pushed latent buds from the cordon and the bases of the arms, many of which were fruitful.

Thirteen-year-old Ruby Cabernet gave an equivalent crop whether hand pruned or machine pre-pruned. However, French Colombard of similar age suffered about a 20 percent yield reduction when machine pre-pruned.

Thus, machine pre-pruning of older vines gave variable results. Substantial cuts on well-developed arms reduced yield of most varieties. These results are the first season's response from machine or simulated machine pre-pruning. We plan to follow repeated treatments on the same vines for at least two more years.

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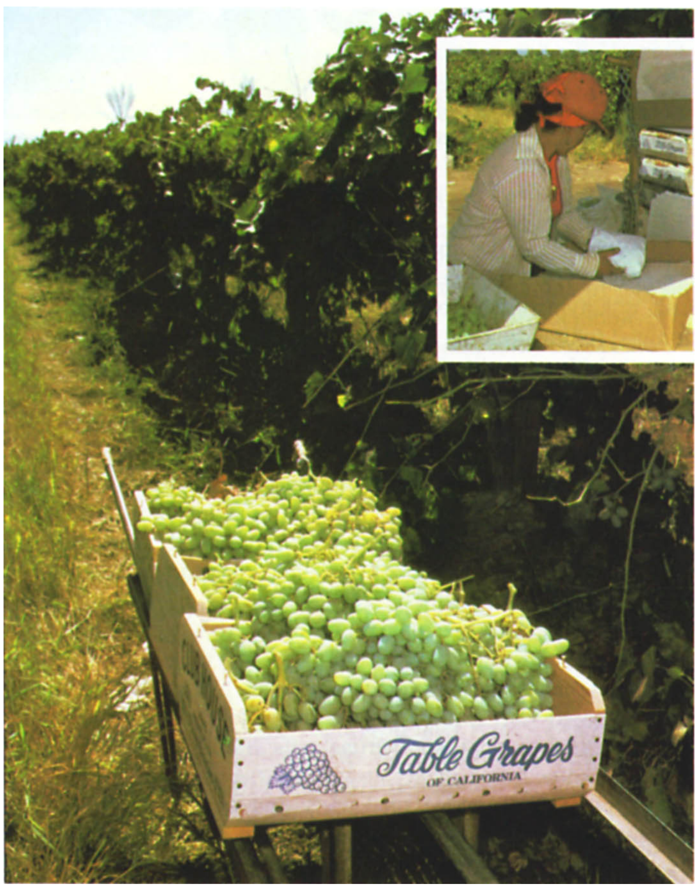
Improved harvesting and handling benefit table grape markets

Klayton E. Nelson



Quality of table grapes is maintained when they are harvested in cool morning temperatures, kept shaded after harvest, and cooled as soon as possible.

Table grapes (*Vitis vinifera* L.) are physiologically a relatively durable fruit. They have a low respiration rate and can therefore live a long time after harvest. However, they are extremely susceptible to decay, can be injured easily, and lose water readily. Modern technology has alleviated these problems so that table grapes can be sold most of the year and in most of the major world markets.

In the United States the production of vinifera table grapes is essentially limited to California and Arizona, in areas with long, relatively dry summers. Until the end of the 19th century, California table grapes were produced almost exclusively for local markets. The large markets of eastern United States became accessible after completion of the transcontinental railroad and, later, development of the ice-refrigerated railroad car. Growth was slow at first, but by 1924 annual shipments had increased to 55,000 cars (1,000 lugs per car) because of more efficient and complete re-icing services across the United States, faster railroad schedules, Prohibition causing growers to switch from wine grapes to table grapes, and enactment of standardization laws prescribing minimum quality standards for the fruit.

Still, delayed and inadequate cooling often resulted in soft, unattractive berries and dry stems that broke readily during handling. Decay was an ever-present hazard, especially when wet weather occurred before harvest. Further, the grapes had to be marketed immediately after harvest, because they could not be held in cold storage for more than a few days without drastically losing quality; the result was market gluts and low prices.

In studying chemical composition of table grapes as the fruit matured, F. T. Bioletti was primarily concerned with the soluble solids content influenced chiefly by the sugars (glucose and fructose). Taste tests were included to relate palatability to sweetness (soluble solids), sourness (total titratable acidity), and a balance of these two constituents (sugar/acid ratio). Bioletti concluded that the soluble solids content was the simplest and most reliable indication of when the grapes were acceptable. He recommended minimum solids contents high enough so that the fruit would be palatable even if the grapes had an unusually high acid content in a cool season.

Many of these recommendations were incorporated into the State Standardization Act of 1921. Unfortunately, the industry was reluctant to accept these standards, because they were considered so high that grapes were often rejected if low in acid content—either because of variety or because unusually high temperatures during ripening depressed the acid level, causing the fruit to taste less sour.

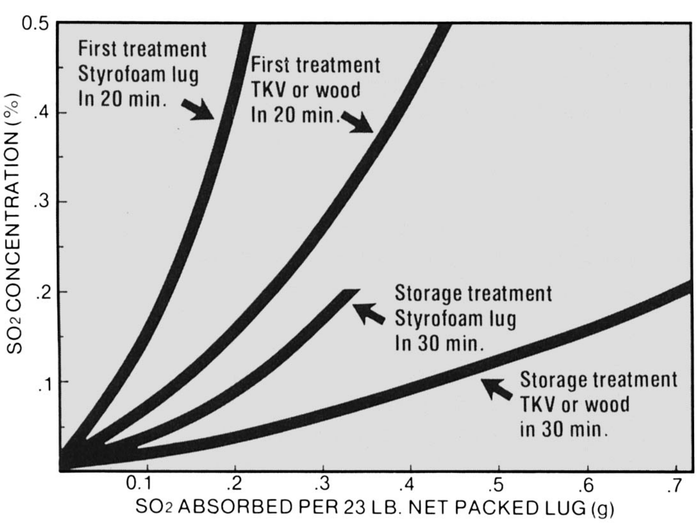
A. J. Winkler concluded in the 1930s that both the soluble solids and total acid contents should be incorporated in the measurement of maturity. These could be combined as the sugar/acid ratio, supplementing the minimum soluble solids standard. The State Standardization Act was amended, and the method has also become widely used by other governments and for other commodities, such as citrus.

The rate of heat accumulation, especially during the ripening phase, significantly affects the rate at which the total acid content is depressed. Winkler introduced the "degree-day" concept as a method of determining not only the rate of heat accumulation, but also the total amount of heat that will bring the fruit of each table grape variety to acceptable maturity.

The 100 or more grapes in a cluster vary in chemical composition, but the cluster is the smallest feasible unit to use in sampling for maturity, and the consumer's reaction is based on just a few berries at a time. Further, consumers vary widely in their preferences for sweetness in grapes.

We began a study in 1959 using a sensory panel of 30 members tasting a given sample several times. The soluble solids content of berries in a cluster varied by as much as 5° Brix (a scale based on grams sucrose in 100 grams of a sugar-water solution) for fruit harvested early in the season; the total acid content of some berries was nearly twice that of others. Therefore, the chemical composition of the juice extracted from such a cluster would represent only the average of a highly variable population. The minimum maturity standard should be sufficiently above the average so that the berries in the cluster below the minimum would be within acceptable limits.

The sugar/acid (soluble solids/total acid) ratio was clearly demonstrated to be the reliable indicator of maturity (palatability) for grapes of high to medium acid content, especially if the soluble solids content was minimal to moderate. At high soluble solids levels, the degree Brix alone was a reliable indicator. When both the total acid and soluble solids contents were very low (still a high sugar/acid ratio), the ratio no longer reliably predicted palatability. We suggested a sliding scale to cover these eventualities.



Sulfur dioxide absorbed by packed grapes and containers (Styrofoam; wood or wood-paper laminate). Amount for first treatment is based on absorption before or during cooling; that for storage treatment based on 90% relative humidity.

Sensory panel members reacted favorably to the color of red and black grapes and also, although less strongly, to subtle changes from green to yellow of the white grapes—associating the yellow color with higher maturity and therefore greater sweetness when compared with green berries. This suggests that packs should be uniform in color.

The panel members varied in their preferences, and some were quite tolerant of or even preferred the tart flavor of the lower maturity grapes. However, most found fruit more acceptable the higher the sugar content.

Surveys of supermarket customers confirmed the reliability of the sugar/acid ratio in predicting palatability. They also showed that sample order (sweet following tart and vice versa) significantly affected response. Women rated tart samples lower and sweet samples higher than did men.

Sulfur dioxide to control decay

Sulfur dioxide was first used in California to prevent decay and fermentation of wine grapes. In University studies in the 1920s, about 50 milligrams per kilogram (mg/kg) of fruit doubled the keeping period at holding temperatures as low as 50° F. A concentration of 100 mg/kg did not injure color, texture, or flavor of Tokay, Thompson Seedless, or Muscat of Alexandria varieties.

Use of sulfur dioxide in commercial shipments of fresh grapes began in 1924, and by 1928, 10,000 to 15,000 carloads were treated each year. One treatment with air containing 2 to 3 percent SO_2 (by volume), usually applied in the car just after loading, provided 50 to 100 ppm in the grapes and protected against decay only for the transit period of about 10 days.

Later the concentration was lowered to 1 percent SO_2, supplemented with treatments of 0.25 percent by volume every week or 10 days if the grapes were held in storage at or near 32° F. The concentrations were based on the free space in the room—total cubic space minus that displaced by the packed fruit. As the storage periods became longer and the rooms larger, a consistent pattern was inadequate decay control early in the storage season when the rooms were relatively full of fruit and excessive bleaching of the grapes toward the end when the rooms were nearly empty.

During the 1950s we determined that the capacity of the lugs and fruit for absorbing SO_2 was so great that it needed to be considered in a formula calculating the SO_2 dosage as the volume of fruit changed in the room during the storage season. We recommended a basic concentration for the free space of the room, which can be adjusted upward or downward depending upon the amount of fungus infection present in the fruit when packed (infection caused by wet weather before harvest and not detected and eliminated by the packer). At 0.05 percent SO_2, no bleaching injury will result, even during long storage periods, but the fruit must be exceptionally free of infected berries. At 0.2 percent, infection should not spread, but significant bleaching can be expected after a month of storage.

An absorption factor should be added to the free space dose, the amount depending on the type and size of packages and the concentration of the gas used for the free space. In later studies it was determined that the storage relative humidity significantly affected the absorption dose—about 2 percent SO_2 must be added for each 1 percent increase in relative humidity above 90 percent, and 2 percent subtracted for each 1 percent below.

An in-package, two-stage SO_2 generating system was developed to protect against decay for extended periods. The first stage (sheet of paper impregnated with sodium bisulfite) starts to generate SO_2 inside the package within minutes of packing as the relative humidity reaches saturation, in effect, substituting for the conventional initial treatment. After three to five days, the second-stage sheet, with thin polyethylene film shielding the bisulfite from the humidity, starts to evolve SO_2 in very low concentrations and continues to do so for as long as two months at storage temperatures, substituting for the weekly storage treatments.

The unvented container, especially if the liner is a water-vapor barrier, keeps the grapes much fresher, because it drastically reduces water loss. The U.S. export industry uses the second-stage version to extend protection six to eight weeks during transit, and other countries use one or both stages for their export grapes.

Controlling water loss

Prompt, thorough cooling of the fruit after harvest is essential to reduce water loss. In a series of tests, the rate of drying and browning of stems, softening of berries, and weight loss were directly related to temperature of the grapes after harvest until cooling was started. The fruit deteriorated as much in one *hour* at a field temperature of 90° F, as in one *day* at a transit temperature of 40° F and one *week* at a storage temperature of 32° F. To reduce water loss from the fruit before cooling, we recommend harvesting in the morning when grapes are coolest, keeping the fruit shaded after harvest, and minimizing the time after harvest until cooling starts.

Once the grapes are at the cooler, the system must rapidly remove the field heat. Until about 1950, most table grapes were transported to distant markets in ice-refrigerated rail cars, which had sufficient refrigeration capacity to cool the fruit satisfactorily. The cars became relatively efficient coolers when fan systems were installed during the 1930s and 1940s.

After 1950, refrigerated highway vans carried an increasing share of the grapes, and the railroads shifted gradually to mechanically refrigerated cars (reefers). It became evident that these cars could not adequately cool grapes, because their refrigeration capacity was limited and loads heavier. These carriers could hold satisfactory transit temperatures provided the fruit had been brought to transit temperatures before loading.

It is not feasible to cool grapes by either the vacuum or hydrocooling method. Among the methods developed, perhaps the most significant innovation was the forced-air method of cooling. This system has a faster cooling rate than other air handling methods, because it brings the cooling air directly to the fruit in the package rather than just to the package. A pressure gradient across the package creates a positive flow of cooling air through the container providing direct contact with the packed fruit.

A high relative humidity (90 to 95 percent) must be maintained in the storage room to retard water loss from the fruit. Water vapor is removed from the air chiefly by condensation on the refrigeration surfaces and absorption by the wood and paper of the grape containers. Pressure systems producing a fog-spray to replace this water have been effective in commercial storages, especially during the first part of the season when the packages are dry and thereby readily absorb water vapor.

Air velocity, which must be high during cooling to bring the grapes to storage temperatures as quickly as possible, becomes a liability when these temperatures are attained. The rate of moisture loss is related directly to air velocity, which thus should be reduced to that needed only to maintain the desired fruit temperature.

Quality of table grapes can now be maintained for long periods provided proper harvesting methods are followed, measures are taken to prevent decay, and storage conditions are carefully monitored.

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Trellising and spacing adjust to modern needs

W. Mark Kliewer

The early trellis systems for growing raisin and wine grapes were quite simple. For head-trained, spur-pruned vines, a single 2- by 2-inch split redwood stake or other wood was placed at each vine, and the vine was then trained to the stake. For cordon- or head-trained, cane-pruned vines, one or two wires were fastened to a 5- or 6-foot stake at each vine 34 to 48 inches from the ground and held taut by firmly set end posts. This type of trellis in California has withstood the test of time and is probably the most widely used for growing raisin and wine grapes; however, the trend now is to place the wires higher to facilitate mechanical harvesting.

Table grape growers in the San Joaquin Valley pioneered the use of wide flat-top trellis systems between the First and Second World Wars. The sloping wide-top trellis was introduced in 1930 to Emperor growers by W. E. Gilfillan, Farm Advisor for Tulare County.

It has only been during the last 15 years that replicated field trials in California have compared trellis systems for grapevine productivity. A two-wire horizontal trellis, 22 inches between wires, when compared with a single-wire trellis, significantly increased Thompson Seedless raisin yield without reducing soluble solids.

Later, the benefits of increasing trellis height and width were demonstrated: vines trained on a single wire, 6½ feet from the ground, had significantly greater crop weight, pruning weight and number of clusters per vine than vines trained to a wire 4½ or 5½ feet from the ground. Soluble solids in fruits did not differ significantly between these treatments, but total sugar in fruits per vine increased with increasing trellis height. In a five-year study with Thompson Seedless vines in Parlier, wider trellises were found beneficial. Vines trellised on a four-wire double crossarm trellis, 30 inches between wires on the lower crossarm and 42 inches between wires on the upper crossarm, averaged about 20 percent higher yield, 40 percent greater growth, and significantly higher soluble solids in fruit than vines trained to a single cane-supporting wire. Trellis height was the same in each case. The increased yield resulted from a greater number of clusters per vine, because more buds were retained at pruning time.

The effects of trellising in combination with different irrigation treatments on crop yields and fruit composition of Cabernet Sauvignon were recently studied in the Salinas Valley. With adequate moisture to retain leaves, vines trellised to two vertical wires with a 30-inch crossarm for foliage support had 14 to 16 percent greater yields and 17 to 19 percent higher fruit sugar than vines similarly trellised, but without a crossarm.

In another study of four trellis systems in Napa Valley using Cabernet Sauvignon vines, raising the height of the crossarm for foliage support from 4½ to 5½ feet from the ground and using two vertical cane support wires 8 inches apart increased yields 27 to 45 percent when compared with a standard two-wire vertical trellis or a three-wire low "T" trellis. Fruit maturity (total soluble solids) and pruning weights (indicating overall vine growth and vigor) did