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

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 commod-
ities, 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 composi-
tion, 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 prefer-
dences 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 har-
vested 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.

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 con-
centration 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 SO2 (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 SO2, sup-
plemented 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 con-
centrations 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 SO2 was so great that it needed to be considered
in a formula calculating the SO2 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 SO2, no bleaching injury will result,
even during long storage periods, but the fruit must be exception-
ally 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 con-
centration 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 SO2 must be added for each
1 percent increase in relative humidity above 90 percent, and 2 per-
cent subtracted for each 1 percent below.

An in-package, two-stage SO2 generating system was developed
to protect against decay for extended periods. The first stage (sheet
of paper impregnated with sodium bisulfite) starts to generate SO2
inside the package within minutes of packing as the relative
humidity reaches saturation, in effect, substituting for the conven-

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

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Taking into account the importance of preventing decay, and carefully monitoring the storage conditions, the process of cooling becomes paramount. To that end, methods have evolved to ensure the desired fruit temperature is maintained, especially for cool-transportation purposes.

The first part of the season, when the packages are dry and thereby readily absorb water vapor, provides an opportunity to implement hydration strategies. Pressure systems, such as fog-spray, have been effective in commercial storages, especially during transit temperatures provided the fruit had been brought to transit conditions. Water vapor is removed from the air chiefly by condensation on the refrigeration surfaces and absorption by the wood and paper of the grape container walls. Pressure systems producing a fog-spray to replace this barrier, keeps the grapes much fresher, because it drastically reduces water loss. The U.S. export industry uses the second-stage treatment, especially if the liner is a water-vapor barrier, to prevent decay, and storage conditions are carefully monitored.

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. To prevent decay, and storage conditions are carefully monitored.

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Treillage and spacing

Towards adjusting 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

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