vines not girdled. This benefit is contingent on the vines that have been thinned to normal load. Vines that are girdled and not thinned are nearly always overloaded, with consequent poor quality of fruit and weakening of the vines.

Sometimes the vines are double girdled, that is, at fruit set for berry weight increase, and again at the beginning of ripening to enhance maturity. This is believed to be rather hard on the vines. Only few growers follow this practice on certain varieties, and varieties should be tested to know the reaction. When vines are doubled-girdled, the girdles are reopened in the same spot by removing the tissue in the healed-over girdled, frequently with a narrower knife than the first time.

The practice of girdling itself would seem to be weakening since the supply of nutrients to the roots is cut off for the period of healing. However, many vines have been girdled annually for many years (a few for about 50 years) and there is no evidence that vines cannot tolerate the practice if properly done and the



vines well cared for.



Figures 15-17: Starting top left and going clockwise. Shows the newly girdled vine. Shows the incompletely girdled vine, a small amount of phloem tissue remaining can negate the effects of the girdle. Shows the healed girdle.

10.4 Plant growth regulators

Within the last four decades plant growth regulators have become established as possible aids in the field of viticulture. The most widely used growth regulator in improving grape production and quality are discussed:

2-Chloroethylphosphonicacid-Ethephon (trade name, Ethrel)

Ethylene is a natural hormone that trigger ripening process in plants. In grapes it causes the berries to soften and begin to change color while developing sugars. Ethephon is a chemical, which can be sprayed onto many grape varieties to enhance their ripening process. The plant releases ethylene gas within the fruit, which enhances ripening, absorbs this non-toxic material. Many varieties such as Cardinal, Emperor, Flame seedless, Ruby seedless, Queen, Red Malaga and others develop a much richer and more uniform color to berries when treated with Ethephon at the beginning of natural ripening period. For most varieties Ethephon is applied as a spray to the plant when the berries first begin to show a slight change in color.

Gibberellic Acid (GA3)

In seedless varieties like Thompson seedless, Flame seedless and Perlette, Gibberellic Acid is used for either thinning out the number of flowers which set fruit, a bloom thinning spray, or for increasing the size of the berries, sizing spray, which is applied about one week flowing bloom. In some varieties both a bloom spray and one or two sizing sprays are generally applied. Not all varieties respond to bloom spray for thinning. For these varieties, a gibberellin spray may be used only for increasing the size of the berry.

Gibberellic acid is also used commercially on some tight clustered seeded wine grape varieties to elongate and loosen the clusters and thus reduce bunch rot damage.

Auxin-4-Chlorophenoxyacetic acid (4-CPA)

4-chlorophenoxyacetic acid was widely used in the 1950s to replace girdling in increasing fruit size. To achieve good set with this auxin, the cluster must be thoroughly sprayed with a solution of 2 to 10 ppm 4-CPA three to six days following full bloom. Set is usually equal to or greater than that obtained by girdling, and the berries produced are equal or larger in size. Concentrations of 4-CPA higher than those recommended are very injurious to the vine, In addition spraying with 4-CPA sometimes results in compact clusters that are subject to rotting. For these reasons gibberellin has replaced 4-CPA as a girdling substitute and further 4-CPA is no longer cleared for use on grapevines in California by the Environmental Protection Agency.

2-Chloroethyl trimethylammonium chloride (CCC)

Application of the growth retardant, CCC, either to foliage or the fruit cluster from one to three weeks before bloom increased fruit set by 20% in several seeded and seedless *vinifera* grape varieties. The mechanism of the effect of CCC on increasing fruit set is believed to be due to inhibition of shoot growth, whereby organic nutrients are diverted from the shoot tips to the developing ovaries. Another growth retardant, succinct acid -2, 2-dimethylhydrazide, has also been shown to increase fruit set in two labrusca grape varieties, Himord and Concord, but has not generally been as effective as CCC in vinifera varieties.

The effect of proper application of selected regulators to increase the size of seedless berries is very similar to the effect produced by girdling. When the application of the compounds is combined with girdling, berry size is increased even more.

11. GLOSSARY

ANTITHESIS: flowering.

ADVENTITIOUS ROOT:

BUDDING: means of vegetative propagation where the scion is a single bud and it is inserted into a rootstock.

CAMBIUM:

VASCULAR CAMBIUM: A thin sheath of undifferentiated meristematic (dividing) tissue between the bark and wood. When active, it gives rise to secondary xylem (to the inside) and phloem (to the outside) resulting in growth of the diameter of stems and roots.

CORK CAMBIUM: Dividing tissue that is partly responsible for the development of the bark. Produces cork cells the outer of which are impregnated with fatty substances impervious to water and gases.

CARBOHDRATE: the substrate produced through photosynthesis. Used as building blocks for plant growth.

CHILING: the time of exposure to cool temperature to allow for normal bubreak and development the following spring.

DORMANCY: a temporary suspension of visible growth in organs containing meristems; occurs each winter in temperate fruit trees.

EVAPOTRANSPIRATION: the conversion of water from the liquid state to the gaseous state and its subsequent loss through to the atmosphere through the stomata

GIBBERLLIC ACID: a natural plant growth regulator sprayed onto many seedless grape varieties to reduce fruit set (bloom sprays) or to increase the size of the berries (sizing sprays).

GIRDLING: removal of a ring of bark from the vine when color first begins to develop on the fruit. This increases the color and maturity of many varieties. This process temporarily interrupts the downward translocation of metabolites.

HARDPAN: the presence of an impenetrable B soil horizon

HEAD: The upper portion of a vine consisting of the top of the trunk and arms. Sometimes growers call the head the crown.

INFILTRATION: the downward percolation and water into the soil structure.

IRRIGATION EFFICIENCY:

LIGHT COMPENSATION POINT: the point at which the plant organ begins to degrade because of the lack of the photosynthetic activity

LIGHT SATURATION POINT: the point at which additional light does not yield response of energetic activities

MASS FLOW: the movement of water via passive pathways down a gradient from higher osmotic potential to lower osmotic potential

NUTRIENT UPTAKE: the influx of minerals by the plant roots from the soil.

Osmotic Pressure –

OVERCROPPING: The production of more crop than the vine can bring to maturity at normal harvest time.

Oxidized

PEDICLE: The stalk of an individual flower or berry in a cluster.

PERCOLATION: the downward movement of water through the soil profile.

PHOTOSYNTHESIS: The process by which a plant converts carbon dioxide and water into carbohydrates. Solar radiation is the energy source for this process.

PHOTOSYNTHETIC ACTIVE RADIATION (PAR): the wavelengths of light which can be utilized by the plant for photosynthesis

RACHI: the main part of the cluster stem

ROOT ZONE: the area of the soil profile which the roots can and will grow

SENESENCE: the decay and abscission of plant parts

SOIL TEXTURES: the amount of sand, silt, and clay in the soil. Affects physical properties of the soil including drainage, water holding capacity and fertility.

STOMATA: openings on the undersides of leaves that facilitate gas exchange and the loss of water through evapotranspiration.

THINNING: removal of entire clusters or flowers to enhance fruit set of other clusters

TRELLIS: a permanent vine supporting system consisting of a stake and one wire at a minimum, and at a maximum, a stake plus one or more crossarms with additional wires on an arbor system.

TURGIDITY: the maintenance of plant structures.

WATER DEFICITS: occur when there is not enough water in the soil profile to satisfy the plants demands. Will affect vital plant functions.

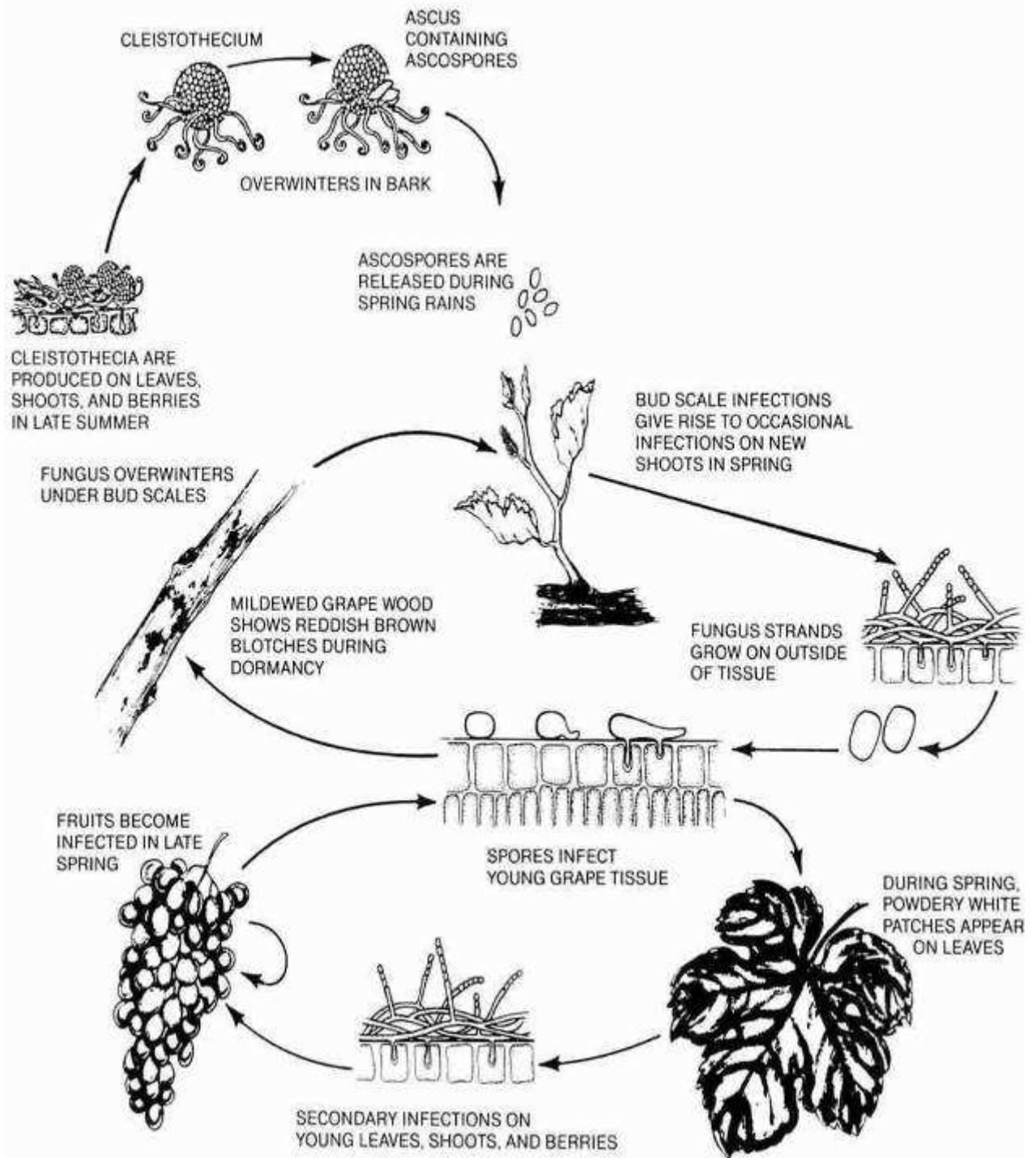
WATER RESEVOIR: the amount of water able to be held in the soil profile at levels available for crop use.

VAPOR STATE: the gaseous state of a compound. In plant physiology usually refers to water transforming from a liquid to gas during evapotranspiration.

12. PICTURES

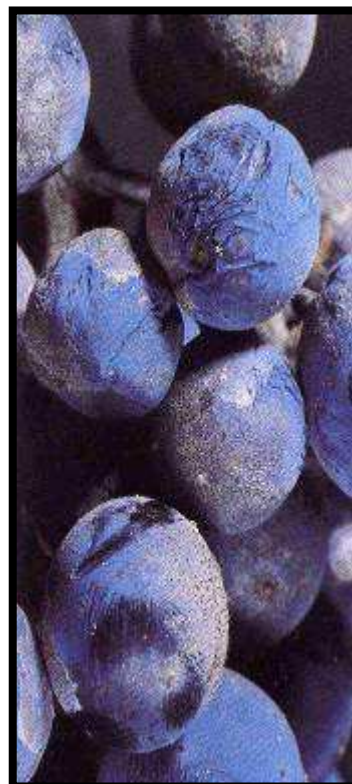
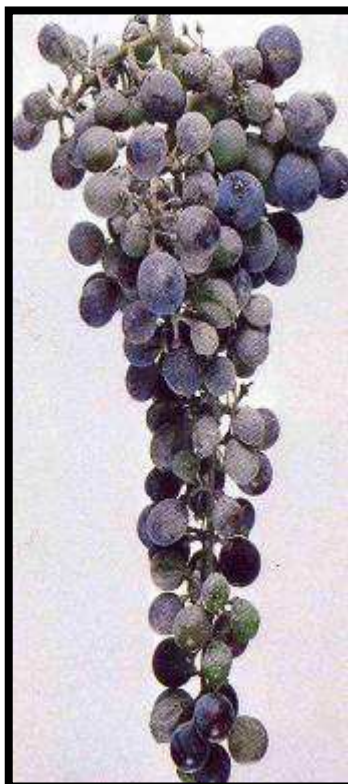
Plate1

Powdery Mildew Cycle





2-4: Mildew symptoms on berries

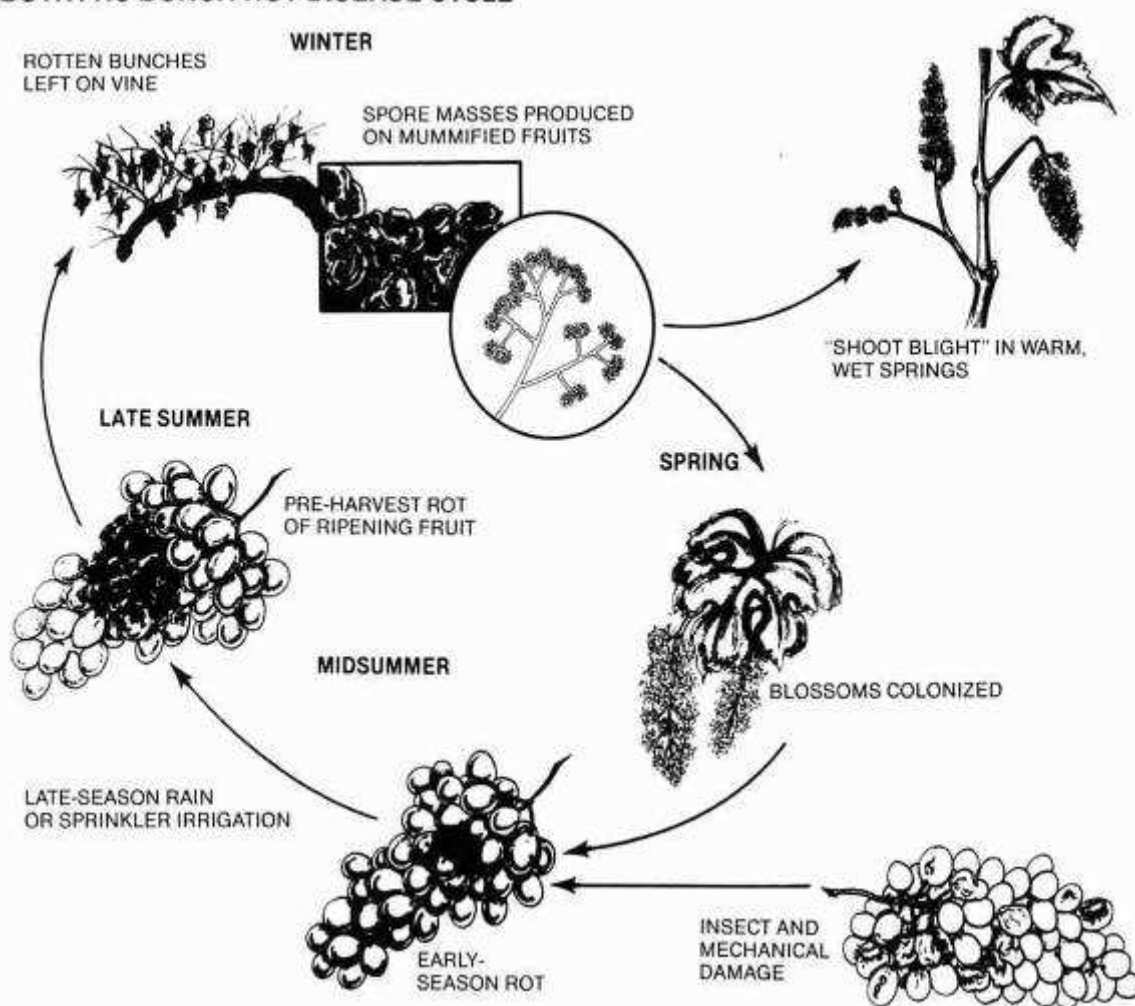


5: Symptoms on stem



6: White fuzzy growth on the tops and bottoms of leaves.

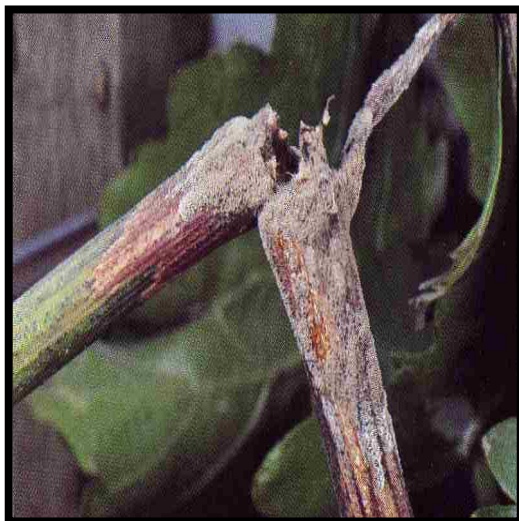


BOTRYTIS BUNCH ROT DISEASE CYCLE



8: Early spring infection of *Botrytis* on leaf.

9: Rotting of tissue due to *Botrytis*.



10: Lesion at the base of a young shoot.



11: Lesion at node.



12: Affected flower cluster.





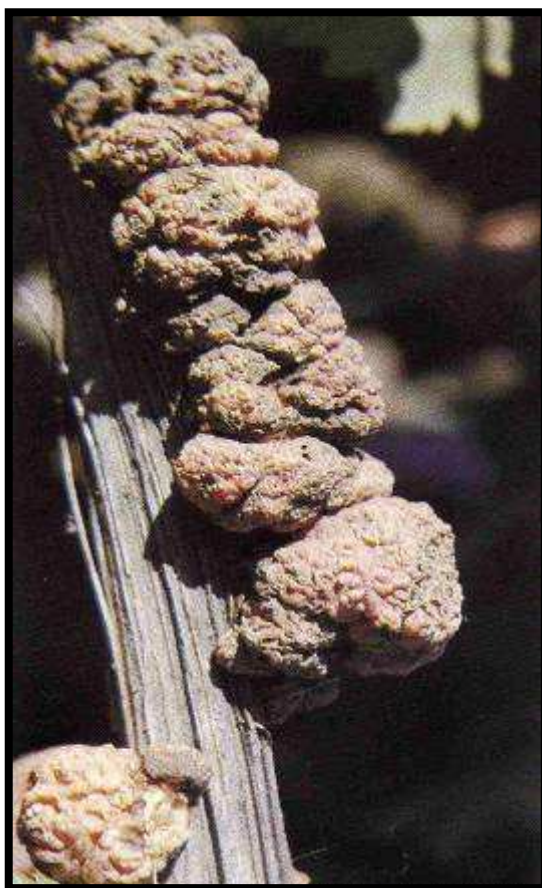
13: Crown Gall infected plants in a nursery.



14: Swollen, knobby outgrowths or galls are often found at the base of the vine.



15: Gall tissue may extend up the vines trunk.



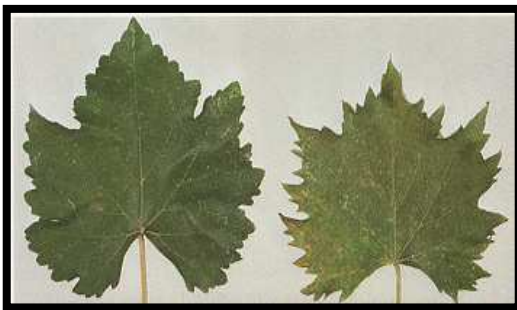
16: Gall tissue may sometimes extend up vine trunk.



17: Some fruit symptoms of Fanleaf are small and misshapen berries.



18: Mature fruit clusters are straggly with large and small berries.

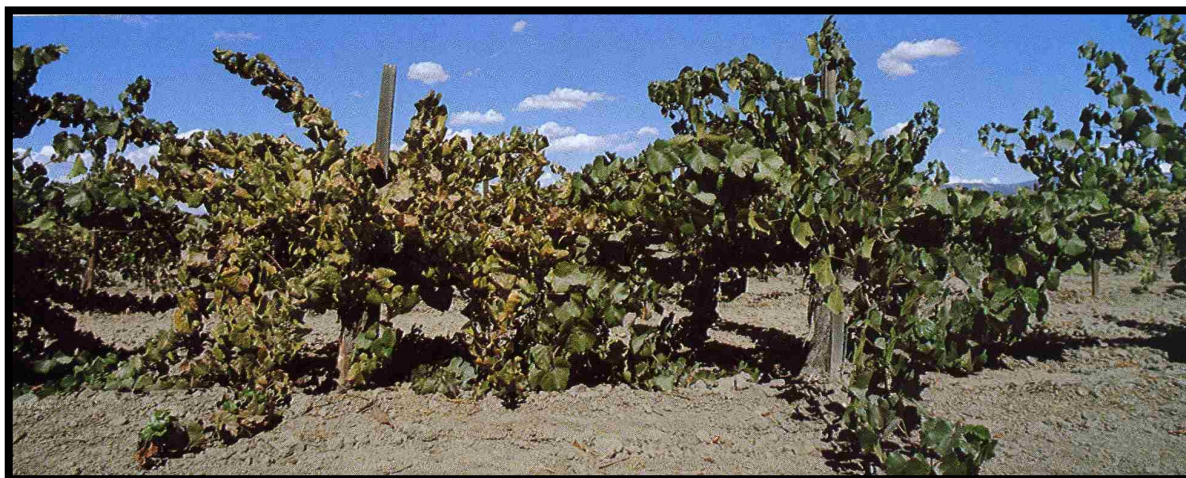


19-20: Leaf Symptoms.



21: Infected Fanleaf Virus Vines have bunched foliage because of shortened and irregular spaced internodes.





22: Diseased vine on left, showing yellowing and leaf rolling.



23-24: Symptoms of viral diseases on red and white grape varieties. Red Varieties turn a vivid dark red after harvest and areas between major veins turn red. On white-fruited varieties, rolled leaves with green veinbanding occurs.



25-26: Corky bark-affected vines on resistant rootstock often die back leaving which can lead to prolific suckering.

27: If an affected rootstock is cut transversely below ground, the cylinder is deeply convoluted and the inner wood is stained pink.



woody



28: Frass (arrow) on old pruning wounds helps identify branch and twig borer infestations.



29: A heavy branch and twig borer infestation may result in damage to cordons.

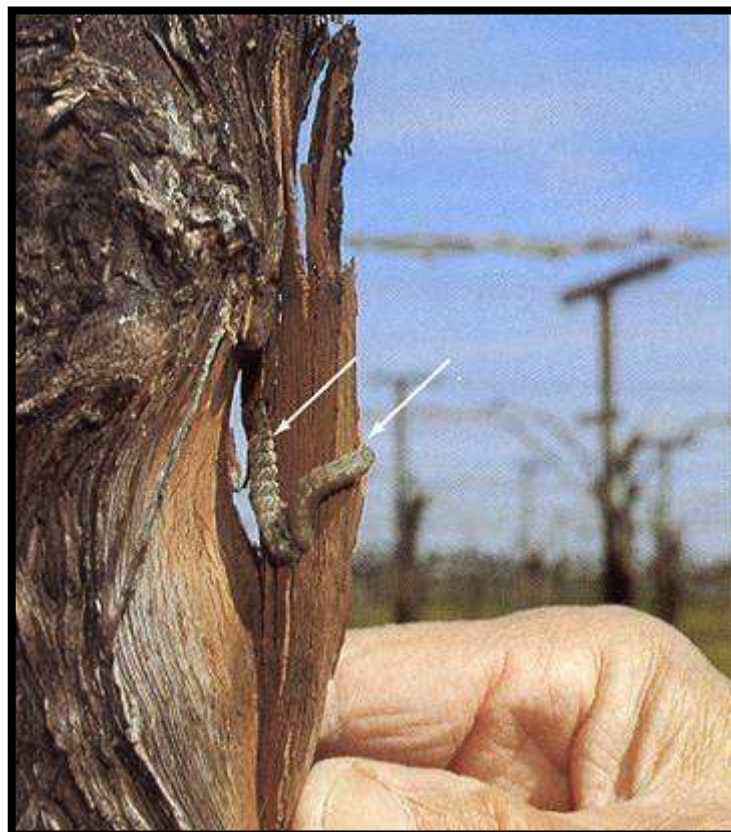


30: Cutworm damage to bud.

31: Cutworms feed at night.



32: Cutworms under bark.





33: Typical grape leafhopper feeding damage. Heavy feeding damage (right).



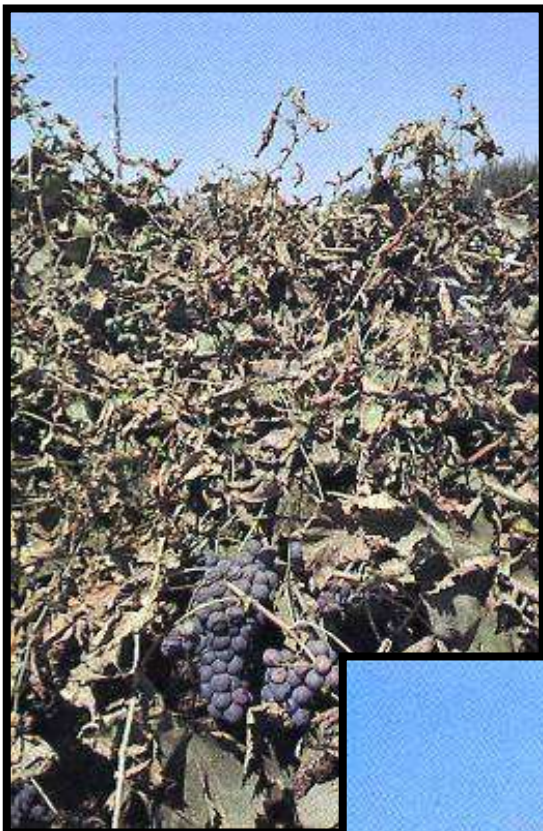
34: Leafhopper spotting on table grapes. Spotting on darker table grapes requires close examination.



35-36: The fifth instar cast skins of grape leaf hopper (left). The Grape leafhopper adult emerges from its shed skin (right).



37: Nymph with developing wing pads.



39: Heavy leafroller damage exposing fruit.



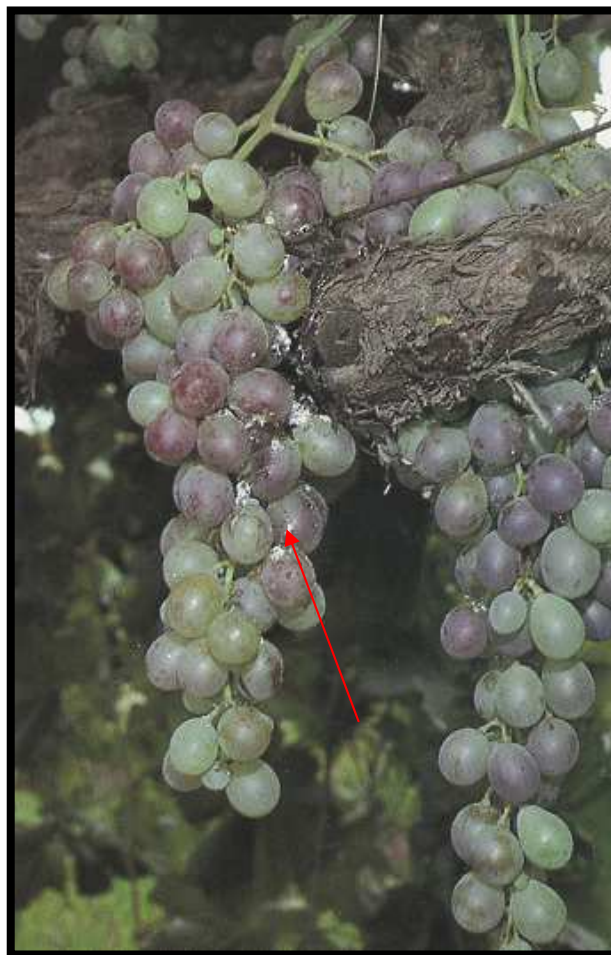
38: Leaves pulled apart show young leafroller larvae and damage.



40: Leaf rolls made by grape leafroller.



41: Grape mealybug egg mass under bark. (arrow).



42: Infested bunches



43: Mealybug crawlers as seen on berries.



44: Flower thrips stunted growth of vines. Normal growth is shown on right.



46: Typical starfish pattern of berries.



45: Thrips damage on berries.



47: Grape thrips injury to foliage.



48: Heavy/old infestation injury.



49: Close-up of flower thrips damage to young shoots.

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