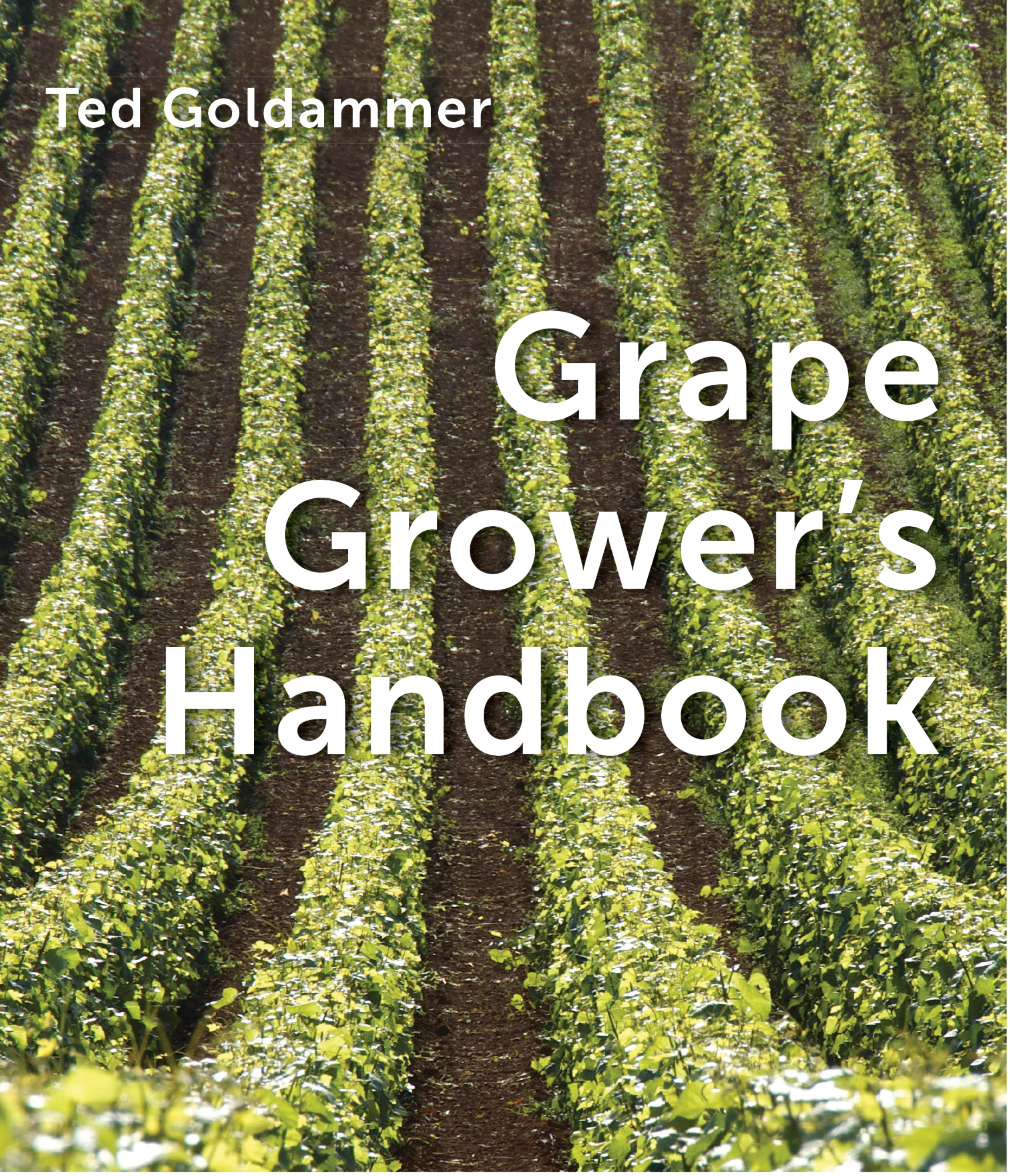
Ted Goldammer

Grape Grower's Handbook



A Guide to Viticulture for Wine Production

FOURTH EDITION

Grape Grower's Handbook

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Fourth Edition

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By Ted Goldammer

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In preparing such a book we anticipate there will be errors, and we encourage the reader to send us comments. From simple typographical errors, to missing topics, errors in data or interpretation, and even suggestions for new approaches to explaining wine grape growing, all suggestions are encouraged. Please send your ideas to: apexbookpub@gmail.com. In closing, we acknowledge the work of the many researchers in the international wine science community that we have drawn upon in formulating this book, and also appreciate the feedback from the many grape growers who helped shape the book.

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Introduction to Fourth Edition

Grapes are among the first fruit species to be domesticated, and they are today the world's most economically important fresh fruit crop, used to make a variety of fresh, dried, and processed products, such as wine. It has been said that "the secret to great wine starts in the vineyard," and "you can make poor-quality wine out of high-quality grapes, but you cannot expect to make great wine from poor-quality grapes." Growing high-quality grapes for premium wine requires the grower to understand the principles of viticulture fully. The new revised edition of the *Grape Grower's Handboo*k is a complete rewrite. It provides the grower with a broad spectrum of expertise and knowledge in growing grapes for wine grape production in commercial vineyards. Some books offer a strong academic perspective with little practical application to growing grapes for wine production. Other books provide a broad overview of growing grapes but offer little detail, while most books narrowly focus on more traditional topics of grape growing. Unlike most books on growing grapes for wine production, the Grape Grower's Handbook is meant to be a stand-alone publication that describes all aspects of wine grape production. The book is written in a nontechnical format designed to be practical and well-suited for field application. Some of the topics discussed, but not limited to, include grapevine growth, varieties, rootstocks, climate requirements, training and pruning, canopy management, development and nutrition, water and soil management, pests and diseases, pesticide application, frost protection, winter protection of grapevines, cover crops, and pre-harvest operations. The book is thoughtfully organized, presenting a seamless flow of topics within chapters that makes it easy to find specific information of interest to the reader. The information in this book is distilled from a variety of sources, including scientific literature, extension publications, trade publications, reader feedback, and the generous sharing of years of experience by growers. This book also offers the added value of numerous citations, providing in-depth discussions on many topics. The book is thoughtfully organized in an easy-to-read format, presenting a seamless flow of topics within chapters. The *Grape Grower's Handbook* has removed some of the intuition and guesswork in understanding how to grow wine grapes. The result is a more consistent product of higher quality, providing a practical "real-world" application of vineyard operations. The primary audience includes growers, extension agents, crop consultants, technical industry representatives, and students studying viticulture.

However, a proportion of coulure and millerandage is not necessarily a bad thing for the quality of the final crop.

Millerandage

Millerandage (pronounced mil-ROHN-dahdzh) or "shot" berries, on the other hand, is poor fertilization, giving small grapes without seeds, though which still have the capability to mature and ripen (Figure 1.4). These exist on the same bunch as successfully set berries. Millerandage is sometimes referred to as "hens and chickens," where hen berries (the bigger ones) are the result of a normal fruit set. Hen berries contain seeds. Chicken berries (the smaller ones) are seedless berries that are still able to ripen normally. While millerandage will always cause a drop in yield, its potential impact on wine quality will vary, particularly by grape variety. For some varieties that are prone to uneven ripeness within a cluster, such as Sangiovese, Zinfandel, and Gewürztraminer, the development of millerandage may be unfavorable due to "green flavors" from the potentially unripe grapes hidden within the cluster. For other varieties, such as Pinot Noir or the Mendoza clone of Chardonnay, wine quality could potentially be improved due to the reduced overall berry size and higher skin-to-juice ratio (Robinson, 2006).

Figure 1.4 Millerandage

Coulure

Coulure (pronounced coo-LYUR), French for "shatter," occurs during flowering in the spring, wind and rain as well as chemical deficiencies can keep grapevine flowers from being properly fertilized, causing these flowers to drop off the cluster (Figure 1.5). Since each flower is responsible for a grape, the cluster of grapes that eventually forms is loose and missing grapes. If the improperly fertilized flower stays attached, it produces a puny, seedless grape called a "shot" grape. Although the yield is reduced, there is a corresponding benefit—loose clusters that allow for increased air circulation are less susceptible to rot in humid conditions. Commonly, only 20 to 30 percent of flowers on a cluster develop into mature berries, but this is adequate to produce a full cluster of fruit (Hellman, 2003). The yield of a vine with coulure will decrease substantially and is what is meant by the term "poor fruit set." Grape varieties with high proclivity to coulure are Grenache, Malbec, Merlot, and Muscat Ottonel. Other causes of coulure may be vineyard conditions and practices, pruning too early or too severely, excessively fertile soils or overuse of fertilizers, and improper selection of rootstocks or clones. It also occurs in vines that have little sugar content in their tissue.

Figure 1.5 Coulure

1.5 Berry Growth

Stages of Berry Development

Berry growth occurs in three general stages: (1) rapid initial growth, (2) followed by a shorter period of slow growth, and (3) finished with another period of rapid growth.

Figure 5.4 Offset disk harrow

cultivation reduces the annual weed seed populations in the soil, thereby lowering weed growth. Perennial weeds, such as Bermuda grass and Johnson grass, can be controlled by cultivating the soil when it is very dry. Cultivation cuts the rhizomes into small pieces, causing them to dry out when exposed to air. The primary benefit of shallow cultivation is that it eliminates competition for moisture and nutrients between young grapevines and actively growing weeds. Shallow cultivation also eliminates a potential refuge for insect pests. The drawbacks are that it requires multiple tillage passes per year. The labor, fuel, and wear and tear on equipment involved can be costly. The bare soil is also more susceptible to water or wind erosion than a vegetated vineyard floor. Finally, a clean-till vineyard floor is inaccessible longer after rainfall or irrigation than one with an established cover crop.

Weed Management with Herbicides

Herbicides can be a valuable tool in a weed management program. Weed seedlings and established weeds can be controlled either with preemergence or postemergence herbicides (e.g., glyphosate) before planting the vineyard. A preemergence herbicide can be used before planting a vineyard, but make sure the residual life of the herbicide does not interfere with planting the vines. Many herbicide labels list a time period that must be met before planting the vineyard, as residual carryover can persist for one or more years. Many wine grape growers prefer to use preemergence herbicides only after the vines have been planted to avoid possible exposure to herbicides that may still exist in the soil. Postemergence herbicides generally have a short soil residual life, and thus are safer to use before planting the vines. If a cover crop were planted, glyphosate can be applied in strips in the fall to control the groundcover, and grapevines can then be planted into the killed strips or tilled before planting.

Site Drainage

Several factors determine the need for artificial drainage, including slow soil permeability, flat or depressional topography, restrictive layers at shallow depth, and periods of excessive precipitation. Soil factors that cause drainage problems include the texture (higher clay content results in slower permeability), soil structure (a massive structure without macropores leads to poor percolation), compaction of surface or subsurface soil by vineyard equipment, and sealing of the soil surface and depositional crusts in lower-lying areas.

Two forms of artificial drainage can be distinguished: surface and subsurface drainage. Surface drainage removes standing water from the soil surface. It affects the water table by removing water before it enters the soil profile. Surface drainage usually involves land leveling and smoothing, the installation of surface inlets, and the construction of shallow ditches and grassed waterways that lead water to streams and rivers without causing erosion. Subsurface drainage is designed to remove excess water from the soil profile. The water table is controlled through a series of drainage pipes (tiles or perforated corrugated tubing) that are installed below the soil surface, usually just below the root zone. Laterals collect water from the soil, drain into the submain, and then into the main, ultimately leading to the outlet. There are two main types of subsurface drainage systems.

Mole Drains

Mole drains are used on heavier, low-permeability, clayey soils where downward movement of water through the soil profile is slow. The mole drains are unlined cylindrical channels formed using a mole plow. The mole plow comprises a cylindrical foot attached to the bottom of a vertical leg. The foot is usually approximately 3 inches (7.6cm) in diameter and is commonly followed by a chain attached to a 4-inch (10.1cm) diameter “expander” which enlarges and helps stabilize the channel. The mole plow leg generates vertical fissures in the soil, which extend from the surface layers downwards into the mole channel. These fissures remove water from the surface layers, rapidly transferring it to the drain. The success and longevity of mole drains depend on the soil. Once a mole drain is formed, it should maintain the channel for many years. Mole drains are not suitable for soils with slaking or dispersive layers. They are also not suited to loose soils due to the collapse of mole channels. They are also not ideal for heavy plastic soil where mole seals the soil to the movement of water. Mole drains are only suitable where soil depth and slope can follow the land profile, and there is little traffic down the center of the row. Any frequency

Cluster Thinning

Cluster thinning is a viticultural practice that involves removing excess grape clusters from a vine to adjust fruit yields and achieve a balance between fruit and canopy, thereby optimizing ripeness (Figure 10.4). Crop thinning can be used to remove undersized, poorly set, or immature clusters. It can also be used to reduce bunch rot in tight-clustered varieties, such as Chenin Blanc. In determining what to thin, it is generally advisable to thin the crop uniformly, rather than removing all the clusters from several shoots or a section of a cordon. Often, one or two clusters are left per shoot, leaving the basal cluster and sometimes the secondary cluster. The number of clusters per shoot will depend on whether the clusters are maturing simultaneously, the variety, the strength of the shoots, and other factors. However, the question becomes which cluster to retain. Basal clusters are usually more mature than those farther out on the shoot (Wolpert *et al.*, 1983), but some growers prefer to leave the second cluster, which is usually smaller. On weak shoots, remove all clusters. Furthermore, it may be desirable to remove clusters that are intertwined, as they often harbor insect pests or foster bunch rots as the fruit ripens. Cluster thinning is especially useful with French-American hybrids, such as De Chaunac and Seyval, which have fruitful basal clusters that tend to overcrop.

The amount of crop to remove during thinning depends on the yield potential, vine size, the variety, and the growing region. Vigorous vines (large vine size) have large canopies and are generally capable of ripening more fruit than small, lower-vigor vines. Vines in cool climate regions are often crop-thinned to a higher degree than those in warmer regions to increase the canopy size relative to the yield. It is essential to remember that reducing the crop level excessively can lead to increased vegetative growth and canopy density, which negatively impacts fruit quality and future vine productivity. Weak or low-vigor vines generally produce less fruit and may not require heavy crop thinning to achieve balance.

Timing of Cluster Thinning

Cluster thinning can be performed at any time, from pre-bloom to just before harvest. Timing is crucial because shoots and flowers (or fruit) compete for resources within the vine, and depending on when thinning is reduced, different results may occur for either the canopy or the fruit. Pre-bloom thinning can lead to increased fruit set in the remaining clusters and potentially enhance vegetative growth. In small or weak vines, removing the crop earlier in the season may help improve berry development because there is less competition, allowing for more vegetative growth to support the berries through ripening.

Figure 10.4 Cluster thinning

Thinning at or near fruit set has been shown to increase concentration of such metabolites in the berry as phenolics (mouth feel characters) and anthocyanins (color) by harvest. Having fewer clusters on the vine at fruit set allows the remaining clusters to develop with less competition. Thinning during the lag phase enables growers to estimate yields and determine the amount of fruit to remove to achieve their yield goals. When clusters are thinned at *véraison*, the grower aims to remove fruit that is lagging in development as well as make a reliable crop estimate. If clusters are removed at *véraison*, maturity can be advanced in the remaining clusters, especially if lagging clusters are removed. Pre-harvest cluster thinning is conducted to remove damaged and unmarketable fruit.

Crop thinning, when warranted, can help ensure that the fruit achieves adequate ripeness (as measured by Brix, pH, and titratable acidity). However, there is a point in some cultivars at which the crop level can be either too high or too low in terms of fruit quality. There are no set crop levels that will guarantee the best fruit quality.

Up to 50 percent of the nitrogen in solid urea or ammonium-containing fertilizer sources can volatilize to the atmosphere when applied to grapevines under two circumstances: (1) surface-applied ammonium fertilizer sources on calcareous or freshly-limed soils; and (2) surface-applied urea on acidic or alkaline soils.

Figure 17.3 Broadcasting fertilizer

Ammonia is easily lost from urea because it rapidly converts to ammonium carbonate following surface application. If not incorporated or watered in, ammonium carbonate readily decomposes to produce ammonia and carbon dioxide gases. If solid urea is dissolved and moved into the soil by irrigation or rainfall immediately after application, volatilization is insignificant.

When ammonium-containing fertilizers are surface-applied to soils containing free calcium carbonate (e.g., calcareous or recently limed soils), an alkaline environment is maintained, allowing for the conversion of ammonium ions to ammonia gas. The degree to which this reaction proceeds depends on the anion associated with the ammonium fertilizer. Those nitrogen fertilizers that react to form calcium-reaction products of low solubility will lose considerably more ammonia than fertilizers producing reaction products of relatively higher solubility. For example, ammonium sulfate will produce low-solubility gypsum ($CaSO_4$) in combination with soil calcium, while ammonium nitrate will produce highly soluble calcium nitrate. Thus, if ammonium sulfate and ammonium nitrate are surface-applied to calcareous soil and are not immediately irrigated into the soil, more ammonium will volatilize from ammonium sulfate.

Banding

Compared to broadcast and incorporated fertilizers, the banded application minimizes contact between soil and fertilizer (Figure 17.4). This reduces fixation or "tie up" of phosphorus and potassium in the soil. Fixation of phosphorus varies with soil pH. In very acid soils (pH < 5.0), the fixation occurs as insoluble iron and aluminum phosphates. In calcareous soils (pH > 7.4), fixation occurs as insoluble calcium phosphates. The "tie up" of potassium does not vary with soil pH. Instead, the type of clay in the soil is essential. Narrow bands of fertilizer are applied on or below the soil surface adjacent to the vine row.

Figure 17.4 Fertilizer placed in a band

Fertigation

Fertigation refers to the process of injecting fertilizer into an irrigation system. This is accomplished in a drip (trickle) system by using an injector to meter the concentrated fertilizer solution into the irrigation water (Figure 17.6). In addition to greater flexibility in application timing and optimal placement, fertigation increases the rate of nutrient uptake and predictability of vine response to fertilization compared to broadcast and band applications. Consequently, it is typically the most efficient method of fertilizer application. The total seasonal nutrient need of a vineyard can be estimated based on yield, vigor, and soil conditions. This is used to create a schedule of nutrient applications to meet the specific needs of particular developmental stages (pre-bloom, post-bloom, ripening, and postharvest). In recent years, several innovative, highly soluble fertilizers have been developed expressly for fertigation. These include the thiosulfates, carbonates, hydroxides, and organic acid complexes. Some of these materials have characteristics that make them suitable for specific soil conditions, while others are suitable for a wide range of soils. Chapter 18, *Fertigation Systems for Vineyards*, provides a more in-depth discussion on fertigation.

Foliar Fertilization

Traditional soil fertilization methods, while commonly used, often fall short in meeting the micronutrient needs of plants due to various soil-related factors, such as pH and sour rot organisms, which become apparent at harvest, or to spoilage microorganisms (e.g., Brettanomyces) that reduce wine quality. Infected red and purple varieties will fail to color and have a blotchy appearance. Berries are susceptible to infections until the Brix level is high enough.

A severe attack of powdery mildew will not only destroy the current year's crop, making it unsuitable for winemaking. Still, it may also affect vine development and fruit budding in subsequent years. Old infections appear as reddish brown areas on dormant canes. Severely infected canes mature irregularly and die back from their tips.

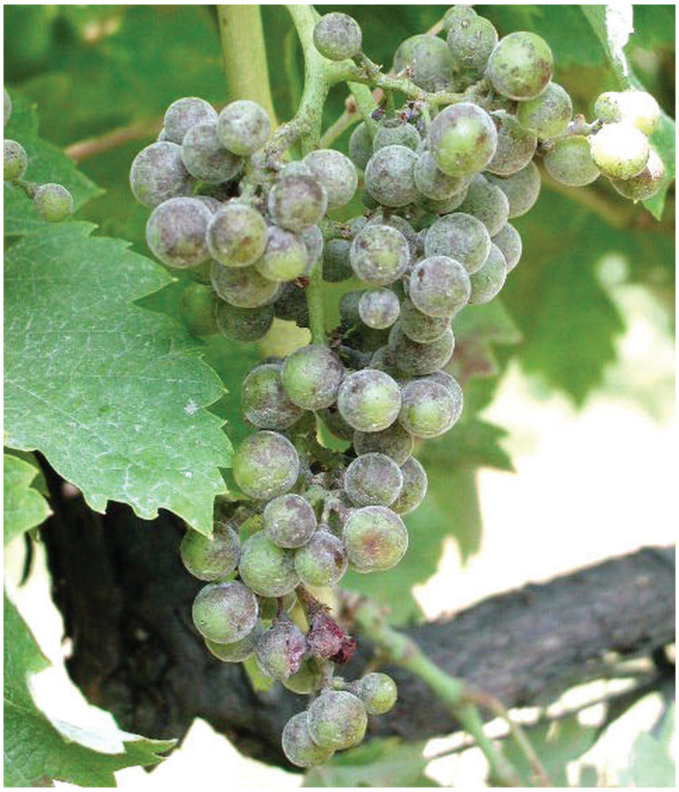

Figure 21.12 Powdery mildew

Disease Cycle

Powdery mildew also overwinters as cleistothecia (tiny, round, black fruiting bodies), in bark crevices, on canes, buds, left-over fruit, and on dead leaves on the ground. Each viable cleistothecium contains numerous spores known as ascospores that are released in the spring after a rainfall with temperatures of at least 50 degrees F (10°C). Primary infections at the beginning of the season typically occur on leaves near the vine's trunk, where cleistothecia had overwintered. In general, acrospore discharge starts soon after bud break and is completed by the end of bloom or shortly thereafter.

Once primary infection has occurred, the disease switches to its secondary phase. Secondary colonies (white mildew patches) formed from the acrospores typically develop within 7 to 10 days, although the disease is not noticeable early in the season. The white patches of powdery mildew produce millions of spores (conidia), which are spread by wind throughout the vineyard. The incubation time (the time between infection and the production of spores) can be as short as 5 to 6 days under optimal temperatures. The conidia serve as "secondary inoculum" for new infections throughout the remainder of the growing season. Thus, powdery mildew epidemics can explode when temperatures are favorable, unless the disease is managed efficiently.

It is essential to remember that powdery mildew can be a significant problem during growing seasons when conditions are too dry for most other diseases, such as black rot or downy mildew, to develop. In fact, rainfall tends to inhibit spore germination and disease development. Temperature is the most critical environmental factor; temperatures between 70 and 85 degrees F (21–29°C) are optimal for infection and disease development. Extended periods of hot weather, at 95 degrees F (35°C), will slow the reproductive rate of powdery mildew, as well as reduce spore germination and infection. Sunlight is inhibitory to powdery mildew, hence the disease is strongly favored in shaded sections of the vineyard or within dense canopies where light penetration is poor. Moisture, however, has less impact on powdery mildew development than temperature or solar radiation.

The Gubler-Thomas model, also known as the UC Davis Risk Assessment Index, is currently used in California and other production areas as a predictive and risk assessment tool for determining increases or decreases in powdery mildew. A high index (60–100) prompts the grower to shorten the interval between treatments and to switch from less effective to more effective fungicides. An index between 40 and 50 prompts the grower to lengthen the spray application intervals, while an index between 0 and 30 requires no treatment.

Cultural Control

Proper site selection is imperative in controlling powdery mildew. Start with a site where vines are exposed to sunlight all day, orienting the row direction to the prevailing winds, as this pathogen thrives in low, diffuse light and low airflow. The most efficient way to control powdery mildew is the use of good cultural practices. For example, mowing the cover crop during periods when temperatures and humidity are at their optimum range will improve airflow and reduce humidity in the vine canopy, thus reducing the incidence of the disease. Canopy management techniques such as shoot positioning, shoot thinning, hedging, leaf removal, and using training systems that allow good air movement through the canopy reduce egg viability. Insect growth regulators are primarily used to kill immature stages of plant-feeding insects, including caterpillars, fungus gnats, leafminers, mealybugs, scales, shoreflies, thrips, and whiteflies.

25.6 Pesticide Formulations

A pesticide formulation is a combination of active and inert ingredients that forms an end-use pesticide product. The active ingredients in a pesticide are the chemicals that control the target pest. A formulation will consist of one or more active ingredients plus "inert ingredients" (materials with no pesticide action). Inert ingredients are used for many reasons, including making the pesticide more convenient to use or enhancing its effectiveness. Even though these inert ingredients will usually be the largest ingredients (for example, by percentage), they are often not listed on the label. NOTE. The word "inert" does NOT mean that the ingredient is harmless. An "inert" ingredient can be more hazardous to workers than the active (pesticide) ingredient itself.

Pesticide Labels

Pesticides are formulated to make them safer or easier to use. This is because many pesticide active ingredients, in *pure* (technical grade) form, are not suitable for application. Pesticide labels will often convey information about how the pesticide is formulated by a suffix to the brand or trade name. A suffix can also include a number that indicates the amount of active ingredient in the product. For example, the brand name Sevin 50 WP indicates that the product is formulated as a wettable powder (WP) and that it is 50 percent active ingredient by weight. On the other hand, the number included in the brand name suffix of a liquid formulation describes the amount of active ingredient in the product based on pounds per gallon. The brand name Danitol 2.4 EC indicates that this insecticide is formulated as an emulsifiable concentrate (EC) and that it contains 2.4 pounds (1.1kg) of active ingredient per gallon of product. Formulations are classified as solids or liquids based on their physical state in the container at the time of purchase. A formulation can contain more than one active ingredient, and many must be further diluted with water, a petroleum-based solvent, or air (as in airblast or ultra low volume applications) before they are applied. A single active ingredient is often sold in several different kinds of formulations. Some formulations are ready for use.

Abbreviations are often used with the trade name on the pesticide label to indicate the type of formulation. Some examples of words and abbreviations used for pesticide label formulation statements are:

A - Aerosol

D or DU - Dust of Powder

DF - Dry Flowable

E or EC - Emulsifiable Concentrate

F - Flowable

G or GR - Granular

P - Pellet

S - Solution

SC - Sprayable Concentrate

SP - Soluble Powder

ULC - Ultra low volume concentrate

WDG - Water Dispersible Granules

W or WP - Wettable Powder

WS - Water Soluble Concentrate

Liquid Formulations

Most liquid formulations are diluted with water to make a finished spray. However, some labels direct users to mix the product with another solvent such as crop oil or other light oil as a carrier.

Liquid Flowables

Liquid flowables (L or F) are made with active ingredients that do not dissolve well in water or oil. The active ingredient is very finely ground and suspended in a liquid along with suspending agents, adjuvants, and other ingredients. The result is a suspension requiring further dilution with water before use. The benefit of this formulation is that there is no inhalation hazard to the applicator during mixing since the powder already is suspended in water, permitting it to be poured. They usually cause less injury to fruit and foliage than EC formulations and generally, but not always, are as safe as WP formulations. Liquid flowables form a suspension in the spray tank and have the same potential problems inherent in any suspension. However, they usually do not require constant agitation during application due to the extremely small size of the suspended particles.

Emulsifiable Concentrates

An emulsifiable concentrate (EC or E) formulation usually contains an oil-soluble liquid active ingredient, one or more petroleum-based solvents, and a mixing agent. The mixing agent allows the formulation to be mixed with water to form an emulsion. Emulsifiable concentrates are mixed with water and applied as a spray. As their name implies, they form an emulsion in the spray tank. The

28.2 Grapevine Frost Damage

Spring Frost

The onset of budburst each spring is a period of anticipation and anxiety. Inflorescence primordia initiation in the previous summer and winter pruning establishes yield potential for the coming season. However, every year poses the possibility of a frost causing an economic disaster. While the compound bud of grapevines has three shoot primordia, the fertility and hence potential productivity of the primordia decrease as secondary or tertiary buds develop. At the same time, frost damage to the primary bud in the spring results in the bud break process having to start again, later in the season.

In grapevines, buds and shoots that are still dormant will tolerate temperatures as low as 5 degrees F (-15°C). At this stage, buds have no free space for ice nucleation and effectively tolerate these low temperatures by supercooling. Supercooling occurs when water remains undisturbed, and there are no nucleation points for ice formation to occur. As the buds start to develop the capacity for supercooling is lost. These developing buds will be killed immediately upon ice crystal formation in these tissues. In general, younger tissues, which have a higher water content, tend to freeze at lower temperatures; hence, shoot tips, emerging leaves, and developing inflorescences are most sensitive to frost (Figure 28.1). There are variations in tissue susceptibility, as shoots adjacent to one another may exhibit differing degrees of damage after a frost. Some leaf cells can be killed while others remain healthy. Shoots, buds, and leaves can be damaged in the spring at ambient temperatures as high as 30 degrees F (-1°C) (Evans, 2000).

Fall Frost

Fall frosts affect a vine in a different way than spring frosts. Frosts before harvest will invariably cause death of leaves, which are already in the process of senescence, and will lead to premature leaf fall. This effectively prevents any further accumulation of photosynthate by the vine and any transfer of nutrients from the leaves to the vine. In some cases (when the frost is early enough), it may prevent wood from becoming fully mature, leading to a decreased tolerance of lower winter temperatures. In general, fruit will not be adversely affected, unless the temperature falls to 18 degrees F (-8°C), when fruit will freeze (Trought, *et al.*, 1999).

Figure 28.1 Grapevine frost damage. Image courtesy of DJ's Growers.

28.3 Passive Methods for Managing Frost in Vineyards

Passive frost protection methods are used to avoid frost danger, rather than protect against a frost occurrence. Generally, passive methods do not offer the same degree of protection as active methods, but do not cause significant increases in establishment costs for most vineyards. Passive protection methods can be divided into those implemented before vineyard establishment and those implemented after vineyard establishment.

Before Vineyard Establishment

Site Selection

The best time to protect a crop from frost is before it is planted. The importance of selecting a suitable site for a vineyard operation's long-term sustainability cannot be overstated. In windy (advective) sites, lower-lying areas are protected from the wind and are usually warmer than the hillsides. However, under radiative frost conditions, the lower regions are cooler at night due to the collection of cold air from the higher elevations. Good, deep soils with high water-holding capacities will minimize winter injury to roots. The potential vineyard site must also be evaluated for impediments (natural and man-made) to cold air drainage, both within and downslope of the vineyard, that will cause cold air to back up and flood the vineyard. There is little that can be done for most natural impediments. However, the placement of man-made barriers may be either beneficial or extremely harmful. A north-facing slope in the northern hemisphere is usually colder than a south-and need ample soil nitrogen to thrive. However, they do not generally have the deep roots or very fast growth rate of brassicas. Therefore, the forb subgroup has much lower nitrogen scavenging potential. The C:N ratio and durability of forb residues vary. Buckwheat and phacelia residues tend to disappear quickly; mature sunflower residues can be longer lasting. Buckwheat is a summer annual that is easily killed by frost. It will grow better than many other cover crops on low-fertility soils. It also grows rapidly and completes its life cycle quickly, taking around six weeks from planting into a warm soil until the early flowering stage. Buckwheat can grow more than two feet tall in the month following planting. It competes well with weeds because it grows so fast and, therefore, is used to suppress weeds following an early spring vegetable crop. It has also been reported to suppress important root pathogens, including *Thielaviopsis* and *Rhizoctonia* species. Its seeds do not disperse widely, but it can reseed itself and become a weed. Mow or till it before seeds develop to prevent reseeding.

Figure 30.4 Buckwheat shows promising potential as a cover crop in vineyards as it germinates easily and has a short sowing-flowering time.

30.4 Cover Crops: Monocultures or Mixtures?

Growers have the option of either planting a single species cover crop, referred to as a monoculture, or planting a mixture of various cover crop species, known as "polyculture" by some. Whether to grow a monoculture or a mixture of cover crop species depends mainly upon the objectives in the overall vineyard management plan.

Monocultures

Monocultures (single species) of sown cover crops are often used in vineyards. Single species of cover crops are typically planted when operational constraints limit selection to a single species or when the species has a proven track record of performance (Figure 30.5). The use of a single species is a common practice, particularly with species such as cereals, "Blando" brome, and bur medic. One advantage of planting a single-species cover crop is the ease of planting and uniform establishment and maturity. Disadvantages include increased risk of poor establishment and development due to adverse weather conditions or pests. For example, continual plantings of Cahaba white vetch may be affected by soil diseases; also, in some areas, alfalfa weevil can be a serious pest of bur medic. Additionally, local environmental variations, such as sandy or clay soils with distinct chemical and physical properties, may limit the growth of a single species (Ingels *et al.*, 1998).

Figure 30.5 Single species of cover crop

Mixtures

Plant mixtures tend to have greater efficiency than monocultures (Figure 30.6). Providing different species in a mix may enable one species to thrive in areas where another might be weak, increasing the chances for a healthy stand throughout the vineyard. For example, incorporating drought-tolerant plants into a perennial mix enhances its persistence during dry years. Vigorous polyculture stands may also reduce weeds that would otherwise fill the voids in the stand. Planting mixtures of cover crops can utilize the allelopathic potential of these crops to suppress weeds. Allelopathic potential refers to the release of natural substances that inhibit the growth of neighboring plants. Therefore, a broader spectrum

32 Evaluation of Wine Grape Maturity

Harvest time is a critical moment in the life cycle of grape growing. The timing of the harvest can significantly influence the taste and quality of the wine. Quantitative parameters can be determined to a high degree of numerical accuracy, whereas qualitative parameters are more subjective in nature. Some of the quantitative measures include soluble solids content, titratable acidity, and pH, which are specific to the intended type and style of wine. Of equal importance are the grower's observations of the qualitative indicators—integrity of fruit, color intensity of skins, seed coat color, the degree of tannin "ripeness" when the skins are chewed, degree of lignification of the cluster peduncle development, and observations of the physical condition of the vines. Practical and economic considerations also play a role, including the availability of labor and weather conditions.

32.1 Determining Wine Grape Ripeness

The most significant potential of any wine grape variety is realized only when it is harvested at the right time in order for the wines to possess the characteristic varietal aroma, flavor, and balance intended for its use. The dates of previous harvests can be used as a guide when determining the projected harvest date. However, such dates alone should never be relied upon exclusively, given management practices and environmental influences that come into play. The maturity of grapes is typically determined by three key parameters: sugar content, titratable acidity, and pH. All of these parameters change over time, and the rate at which they change depends on conditions during the growing season. Therefore, it is crucial to accurately monitor and assess fruit quality and maturity to make informed management, harvesting, and winemaking decisions, thereby producing the highest quality grapes and wine possible.

Table 32.1 Main Types of Grape Maturity

Type of Maturity	Focus	Used For
Technological (physicochemical)	Sugar, acid, pH balance	All wine types (main harvest decision)
Phenolic	Tannin and anthocyanin development in skins and seeds	Red wines (color and astringency)
Aromatic	Development of flavor precursors and aroma compounds	White and aromatic wines
Physiological	Overall vine and berry ripeness—berry softening, seed browning,	General harvest readiness

Technological Maturity

As grapes ripen, sugar levels rise and acid levels fall. Thus, the objective in assessing wine grape ripeness is to reach the optimum crossover point, where sugars are high enough, as well as acid levels, allowing for good winemaking. Table 32.2 provides the recommended sugar, acid, and pH levels for harvesting grapes for various wine styles. In some cases, all the parameters will be in acceptable ranges at harvest. In other cases, the harvest date is determined by a single parameter, even though other indices may fall outside the ideal range.

The complexity in correlating wine quality with the aforementioned measurements will likely vary from variety to variety, from vineyard to vineyard, and from year to year. In addition, what is desirable from one wine style will almost certainly be different for another. For example, Pinot Noir intended for sparkling wine production will have a very different ripeness target compared to that for Pinot Noir used in still wine. Lower sugar, higher acidity, and more neutral flavors are desired for sparkling level accuracy, making them ideal for measuring slight variations in plant height and canopy density.

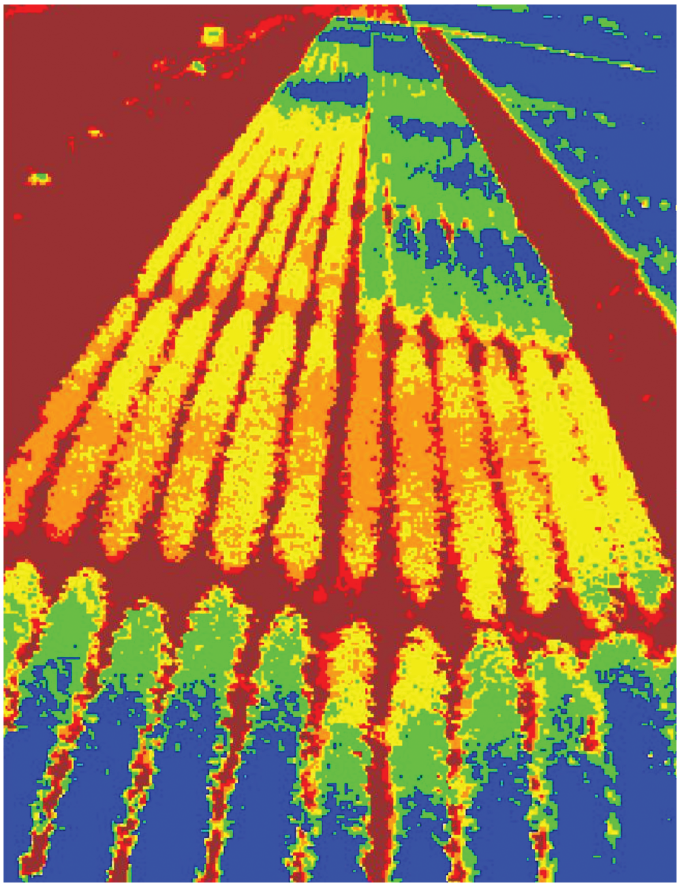

Figure 34.5 A thermal image of a vineyard for assessing crop water status in grapevines.

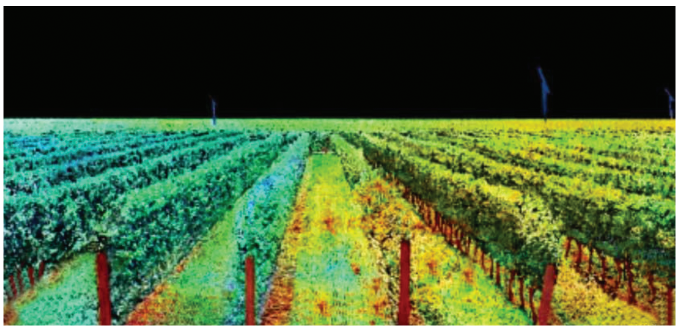

Figure 34.6 Structural LiDAR sensors are used to map, inspect, or model physical structures in high-resolution 3D.

Remote Sensing Platforms

Remote sensing platforms are defined as vehicles, such as satellites, aircraft, and unmanned aerial vehicles (UAVs), that can carry sensing devices to perform remote measurement operations. These platforms acquire images with different spatial coverage, spatial resolution, temporal resolution, operational complexity, and mission cost. These platforms are continually improving in terms of operational time, reliability, simplicity, and temporal resolution (the time interval between successive remote sensing measurements), which in turn affects the spatial resolution. With diverse options available with specific characteristics, choosing a suitable platform depends on the nature of the problem (Table 34.1). Three critical factors for selecting the best platform are spatial resolution, vineyard size, and operation cost.

Satellite Remote Sensing

Space-borne platforms for remote sensing are considered the most stable among all others. Space-borne platforms are categorized based on their orbits and timing. Unlike UAV platforms, which are a suitable solution when a "micro" view of the land is of interest, satellites provide a relatively low-cost "macro" view of the terrain, making them an efficient method for large-scale mapping, such as desertification, land cover classification, climate change, and inter-field comparisons. As the literature suggests, vast areas can be mapped using satellite remote sensing, primarily for large-scale studies and monitoring, making it promising to extract extensive time-series data. Different temporal and spatial resolutions characterize every satellite and sensor. Temporal resolution is associated with the satellite itself, which can range from a few days to 10 days or more. It is considered the time it takes the satellite to complete an orbit and revisit the same observation area. The revisitation may pose a problem due to their strictly fixed schedule, as data cannot be collected at critical times, which makes viticultural applications difficult, particularly those related to water and nutrient management. The spatial resolution of satellites for viticultural applications varies, with some offering broad coverage at a resolution of 30 meters or more. In contrast, others provide very high-resolution imagery with a resolution of less than a meter, enabling detailed crop monitoring, pest detection, and yield analysis.

Manned Aircraft Remote Sensing

Aircraft often have a distinct advantage due to their high mobilization flexibility. They can be deployed wherever and whenever weather conditions are favorable. Aircraft on site can respond with a moment's notice to take advantage of clear conditions, while satellites are locked into a schedule dictated by orbital parameters. Aircraft can also be deployed in small or large numbers, making it possible to collect imagery seamlessly over an entire area in a matter of days by having multiple planes in the air simultaneously. Aircraft platforms range from the very small, slow, and low-flying to twin-engine turboprop and small jets capable of flying at altitudes up to 35,000 feet. However, the use of aircraft can also be cost-prohibitive due to the associated

Appendixes

Glossary of Viticultural Terms

ACCLIMATION. Phase during late summer when shoots stop growing and become brown and woody, and tissues acquire increased cold hardiness.

ACID FORMING FERTILIZER. Fertilizer which increases acidity and lowers the soil pH after it is applied and reacts with the soil.

ACID SOILS. Soils with a pH less than 7.0.

ADJUVANT. A pesticide adjuvant is broadly defined as any substance added to the spray tank, separate from the pesticide formulation that will improve the performance of the pesticide. This can include everything from wetter-spreaders to feeding stimulants.

AIRBLAST SPRAYER. It is a sprayer that uses a large, axial fan which directs spray into the vine canopy.

ALKALINE SOILS. Soils with a pH greater than 7.0.

ALLEYWAYS. Intentional breaks in vineyard rows to facilitate the lateral movement of equipment and workers.

AMERICAN HYBRID. Grape varieties which were produced in by crossbreeding (usually crosses between one or more native American varieties and one or more European traditional wine varieties).

AMERICAN VITICULTURAL AREA (AVA). American Viticultural Area (AVA) A delimited, geographical grape growing area that has officially been given appellation status by the Alcohol and Tobacco, Tax and Trade Bureau (TTB). Two examples of AVAs are Napa Valley and Sonoma Valley.

ANION. A negatively charged ion such as chloride (Cl^-), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}), or bicarbonate (HCO_3^-).

ANNUAL WEEDS. Reproduce primarily by seed on an annual basis.

ANTHOCYANINS. The natural compounds found in the skins of red wine grapes which most strongly influence a red wine's color. These are the compounds that impart red, blue, or purple colors to the fruit and leaves of the grapes.

APICAL DOMINANCE. The tendency of the bud located at the highest point on a cane or shoot to grow the most vigorously.

APPELLATION. An appellation is a legally defined and protected geographical indication used to identify where the grapes for a wine were grown. If a wine label cites an appellation (e.g., Russian River Valley), 85 percent of the grapes must be grown in that appellation.

ARM. A short branch of old wood extending from the trunk or cordon on which canes or spurs are borne.

ASTRINGENCY. Astringency is the drying, roughing and sometimes puckering sensation that is experienced after tasting most red wines.

AVAILABLE WATER-HOLDING CAPACITY (AWC). The portion of water in a soil that can be readily absorbed by plant roots. It is the amount of water between field capacity and permanent wilting point. Usually measured in either %, in/ft, in/in, mm/mm, or m/m.

AXIL. Area of the stem between the upper side of a leaf and the supporting stem.

BALANCED PRUNING. Pruning a vine based on its growth in terms of the amount of one year old wood it produced the previous growing season.

BANDING. The process of applying fertilizer in bands along the soil surface.

BASE (BASAL) SHOOT. A shoot arising from a bud located at the base of a cane.

BENCH-GRAFTING. Grafting a scion to a rootstock on a bench in the nursery.

BERM. Swath of soil directly under the vine row, can vary from 1 to 3 feet wide. Commonly kept weed-free or mulched to mitigate erosion risk.

BILATERAL CORDON. A trunk that is divided into two branches extending horizontally on a support wire.

BLACK ROT. A fungal disease of the vine, usually found only in the eastern United States.

BOTRYTIS BUNCH ROT. A fungus which can either affect grapes benevolently (as in the Noble Rot, responsible for great sweet wines) or, more commonly, simply spoiling them with mold.

BRIX. Soluble solids or sugar content, measured as percent sugar in juice. It is basically the percentage of sugar in a solution. Brix = grams of sugar per 100 grams of liquid at 68 degrees F.

BROADCASTING. The process of applying fertilizer across the soil surface.

BUD. A compound bud or eye containing the primary, secondary, and tertiary buds located in the axil or each leaf.

BUD BREAK. Refers to the start of the new growing season, when tender green buds emerge in early spring's warm temperatures; typically March in the Northern Hemisphere and September in the Southern Hemisphere. The vines are especially vulnerable to frost at this stage.

BUD FRUITFULNESS. The ability of the bud to produce fruit and measurable as clusters per shoot or weight of fruit per shoot.

BUFFER. An adjuvant that lowers and stabilizes the pH of alkaline water.

CALLUS. Parenchyma tissue that grows over a wound or graft and protects it from drying or injury.

CAMBIUM. A very thin layer of undifferentiated meristematic tissue between the bark and the wood.

CANE. A mature woody, brown shoot as it develops after leaf fall. Canes were last year's fruiting or renewal shoots. The buds on the canes will produce this season's fruiting shoots.

CANE PRUNING. System of cutting the vine down to one or more 1-year old canes that will produce new shoots.

CANKER. A necrotic, localized disease area with a sharp line of demarcation between healthy and diseased tissue. It is usually on trunks or canes.

CANOPY. The above-ground parts of the vine, especially its leaves.

CANOPY MANAGEMENT. Viticultural techniques designed to manipulate the canopy to achieve a specific end, usually optimizing the quantity of grapes and quality of wine.

CARBOHYDRATES. Starches and sugars produced by grapevines as a means of storing energy.

CATCH WIRE. A wire that serves as a attachment point for developing grape shoots.

CATION. A positively charged ion such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), or ammonium (NH_4^{+}).

CATION EXCHANGE CAPACITY (CEC). The sum total of exchangeable cations that a soil can adsorb, expressed in centimoles per kilogram of soil, used in interpreting soil test results.

CHLOROSIS. Yellowing of normally green parts of the plant—shoots and leaves.

CLONE. An example of a variety replicated using a cutting from a specific mother vine which is selected as a result of some particular attribute(s). Hence, the new vine will be genetically identical to the parent. Due to the targeted nature of the clonal reproduction, the offspring vines will carry a specific designation identifying them as clones. Within certain cultivars (such as Pinot Noir) clonal variation tends to be very important.

CLONAL SELECTION. Vineyard management term for a technique by which dead or under-performing vines are replaced with new vines grown from a single superior vine, or mother vine.

COMPATIBILITY AGENT. An adjuvant that facilitates more uniform mixing of liquid fertilizer and pesticides, or mixing of two or more pesticides in a tank mix with any liquid carrier.

COMPOST. Material produced as a result of the breakdown of organic matter by micro-organisms.

CONTACT HERBICIDE. An herbicide that kills primarily by contact with plant tissue rather than as a result of translocation; also called non-systemic. Only the portions of the plant which came into contact with the herbicide will be affected.

CORDON. An extension of the grapevine trunk usually horizontally oriented and trained along the trellis wires. Cordons are considered permanent (or perennial) wood.

COVER CROP. A cover crop is a plant which is grown (or allowed to grow) between the vine rows to provide cover for the vineyard floor. A cover crop is generally used to control weeds and to improve the soil in the vineyard.

CROP COEFFICIENT. A number that is multiplied by the potential evapotranspiration to obtain the actual crop or plant evapotranspiration. They are crop dependant numbers and change over time with the crop's growth stage.

CROP LEVEL. The number of clusters retained per shoot, per unit of cane pruning weight, or per unit canopy length.

CROP LOAD. Crop load is used to describe the ratio of yield to the pruning weight or leaf area (i.e., optimal vine balance).

CROWN GALL. A bacteria disease of the vine (usually facilitated by freeze injury to the vine's tissue).

CULTIVAR. A plant that was produced from a natural species and is maintained by cultivation. Quite often cultivar and variety are used interchangeably.

CURTAIN. A portion of the canopy composed of the current season's shoot growth.

DEEP PERCOLATION. Movement of water downward through the soil profile below the root zone, which is lost to the plants and eventually ends up in the groundwater.

DEFOAMING AGENT. An adjuvant used for suppressing both surface foam and trapped air in the spray mixture.

DEGREE DAYS. A method of classifying the climate based on the number of days the temperature is within a range that vines can grow. In California, climates are rated from coolest (Region I) to the warmest (Region V). This classification can help winemakers determine where to plant which variety.

DESUCKERING. The removal of young, non-fruit-bearing shoots from a vine.

DEVIGORATION. Controlling vine vigor, either by using a devigorating rootstock, limiting irrigation, planting on shallower soils, or training the shoots downward.

DISTAL. The end of the stem towards the growing tip.

DORMANCY. That stage when the plant is not actively growing. For grapevines it is usually characterized by average air temperatures below 50 degrees F (10°C). Vines need a minimum of about 60 days of dormancy.

DORMANT BENCH-GRAFT. A grapevine consisting of a rootstock and a scion, grafted in the nursery and planted out in a nursery row for its first year of growth. It is then dug up when dormant and sold to the customer.

DORMANT PRUNING. Annual removal of wood during the vine's dormancy.

DOUBLE PRUNING. One pruning cut in late winter or early spring followed by a second pruning cut after the threat of frost is past but before appreciable shoot growth has occurred. Practiced where spring frosts are common.

DOWNY MILDEW. A fungal disease of the vine.

DRIFT RETARDENT. An adjuvant used in spray mixtures to reduce drift.

DRONES. See Unmanned Aerial Vehicles (UAVs).

EARLY HARVEST. Denotes a wine made from early-harvested grapes, usually lower than average in alcoholic content or sweetness.

ELECTRICAL CONDUCTIVITY (EC). Electrical conductivity is a measure commonly used as a fairly reliable indicator of the degree of salinity of a water sample. Units are millimhos/centimeter (mmho/cm) or decisiemens/meter (dS/m).

ENOLOGY. The science and study of wine making.

EUTYPA DIEBACK. A fungal disease of the vine.

EVAPOTRANSPIRATION (ET). Combined water use by plants and water evaporated from the soil surface in a given time period. ET usually is expressed as inches or millimeters of water per day.

EXCHANGEABLE SODIUM PERCENTAGE (ESP). The percentage of the cation exchange capacity of a soil which is occupied by sodium.

FANLEAF. A viral disease of the vine.

FERTIGATION. The process of applying fertilizer through an irrigation system.

FERTILIZER. An inorganic or organic substance applied to provide nutrients.

FIELD CAPACITY. Soil eventually reaches a point where it can't hold any more water, and any excess drains away freely. The soil moisture content after the excess water has drained is the field capacity.

FIELD GRAFTING. Grafting a new variety on to an established rootstock already growing in the vineyard.

FLOCCULATION. The joining together of smaller individual particles of soil, especially clay, into larger units or flocs.

FLORET. The individual flower of a cluster.

FOXY. The distinctive taste of the grapes and wine of some Native American cultivars, especially *Vitis labrusca* and some of its hybrids.

FRENCH HYBRID. Varieties resulting from crosses of *vinifera* and native American species made by French breeders.

FRUIT (BERRY) SET. When the vine flowers, a proportion of the flowers are fertilized, or 'set', to become berries, and eventually grapes.

FRUITING WOOD. The vine's one year old wood. This wood will produce the current season's crop.

FRUITING ZONE. A horizontal band running down the row of vines, wherein all of the fruit clusters can be found. Many grape growers will often aim to create a tight or narrow fruiting zone so that certain vineyard operations (such as leaf removal around the clusters and harvesting) can be simplified.

FUNGICIDE. A chemical or physical agent that kills fungi or inhibits its growth.

GALL. An abnormal growth of plant tissue caused by stimuli external to the plant itself. They are generally caused by insects (as in Phylloxera leaf galls), bacteria (as in Crown gall) or parasitic fungi.

GDD (Growing Degree Days). Sum of the mean monthly temperature above 50 degrees F (10°C) for the period concerned (in grapes, from April 1 to October 31), expressed as degree-days.

GEOGRAPHIC INFORMATION SYSTEM (GIS). A computer-based system used to input, store, retrieve, and analyze geographic data sets. The GIS is usually composed of map-like spatial representations called layers which contain information on a number of attributes such as elevation, land ownership and use, crop yield and soil nutrient levels.

GIRDLING. The removal of a ring of bark (down to the phloem, not including the cambium) from a shoot, cane or trunk. Often done in table grape production to increase berry size.

GLOBAL POSITIONING SYSTEM (GPS). A system using satellite signals (radio-waves) to locate and track the position of a receiver/antenna on the Earth. GPS is a technology that originated in the U.S. It is currently maintained by the U.S. government and available to users worldwide free of charge. There are 30 satellites in the GPS constellation.

GRAFT. The union between the scion of and a resistant rootstock of another species.

GRAFT UNION. The point where rootstock and scion variety are joined.

GRAFTING. In a viticultural context, usually grafting a European fruiting vine (or scion) on to a native or American-hybrid rootstock.

GROW TUBE (a.k.a. VINE SHELTER). A hollow, cylindrically shaped, man-made tube (usually made of plastic) which is sometimes placed over vines in an effort to enhance the growth environment of young vines.

GUYOT SYSTEM. A training system popular in Europe, the vine is pruned to one fruiting cane that is secured to a fruit wire, and one renewal spur that will become the fruit cane for the next year.

GYPSUM REQUIREMENT. The approximate amount of gypsum needed per acre to lower the exchangeable sodium percentage of the soil to a desired level.

HARD PAN. A hard compacted soil layer that develops between tilled and untilled layers when soil is continually cultivated at the same depth or when the soil is too wet.

HEAD. The top of the vine, from which either spurs, canes or cordons may emanate.

HEAT SUMMATION UNITS (HSU). The "heat summation units" for any given growing site is calculated by totaling the number of day degrees above 50 degrees F (10°C) for the entire growing season.

HEDGING. Pruning during the growing season by removing only shoot tops and retaining only the nodes and leaves needed for adequate fruit and wood maturation.

HENS AND CHICKENS. It is where the grape bunch at harvest consists of a mixture of a few large, normal berries (hens) and many small berries (chickens) of uneven ripeness.

HONEY DEW. Sugary substance secreted by aphids, mealybugs, and soft scales.

HYBRID. A cultivar bred from members of different species.

INFLORESCENCE. The flower cluster of the grapevine.

INTEGRATED PEST MANAGEMENT (IPM). A pest management strategy that focuses on long-term prevention or suppression of pest problems through a combination of techniques such as encouraging biological control, use of resistant varieties, and adoption of alternate cultural practices such as modification of irrigation or pruning to make the habitat less conducive to pest development. Pesticides are used only when careful monitoring indicates they are needed according to preestablished guidelines, treatment thresholds, or to prevent pests from significantly interfering with the purposes for which plants are being grown.

IRRIGATION SCHEDULING. Process of determining when to irrigate and how much. This can be done by monitoring the soil, the crop, or calculating water use (evapotranspiration). The goal is to schedule irrigation timing and amounts such that the soil water content remains between field capacity and the management allowable deficit.

INSECTICIDES. Biological or chemical compounds designed to kill, injure, reduce the fertility of, or modify the behavior of insects.

INTERNODE. The portion of the shoot or cane between two nodes.

KICKER CANE. An extra cane or canes retained during dormant pruning for subsequent removal during the growing season, intended to divert vigor from the retained, bearing shoots of the vine.

KNOCKDOWN HERBICIDE. A herbicide that kills the green tissue of plants on contact.

LATE HARVEST. On labels, indicates that a wine was made from grapes picked later than normal and at a higher sugar (Brix) level than normal. Usually associated with botrytized and dessert-style wines.

LATERAL. Side branches of a shoot or cane.

LEACHING. The movement of soluble constituents below the root zone with water.

LEAF. The leaf is the vine's primary engine of photosynthesis. Although the grapes get some of their sugar from the carbohydrates stored in the perennial wood of the vine during the earliest stages of ripening, the vast majority of sugar production is performed by the vine's leaves during the middle and later stages of ripening.

LEAFROLL. A virus disease of the vine.

LESION. A wound or delimited disease area.

LIGNIFY. The process that begins late in the summer, whereby shoots accumulate a polymeric compound called lignin, which allows the stems to become resistant to cold and water loss.

MACROCLIMATE. Regional climate, typically measured in square miles, depending on geographic factors.

MESOCLIMATE. Climate of a particular vineyard, which may differ within the regional climate because of factors such as elevation, slope, aspect, etc.

MICROCLIMATE. Canopy climate, within and immediately surrounding a plant canopy, which can show differences between small areas within the canopy, i.e., sunlight exposure, humidity, etc.

MILLERANDAGE. A reproductive disorder in which grape clusters bear significantly different sized berries within the same cluster; the so-called "hens and chickens" berry appearance.

MOG (Material Other than Grapes). An acronym used to describe contaminants such leaves and stems that are associated with harvested grapes.

MULCH. Any layer of material, which is used to cover and protect the soil surface. A mulch can be organic (e.g., straw, plant material) or synthetic (e.g., plastic).

MUMMY. Shriveled, black grape left on the stem. Mummies are often the result of disease, and potentially a critical source of disease inoculum the following growing season.

NECROSIS. The localized death of plant tissue, generally brown or black in color.

NEMATODE . Microscopic, parasitic roundworm that lives in (endo-parasitic) or feeds on (ecto-parasitic) grape roots. They can stunt vine growth and some vector viral disease.

NITRIFICATION. The conversion of ammonium to nitrate by microorganisms, which is an acidifying process.

NOBLE ROT. Noble Rot Also known by its scientific name, *Botrytis cinerea*, noble rot is a beneficial mold that grows on ripe wine grapes in the vineyard under specific climatic conditions. The mold dehydrates the grapes, leaving them shriveled and raisinlike and concentrates the sugars and flavors. Wines made from these berries have a rich, complex, honeyed character and are often high in residual sugar. Noble rot contributes the unique, concentrated flavors in such wines as BA and TBA Riesling from Germany, Sauternes from Bordeaux, Aszu from Hungary's Tokay district and an assortment of late-harvest wines from other regions.

NODE. The thickened portion of a shoot or cane where the leaf and its compound bud are attached.

OMRI. The Organic Materials Review Institute (OMRI) is a national nonprofit organization that determines which input products are allowed for use in organic production and processing. OMRI Listed—or approved—products may be used on operations that are certified organic under the USDA National Organic Program.

ORGANIC MATTER. This consists of the residues of plants and animals and their secretions and excretions.

PEDICEL. A stalk of one flower or fruit in a cluster.

PEDUNCLE. The portion of the rachis from the shoot stem to the first branch of the cluster.

PERENNIAL WEEDS. Weeds with a life cycle greater than two years. Perennial weeds reproduce by seed and vegetative organs, such as rhizomes or tubers.

PERENNIAL WOOD. It is the permanent wood of a grapevine.

PERMANENT WILTING POINT. The soil moisture content at which plants will not recover from wilting.

pH. A numerical measure of the acidity or hydrogen ion activity of a substance, e.g., grape juice or soil.

PHENOLS. A varied group of compounds found mainly in skins, stems and seeds in the case of grapes. They include anthocyanin, tannins and many flavor compounds. Precipitated, they form an important part of wine's sediment and play a considerable role in wine ageing.

PHEROMONE. A chemical substance (i.e., sex attractant) produced by an animal that serves as a stimulus to other individuals of the same species for a behavioral response.

PHOTOSYNTHESIS. The formation of carbohydrates (sugars, mainly glucose and fructose) in the vine (mostly stored in the fruit) from water and carbon dioxide, by the action of sunlight on the chlorophyll in the vine (produced mostly in the leaves).

PHYLLOXERA. Grape phylloxera (*Daktulosphaira vitifoliae*) is an aphid-like insect that feeds on grape roots, native to the eastern U.S. where American grape species developed a natural tolerance. Susceptible plants decline and die.

PHYTOTOXIC. Causing injury or death of plants or portions of plants.

PIERCE'S DISEASE. A bacterial infection of the vine that is spread by an insect called the blue-green sharpshooter.

PLANT PENETRANT. An adjuvant that enhances a liquid's ability to penetrate plant roots, leaves, and stems.

PPM. Parts per million, a unit of concentration often used when measuring levels of materials in air, water, etc. One ppm is one part in 1,000,000. The common unit mg/liter is equal to one ppm.

POWDERY MILDEW. A fungal disease of the vine.

PRIMORDIA. Primordia are the growing points of a bud.

PRIMORDIAL SHOOTS. The buds which develop on this year's fruiting wood. They will give rise to the fruiting shoots for next year.

PRUNING. Pruning is the removal of portions of the vine for the purpose of maintaining its size and productivity. The size and productivity is maintained by ensuring that the vine retains a proper number of fruiting buds.

PRUNING WEIGHT. Pruning weight is determined by the amount of wood that is pruned off one vine in a single season. This can be used in formulas to determine how many buds should be removed and/or left on the vine as part of balanced pruning techniques.

PTO. Power take off shaft. The part of a tractor used to transmit power to a wide variety of implements.

RACHIS. The main axis of the inflorescence of *Vitis vinifera* is called a rachis. Flowers are borne on smaller stems called pedicels.

RAKE WIRE. A moveable trellis wire that is used to facilitate shoot positioning as in canopy division.

REFRACTOMETER. An optical instrument used to measure the solute (such as sugar) concentration of liquids such as grape juice.

RENEWAL SPUR. A cane pruned to one or two nodes, generally on an arm or cordon. Its primary purpose is to position a cane for fruiting the following season.

RENEWAL ZONE. A zone established by some growers, whereby the buds which will produce next year's shoots are assured proper positioning.

RESTRICTED ENTRY LEVEL (REI). The period of time after a field is treated with a pesticide during which restrictions on entry are in effect to protect persons from potential exposure to hazardous levels of pesticide residues.

ROOTSTOCK. A cutting taken from a vine (usually Native American or American hybrid) and cultivated to serve as a root system for a grafted vine. Hence a grafted vine consists of a scion (the above ground growth) and a rootstock (the below ground growth).

SCION. A cutting (or bud wood) taken from a vine (usually *Vitis vinifera*) and grafted onto a root system from another vine (usually native American or a American hybrid).

SHATTER. The physiological stage following bloom when impotent flowers and small green berries begin to fall from the cluster.

SHOOT. The green, leafy growth developing from a bud on a cane, spur, cordon, or trunk. The developing growth of the shoot is the source of all of the vine's leaves, stems, tendrils, flowers and fruit.

SHOT BERRY. A form of berry asynchrony, where the bunch has excessive numbers of small, green, seedless berries that may or may not ripen at harvest.

SMUDGE POT. Oil-burning heaters used to prevent or reduce frost damage in orchards and vineyards. Typically consisting of a wide base topped by a chimney, smudge pots may be lit when frost threatens. They offer some protection by creating air currents that can disrupt settled colder air at ground level. Due to their consumption of oil and smoke production, as well as labor requirements, use of smudge pots is in decline in favor of other frost-protection methods such as wind machines and aspersion.

SODICITY. Sodic soils are those where the amount of sodium held onto the clay particles is 5 percent or more of the total cation exchange capacity (this is called the Exchangeable Sodium Percentage or ESP and represents the proportion of sodium ions held by clay particles compared to other positive ions).

SODIUM ADSORPTION RATIO (SAR). The relationship between sodium, calcium and magnesium in soil. The SAR has an effect on the water infiltration rate into the soil.

SOIL STRUCTURE. The arrangement of aggregates of sand, silt and clay and the arrangement of spaces (pores) between these aggregates within the soil.

SOIL TEXTURE. The relative proportion (percent) of sand, silt, and clay in a soil.

SPUR. A cane pruned to 3 or fewer nodes, generally on a cordon.

STAMEN. The pollen-producing organ of a flower, consisting of an anther and a filament.

STEM PITTING. A graft-transmittable virus disease, symptoms include pitting and grooving of the wood underneath the bark, weak growth and graft incompatibilities.

STICKER. An adjuvant that increases the adhesiveness of finely divided solids to solid surfaces.

SUCKERS. Suckers are shoots that grow from the crown area of the trunk.

SUCKERING. Removal of shoots arising from the trunk, but often the term is used to describe the removal of all unwanted shoots from the trunk, cordon, cane or head early in the season.

SURFACTANT. A chemical that modifies surface tension. Surfactants can influence the wetting and spreading of liquids, and can modify the dispersion, suspension, or precipitation of a pesticide in water. There are nonionic surfactants (no electrical charge), anionic surfactants (negative charge), and cationic surfactants (positive charge).

TA. Titratable acid is the measure of acid content in juice.

TANNIN. A phenolic compound in grapes that can impart an astringent taste. Commonly found in skins and seeds.

TARTARIC ACID. One of the two major organic acids in grapes and wine. Because it is relatively resistant to microbial breakdown, tartaric acid provides much of the stable acidity to wine.

T-BUDDING. A grafting technique where s single bud is inserted into a "T" shaped incision on the existing vine, matching the cambium tissues of the bud and the trunk. After the bud pushes and has produced a strong shoot, the remainder of the vine above the bud insertion is cut off.

TENDRIL. A curled structure arising from some nodes of the shoot and capable of attaching itself to other portions of the vine and non-vine structures (like the trellis).

TERROIR. French term used to designate a "place" which includes localized climate, soil type, drainage, wind direction, humidity and all the other attributes which combine to make one location different from another. (pronounced "tair wah,")

THICKENER. An adjuvant that increases the viscosity of a spray mixture.

TRACE ELEMENTS. Minerals needed in very small amounts. In plants, these would include micronutrients such as the elements iron, boron, and zinc.

TRAINING. Shaping a vine into a specific shape, usually to effect some form of canopy management. Training systems are often referred to by indicating the location of the fruiting wood in terms of it relation to the vine's perennial wood (trunk, head or cordon) and by indicating the length of the fruiting wood (spur or cane).

TRELLIS. The hardware support structure which supports the vine and the crop.

TRUNK. The main upright structure of the vine from which cordons, shoots, and canes may arise. Vines may have more than one trunk.

UNMANNED AERIAL VEHICLES (UAVs). An unmanned aerial vehicle (UAV), commonly known as a drone and also referred by several other names, is an aircraft without a human pilot aboard. The flight of UAVs may be controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. In agriculture, UAVs are typically used to survey crops. The available two types of UAVs—fixed-wing and rotary-wing—are both equipped with cameras and are guided by GPS. They can travel along a fixed flight path or be controlled remotely.

VARIETY. A clone, or series of related clones, propagated vegetatively from a single parent plant (monoclonal origin) or several genetically similar parents (polyclonal origin). Cultivar is used interchangeably.

VÉRAISON. Stage of ripeness signaling the start of berry softening and color change. (pronounced "veh ray zon," French)

VIGOR. Vigor is the quality or condition that is expressed in rapid growth of the parts of the vine. It refers essentially to the rate of growth. It depends on a combination of factors, including soil type, texture, and depth, water and nutrient availability, and variety choice. Inherently, some grape varieties are more vigorous (e.g., Syrah and Sangiovese) than others, which in turn can produce canopies with an excess amount of leaf area that require more intense management.

VINE CAPACITY. Vine capacity defines the maximum amount of shoots that the vine can support and fruit that will ripen.

VINE DENSITY. Important vineyard parameter, the number of vines planted per unit of area (usually acre).

VINTAGE. A term that describes both the year of the actual grape harvest and the wine made from those grapes. In the United States, the label may list the vintage year if 95 percent of the wine comes from grapes harvested that year.

VITICULTURE. The science of growing grapes.

VITIS. The scientific designation (genus) that includes all grape species.

VITIS VINIFERA. European grape species, which are the classic standard for wine making.

VMD (Volume Median Diameter). A term used to describe the droplet size produced from a nozzle. VMD is defined as the diameter at which half the spray volume is in droplets of larger diameter and the other half of the volume is in smaller droplets.

VSP (Vertical Shoot Positioning) . A method of vine training in which annual canes are tied horizontally to the wires and all new shoots are positioned vertically.

WATER BERRY. A disorder of ripening grapes in which sugar accumulation stops and grapes become soft and watery.

WATER HARDNESS. This refers to the level of calcium and/or magnesium in water. Water with high levels of calcium and/or magnesium can cause scaling in microirrigation systems.

WATERSHED. The area of land that contributes to surface runoff to a given point in a drainage system.

WATER SHOOT. Water shoots arise out of old buds left on the permanent wood of the vine (trunk or cordons).

WETTER (or surfactant). An adjuvant that improves the wetting and coverage of a chemical on the target surface.

YIELD. The amount of wine or grapes produced per unit area, usually measured either as ton/acre, tons/ha or, in much of Europe, hL/ha. Many factors such as planting density, pressing regime, grape variety, and style of wine affect the conversion of weight of grapes into volume of wine but 1 ton/acre is very approximately equivalent to 17.5 hL/ha.

YIELD-TO-PRUNING-WEIGHT RATIO. A measure of the balance between vegetative growth (current season) and fruit production.

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Grape Grower's Handbook

Grape Grower's handbook: A Guide to Viticulture for Wine Production is intended as a stand-alone resource that outlines all current and future technologies used in growing wine grapes. This book is written in a non-technical format, designed to be a practical and well-suited guide for growers, crop consultants, technical industry representatives, students studying viticulture, extension agents, and practitioners interested in the real-world applications of site-specific agricultural management.

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