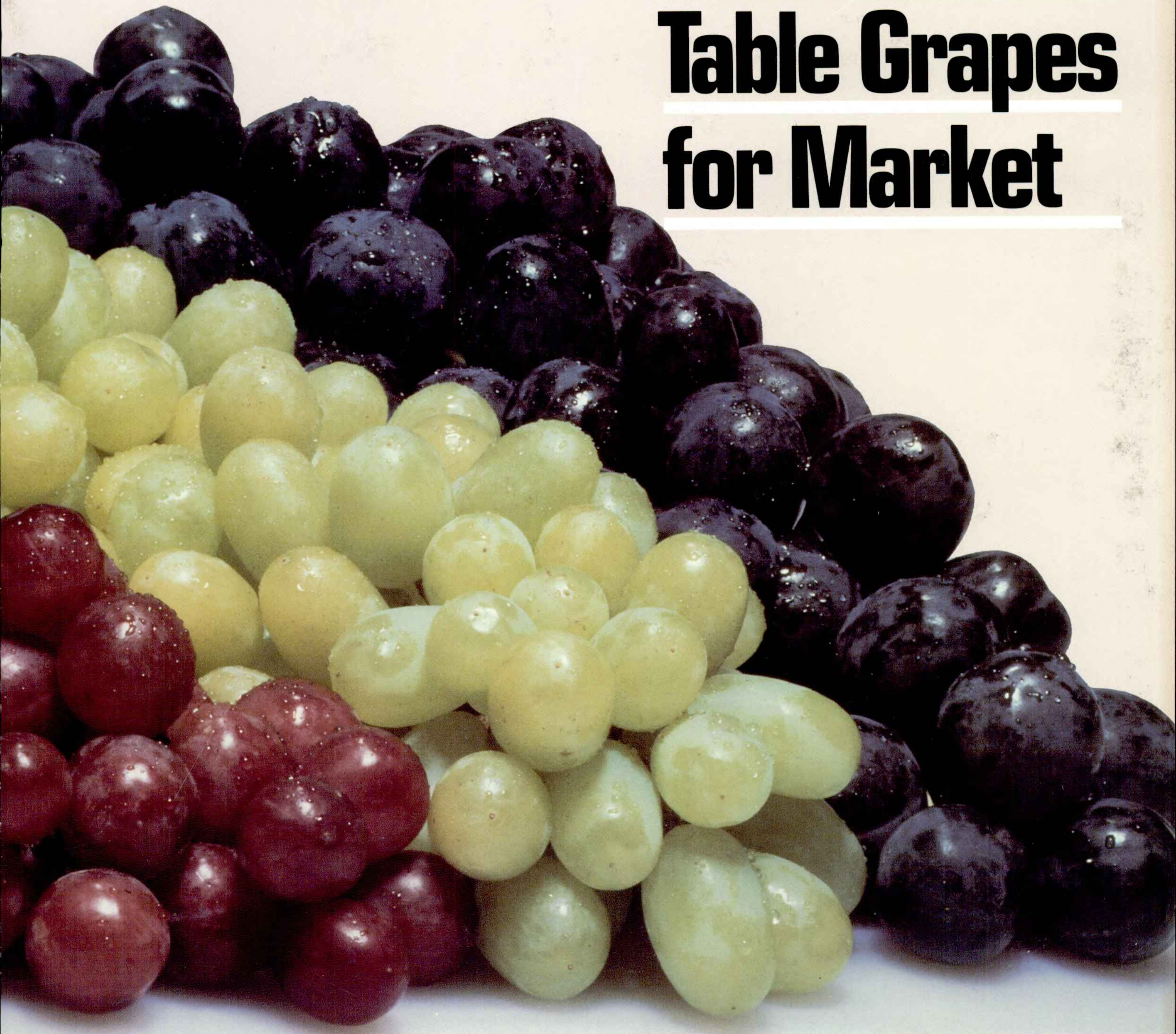
Harvesting and Handling California Table Grapes for Market



Agricultural Experiment Station ■ University of California ■ Division of Agriculture and Natural Resources

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Harvesting and Handling California Table Grapes for Market

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Preface

Table grapes (*Vitis vinifera* L.) are, physiologically speaking, 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. If any of these deterioration factors is not well controlled, the potentially long postharvest life will be drastically shortened. Modern technology has alleviated these problems to the extent that table grapes can be marketed most of the year and in most of the major markets of the world. Significant, then, is the use of this technology to develop systems of handling that will assure full utilization of the potential postharvest life of the fruit.

The last comprehensive publication on harvesting and handling of California table grapes appeared more than 50 years ago (Jacob and Herman 1925). At that time, no house-cooling of grapes existed—cooling was restricted to rail carriers equipped with ice bunkers, but no fans. Long-term storage of table grapes was essentially impossible before the introduction of the use of sulfur dioxide to control mold. Packing and packaging methods were strange by present standards, and distribution of the fruit was limited and seasonal. Palletization was still far in the future—hand trucks capable of transporting a dozen lugs at a time were the extent of shipping-point mechanization. Enormous advances in the technology of postharvest handling of table grapes have been made in the past half century.

This publication presents methods of harvesting and handling of table grapes, which can enable the contemporary grower-shipper to market high-quality fruit over long distances for extended periods of the year. Basic appearance, anatomy, and physiology of table grapes are described and illustrated with colored plates of the major table-grape varieties. Some plates depict responses of the fruit to different stresses of postharvest environment, such as dessication, physical injury, chemical injury, and attack by decay organisms.

Practical application of this information is emphasized as it pertains to the preservation of the market quality of the grapes while the fruit moves through the many stages of postharvest handling from the grower to the consumer. The information should be of value to grape growers, harvesters, and packers; quality-control personnel; refrigeration and fumigation specialists; carrier and distribution handlers; and retail produce managers.

It became necessary to update this publication after only 4 years because of rapid advances in technologies to control temperature, moisture loss, and decay before and during long-distance transport of the grapes. Integration of production and marketing schedules of southern- and northern-hemisphere industries stimulated these developments by putting more stringent demands on these technologies. Concurrently, the increasing consumer preference for seedless grapes brought about the development of new early-, mid-, and late-maturing seedless grape varieties that can be marketed in orderly succession during longer periods of the year.

History, Distribution, and Characteristics of Table Grapes

Origin and Distribution of Grapes

Grapes are the world's largest fruit crop with approximately 40 million tons produced each year. Further, they are the eighth-largest food crop in the world. Almost all of this fruit is from one species— *Vitis vinifera* L. This species grows best in a Mediterranean type of climate with long, relatively dry summers and mild winters. These conditions are restricted to areas in geographical belts generally between the 30th parallel and 45th parallel of the Northern and Southern hemispheres. Although most grapes are made into wine and another large part is dried into raisins, a significant part is marketed annually as fresh fruit, making table grapes one of the world's prominent fresh-fruit crops. This fruit has special significance as it is the only form of the grape that reaches the market in much the same appearance that it had when harvested from the vine. The consumer looks for a variety of colors and flavors of the fruit, as well as the convenient bite size of the berries. As a result, fresh grapes are in demand not only for eating, but also for decorative arrangements. Further, table grapes attract attention by their long history, rich in tradition. The Bible makes numerous references to the fruit of the vine, and frescoes painted on ancient Egyptian tombs depict servants serving clusters of fresh grapes to guests.

Vitis vinifera probably originated somewhere in the Middle East between India and the Mediterranean Sea. Its use antedates recorded history. Grapes were undoubtedly first used as table fruit; that is, consumed directly from the vine. The fresh fruit was so perishable that it was available only when the grapes were ripe and use was restricted to the immediate area of production. The only way to preserve this fruit for later use was to allow the grapes to dry into raisins on the vine, or to dry the harvested fruit in the sun much in the same manner as is done today in the San Joaquin Valley. This probably was the first method of fruit preservation. Later the phenomenon of fermentation was discovered and grapes were preserved in the form of wine.

Cultivars of the vine slowly spread eastward across southern Asia and westward around the Mediterranean Sea. In the process, selections with larger berries became preferred for table use. After discovery of the New World, people carried the vine to North and South America, South Africa, and later Australia. A suitable climate was found in those areas of the Americas known today as Mexico, the southwestern United States, Chile, and Argentina. It should be mentioned that people found many native species of *Vitis* in the New World. Cultivars of some of these, or of hybrids with vinifera, are used for table fruit. Notably, the Concord (a *V. labrusca*-*V. vinifera* hybrid) is popular locally as a table grape in the northeastern United States and in the Great Lakes area. It can tolerate more summer rain and harsher winters than the vinifera cultivars. However, the fruit cannot stand either the rigorous postharvest handling or extended storage that many of the vinifera cultivars can.

Marketing Grapes in California

Until the latter part of the nineteenth century, production of table grapes (*Vitis vinifera* L.) in California was limited almost exclusively to that for local merchants within the state. By present standards, this market was very small. However, the completion of the transcontinental railroad in the 1860s, followed by the development of the ice-refrigerated railroad car, made the large markets of eastern North America accessible. Expansion was slow at first, until the technologies of harvesting, packing, refrigerated car design, and railroad schedules improved so that grapes of acceptable quality could be delivered to markets as far as 3,000 miles away. The volume shipped east increased to nearly 14,000 tons annually by 1900 and to 140,000 tons by 1916. During the next 8 years, the volume increased rapidly to about 750,000 tons annually. This dramatic increase was due to several factors: (1) more efficient and complete reicing services across the United States; (2) faster railroad schedules; (3) advent of Prohibition, which caused many grape growers to switch from wine to table-grape production; and (4) enactment of standardization laws prescribing minimum standards of quality for the grapes.

Still, the market quality of the grapes left much to be desired. Delayed and inadequate cooling often resulted in soft, unattractive berries and dry stems that broke readily during handling. Decay was a major problem especially in years when wet weather occurred before harvest. Furthermore, the grapes had to be marketed very soon after harvest, which often caused market gluts and low prices. Technology had not advanced to the point where the fruit could be held in cold storage for more than a few days without drastic impairment of market quality. To meet these challenges, the industry—cooperating with the Experiment Station of the University of California and the United States Department of Agriculture—made substantial contributions. Marked improvements in grape quality and marketing schedules came about after the 1920s with the application of improved technology in five areas: (1) more complete information on the relationship of consumer preference to the chemical composition of the grapes and their flavor; (2) more accurate assessment of the decay potential of the grapes at the time of harvest; (3) more options and precise programs for utilizing sulfur dioxide to control postharvest decay; (4) more critical application of programs for temperature management to retard the spread of decay; and (5) better control of air temperature, velocity, and relative humidity to reduce the rate of grape deterioration from water loss and decay.

Table-grape Attributes

As the culture of *V. vinifera* spread, some cultivars emerged with morphological features and chemical compositions that were more desirable for table fruit. The berries are conspicuously larger than those of either wine or raisin grapes (plate 1). Large berries are not only more attractive, but also more convenient to eat when of bite size. Further, colored grapes are brilliantly pigmented berries—either bright red or jet black—not with intermediate hues of orange, brown, or purple. Although a berry that has a tender skin and detaches easily from the stem is desirable, relatively tough skins and strong berry attachments are essential attributes for table grapes, which must withstand the unfavorable environment of rigorous handling, storage, and transport. Such rough treatment often extends through long periods of storage and over long distances.

Flavor is another important attribute of table grapes. The sweetness of the sugars dominates, but at the same time is complemented by the tartness of the organic acids. Table grapes usually contain less of these major components than wine grapes: the sugars, because high sugar levels (although usually desired by the consumer) are associated by the trade with overmaturity and lack of keeping quality; and the acids, because high acid levels accentuate a sour or "green-fruit" taste. Prominent varietal flavors such as those of the Italia, Muscat of Alexandria, or Concord are usually desirable. However, excessive astringency, caused by the tannins found chiefly in the skins and seeds, is undesirable. Recently, seedlessness has become much preferred over seededness, especially in American markets, which pay a premium for this characteristic. As proof, growers of Thompson Seedless (classified as a raisin variety) go to great expense to girdle, berry-thin, and apply growth regulators to the vines to increase the size of seedless berries to that acceptable as table fruit (plate 1-K).

The Vascular Anatomy of the Grape Berry

Botanically, the fruit of the grapevine is a berry. The fruit is borne on clusters consisting of one hundred to several hundred individual berries (plate 1-A–1-L). The stem structure consists of a rachis (central stem), and primary and secondary laterals or branches (plate 2-A). Branching from these laterals are pedicels, often called capstems, each with a berry at its terminal end (plate 2-C). The stem structure has special significance with respect to the carrying quality of the fruit. The stems will dry readily and become brittle, especially when cooling is delayed excessively. Plate 2-A shows a cluster photographed within 2 hours of harvest, and plate 2-B shows the same cluster photographed 6 hours later after being held at room temperature. The dry brittle stems of cluster B would break more readily when handled than those of cluster A. Flexing of the stems from rough handling often causes breakage at the base of the laterals and pedicels resulting in detached berries—a form of *dry shatter* or *dry drop* (plate 2-D). The greatest bending occurs at the junction of these parts of the stems, which crushes the tissue and ruptures the cuticle. The result is that the rate of browning and shrinkage is accelerated because of exposure to oxygen and loss of a water-vapor barrier that results in rapid loss of water. Rough handling may also tear berries loose, leaving broken vascular strands as a wet brush still attached to the pedicel (plate 2-E). These strands were part of the central vascular system of the berry, which extends around and among the seeds to the stylar scar at the opposite end of the berry from the attachment area (plate 2-F). This type of separation constitutes a form of *wet shatter.* A weak pedicel attachment, or breaks in the skin around the pedicel attachment caused by stress of handling, aggravates this wet-shatter problem (plate 2-G). Another form of wet shatter or *wet-berry drop* results when decay organisms such as *Botrytis cinerea* Pers. ex Fr., *Cladiosporium herbarum* (Pers.) Lk. ex Fr., or *Stemphyllium* sp. rot the attachment area and cause the berry to slough off (plate 2-E). Symptoms of this type of shatter are the absence of a wet brush adhering to the pedicel, and maceration of the berry tissue in the attachment area.

A serious form of dry shatter often occurs when the pedicel detaches easily and cleanly from the berry during postharvest handling (plate 2-H). Evident are many pedicels without berries that have shattered in this manner. The problem can be especially acute with Thompson Seedless when as much as 15 percent of the berries may be left in the container after the clusters have been removed in the market. This shatter happens sporadically, being more severe in some seasons than in others. This type of shatter is definitely aggravated by improper cooling that results in dry stems, by advanced physiological maturity, and by rough handling.

Shatter is not necessarily restricted to clusters that are very ripe as measured by a high degree-Brix (percent soluble solids in the juice). Advanced physiological maturity may occur when harvest must be delayed because of a heavy crop resulting from inadequate thinning coupled with large berries induced by girdling and gibberellic acid applications. Under this condition maturity, or even senescence, of the vascular tissue of the pedicel attachment continues at a normal rate even if the increase in degree-Brix is abnormally slow. As a result, an abscission zone may form that weakens the attachment area causing shatter of berries that may still be relatively low in sugar content. Plate 2-I shows in longitudinal section the pedicel and attached vascular tissue (brush) of such a berry. Across the bulge of the pedicel in the lower part of the illustration, where it was attached to the skin of the berry, is what appears to be an abscission zone beginning to form. This zone is more clearly evident in the enlargement shown in plate 2-J. The cells in this zone across the "cylinder" of the pedicel appear to be separating. This usually happens when a cork cambium develops from parenchyma cells and, as a result, intercellular bonding weakens. Cleavage of the tissue in this zone can now take place, often with little stress as when the pedicel is twisted or bent during handling. Separation leaves the attachment area of the berry essentially healed with the central vascular strands still embedded in the berry.

A peripheral vascular system originates at the pedicel attachment area and forms an envelope of strands surrounding the pulp just underneath the subepidermal cell layer. This system is shown in a longitudinal section of an Emperor berry (plate 2-F). The network arrangement of the strands is the result of the enormous enlargement of the pulp cells during berry growth that stretched these strands laterally and caused them to assume a diamond-mesh pattern. At the same time, expansion of the pulp cells isolated this peripheral system from the central system. Shown in plate 2-K is an Emperor berry partly peeled to provide a surface view of this network of strands.

The central part of the berry can hold zero to four seeds (plate 2-F). In a Thompson Seedless berry rudimentary seeds can usually be detected indicating that the embryos aborted at a very early stage of development (plate 2-L).

The pulp tissue extends outward to the peripheral vascular envelope (plate 2-F). It is composed of relatively large isodiametrically shaped cells with large vacuoles and thin walls. Most of the soluble solids are in these vacuoles. Just outside the peripheral vascular envelope are four to six layers of much smaller cells that constitute the subepidermal envelope (plate 2-M). The shape of these cells ranges from isodiametrical to laminated. The depth of the cells is much less than the width because the cells stretched in a lateral direction during expansion of the pulp cells. These subepidermal cells have thicker walls than those of the pulp and are heavily impregnated with pectic compounds, which form the middle lamella or intercellular bonding material (plate 2-N). These cells contain the anthocyanin pigments of colored grapes. Plate 2-K shows that the peel (which consists of six to eight cell layers) removes all these pigments.

The Epidermal Anatomy of the Grape Berry

The epidermis is a well-defined layer of cells outside the outer subepidermal layer (plate 2-M, 2-N). The cells are even more distinctly laminated than those of the subepidermal layers. Closely bound to the epidermal layer is a relatively impervious cuticle, about 2 to 4 microns thick (plate 2-O). This cuticle is composed of a complex matrix of wax and waxlike compounds, highly resistant to the transfer of water or water vapor (Radler and Horn 1965). This property of the cuticle is particularly effective in retarding the rate of water loss from the berry after harvest and thus keeping the berry longer in a fresh crisp condition. However, water loss is still a formidable problem in maintaining a crisp fresh condition. Shown in plate 2-P are six Emperor berries at different stages of water loss ranging from 0 percent to about 8 percent. The upper left berry is still in a fresh turgid condition. The taut cuticle gives the berry a shine or luster. Those to the right in the upper row become duller in appearance as the cuticle loses tension because the berries shrink from loss of water. In the lower row, the berries show more and deeper wrinkles as water loss continues and they become even duller in appearance. This change in appearance might be likened to deflating an inflated balloon—it becomes duller in appearance and finally develops wrinkles as it is deflated.

Water loss also causes the skin to pull away from the pedicel attachment and form a depression around the base of the stem. This condition is first discernible in the middle berry of the upper row, becoming very noticeable in the lower berries (plate 2-P). The impression of the average consumer probably would not be adversely affected by the condition of the second berry, but likely would be by that of the third. The pronounced flabby state of those in the lower row, especially of the last berry, would probably be unacceptable. The more pronounced shrinkage in the attachment area is due largely to the "wicking" action of the stem. Stems lose water much more rapidly on a weight-per-unit-volume basis than do the berries because of the high surface-to-volume ratio, and because they have a high concentration of stomata and lenticels through which water vapor can escape readily. Further, the rate of water loss is drastically increased through breaks in the cuticle at the stem—injuries commonly caused by the stress of handling (plate 2-Q).

The bloom on the surface of the cuticle is the effect of light reflected and diffused by the overlapping wax platelets (Chambers and Possingham 1963). Altering the orientation of these platelets by rubbing destroys this bloom, giving the cuticle a shine rather than the desirable luster effect (plate 2-R). To the experienced grape merchandizer, the condition of the bloom is an informative symptom of the amount and roughness of handling that the fruit has received.

The Effect of Sulfur Dioxide on Table Grapes

Lenticels are present on the berry as very small and widely scattered mounds of suberized cells (plate 2-S). They are located on the pedicel also, but are much larger and closer together than they are on the berry surface (plate 2-G). Sometimes these lenticels are incompletely suberized and therefore are pervious to chemicals such as sulfur dioxide. This fumigant can penetrate such lenticels and cause localized bleaching of the skin tissue. The Thompson Seedless berry on the right of plate 2-T shows a few very small light spots in the lower area where sulfur dioxide has penetrated into the epidermal cells through lenticels, causing localized bleaching of the yellow carotene pigment. At the same time, the bleached halo around the stem area was caused by diffusion of sulfur dioxide into the berry through the numerous lenticels and stomata in the pedicel tissue.

Sulfur-dioxide bleaching is more conspicuous in red or black grapes than in white grapes because the gas bleaches the red anthocyanin pigments as well as any carotene or chlorophyll pigments present. Shown in plate 3-A is a Flame Tokay berry with many prominent bleached spots whose locations do not coincide with those of lenticels. To determine how the sulfur dioxide gained access to the underlying tissue, one spot was encircled with India ink and the berry was then submerged in a methylene-blue dye solution for 2 hours. Shown in plate 3-B is this berry after being rinsed thoroughly. Evidently the dye had penetrated into the underlying tissue through microscopic openings in the cuticle—apparently the same openings through which the sulfur dioxide had penetrated earlier (Nelson and Tomlinson 1958).

Sometimes, berries that have been in cold storage for several weeks at high relative humidity, and therefore were treated several times with sulfur dioxide, will have faint bleached areas showing droplets of juice that have exuded from inside of the berry (plate 3-C). Such a berry when treated with the methylene-blue solution will show a dense concentration of blue spots—so dense that the spots often have coalesced into large blue areas. Plate 3-D shows a berry that had been in contact with the lid of the lug so firmly that its side had flattened. The location of the dye spots suggests that abrasion from the lid caused numerous microscopic injuries. Lid pressure may often crack berries causing conspicuous injuries. Later in storage, if this fruit has been adequately treated with sulfur dioxide, the wounded area will be bleached, especially the edges of the crack (plate 3-E). Seldom will such berries decay, because of the high concentration of sulfurous acid that builds up in the open, wet wound during fumigation. From this standpoint, the effect of the gas is beneficial because the berry probably would not have been edible anyway. Further, this bleaching symptom can be useful in determining whether adequate sulfur dioxide has penetrated to the fruit during the storage treatments.

The abrasive effect of one berry rubbing against another can cause microscopic injuries. Plate 3-F shows a berry with a band of blue dye that encircles the shoulder of the berry. This berry had been on top of the pack during a simulated transit test incorporating vibration movement. Apparently, the berry oscillated on the axis of its stem coming into abrasive contact with adjacent berries in the process. Fine particles of matter, such as dust on the surface of the berries, could have been the abrasive agent. At any rate, such movement of berries during transit is possible, especially if the pack is slack—loose from poor packing and shrinkage because of water loss. The ideal pack should be of sufficient density to prevent the fruit from moving, but should not allow the pressure of the lid to crack the berries.

Water loss is aggravated by microscopic injuries coupled with killing of epidermal cells by sulfur dioxide (plate 3-G). The craterlike appearance of the spot in the lower center part of the photograph indicates that juice has been lost from this area. The blue line in the larger bleached area above the crater indicates that the injury was caused by a scratch type of abrasion.

Loss of juice is not restricted to just that from the berry surface. Plate 3-H shows a pedicel with a droplet of juice on the tip of each of several lenticels. In this case, the sulfur dioxide has penetrated the lenticel and injured the underlying stem tissue. As in the berry, the cytoplasm of injured or killed cells loses its semipermeability, resulting in the juice from the vacuoles oozing out through openings to the surface. This juice forms an undesirable sticky surface after it has been smeared about by movement among the berries. This condition is often referred to as *wetness* in the trade, and is distinctly different from the condition when the berry is wet from water vapor that has condensed on the surface of cold fruit when brought into warm humid atmospheres. Not only does this sticky wetness detract from the appearance of the fruit, but when dry the sugars give the grapes an undesirable shiny (varnished) appearance (Nelson and Tomlinson 1958).

The combination of microscopic injuries, sulfur-dioxide injury, and drying conditions drastically shortens shelf life of grapes and impairs their appearance. Plate 3-I shows five Emperor berries with levels of sulfur-dioxide injury ranging from none to very severe. Plate 3-J shows the same five berries after 3 days at room temperature and the effect of the rate of water loss from the fruit. Plates 3-K and 3-L show a parallel situation with Thompson Seedless grapes. The first two berries in the lower rows of 3-I and 3-K would probably have been acceptable; however, after 3 days even these would probably have been unacceptable.

There are normally no functional stomata in the cuticle of the mature grape berry; however, they are present in the pedicel. Their absence in the berry is one reason why the cuticle of grapes is relatively impervious; the fruit can tolerate sulfur dioxide to a much greater extent than most other fruits.

The Effect of Ammonia on Table Grapes

Ammonia, as well as sulfur dioxide, has on occasion injured grapes. Ammonia is not used deliberately, as is sulfur dioxide, but reaches the fruit as a result of accidental leaks in the refrigeration system (Ryall and Harvey 1959). On many occasions, storage grapes have been damaged, sometimes so severely as to be worthless. The mode of penetration is similar to that for sulfur dioxide, but the symptoms of injury are quite different. Any opening in the cuticle can be an avenue for penetration, so symptoms of mild injury are spots in the skin. However, these spots are brown in color on white grapes with no signs of bleaching (plate 3-M). Also, the stems of the injured fruit on the right in the photograph are deep brown to black, whereas the stems of sulfur-dioxide-treated grapes would still be some shade of green. If the stems are still fairly plump, when exposed to the gas, they will have a water-soaked appearance. If the injury is severe, the berries will be deep brown to almost black as shown by the Thompson Seedless fruit on the right in plate 3-N. Red or black grapes do not show the dramatic color change when injured, but the symptoms are still very characteristic. A distinct bluish color is imparted to the anthocyanin pigments because the strong basic reaction of ammonia with water raises the pH of the juice to, or above, neutrality. Plate 3-O shows uninjured and ammonia-injured clusters of Cardinal grapes. The blue-to-black color of injured berries is shown more clearly in plate 3-P. Although not evident in these photographs, the pulp tissue of severely injured white or colored grapes becomes water-soaked in appearance and the berries will exude juice through openings in the cuticle.

The Effect of Freezing on Table Grapes

Table grapes, being living tissue, are damaged by freezing (Ryall and Harvey 1959). On rare occasions, this may occur in California vineyards before harvest. If vineyard temperatures drop to $-2°$ to $-3°C$ (26° to 28°F) for several hours, freezing of the stems can be expected; if the temperature drops further, the berries will probably freeze too. When frozen stems are thawed, they first become water-soaked in appearance, then turn brown and finally black. They will shrivel rapidly and become brittle if drying conditions prevail. The pulp of the berries has a water-soaked translucent appearance upon thawing. This pulp starts to turn brown, especially when exposed to the air. Plates 3-Q and 3-S show Thompson Seedless and Cardinal berries in longitudinal section. The berry on the left in each case had not been frozen, while the one on the right had been frozen and just thawed when sectioned. The browning that had taken place at the time the photographs were taken is evident. Not evident in the photographs, but apparent when the material was viewed, was the water-soaked appearance of the pulp tissue. Berries that had been frozen exuded juice like those in storage that had been injured by sulfur dioxide (plate 3-R). After freezing, browning is associated with this "leaking," but not bleaching as with sulfur-dioxide injury. Plate 3-T shows the effect of freezing on the stems of the berries on the right. They are water-soaked and brown in comparison to those of the nonfrozen berries on the left.

Occasionally, grapes have been frozen accidentally after harvest. This is most likely to occur in fruit most exposed to the air coming from the refrigeration surface in the cooler, storage room, or carrier. If temperatures of $-2°$ to $-3°C$ (26° to 28°F) persist for several hours, the symptoms of freezing described for fruit in the vineyard will likely appear. However, they may not be evident for 2 to 4 days following injury because of the low prevailing temperatures of storage and transit.

The Effect of Pathogenic Organisms on Table Grapes

Several fungi will attack grapes and cause decay or scarring of the berries. The most important postharvest decay organism is *Botrytis cinerea* Pers. It is especially serious because it grows vigorously at ordinary vineyard temperatures of 10° to 25°C (50° to 77°F). Even in storage it will continue to grow, although slowly, at a temperature of $-1°C$ (30°F). Further, it can infect grapes by direct penetration—not even requiring a wound to gain entrance (Nelson 1956). Its parasitic nature is shown in plates 4-A and 4-B. A conidium (spore) of about 10 microns in diameter has germinated on the surface of the cuticle of the berry, producing a germ tube at whose terminal end is an attachment structure (appressorium). This appressorium in turn has produced a very thin infection peg that has penetrated through the red-stained cuticle. Plate 4-B shows the beginning of a subcuticular mycelium that originated from such an infection peg. Plate 4-C, an overhead view in the plane of the epidermal cell layer just under the cuticle, shows plainly the subcuticular mycelium growing between the epidermal cells. This mycelium produces enzymes including pectinase that hydrolyze the pectic compounds of the middle lamella between the cells, causing these cells to separate. Plate 4-D shows a macerated area where the cells appear to be separating in sheets, as though the enzyme were more active on the pectic materials between the cell walls parallel to the surface of the berry than those perpendicular to it. Such lesions are easily seen on white grapes as brownish areas (plate 4-E). On red grapes, they can sometimes be seen as a faint grayish area. The central berry in plate 4-F has such a lesion on the left side. Slight pressure easily ruptures the skin over the lesion at this stage, because the only tissue holding the skin in place is the very thin cuticle (Nelson 1951a). In plate 4-G are two Flame Tokay berries with

Botrytis lesions. The one on the left has the skin still intact and the lesion is barely visible, but the one on the right has been subjected to slight pressure causing the skin to slip from the intact pulp tissue underneath the lesion. The term *slip-skin* is often applied to this type of infection, which is characteristic of an early *Botrytis* infection. Often the lesion may encompass the entire berry with the result that all the skin will slip from the berry leaving the pulp tissue intact. Only the epidermal- and subepidermal-cell layers are macerated until advanced stages of decay are reached. Turgor pressure of the berry often breaks the fragile skin over a field infection of *Botrytis*, with the result that the fungus grows out through the crack forming a ridge of ash-colored conidiophores and conidia (plate 4-H). This phase of *Botrytis* infection is often termed *gray mold rot.*

If a *Botrytis*-infected berry, such as that shown in plate 4-F, is not detected and is packed, the fungus will continue to grow in the berry. The fungus cannot be eradicated with sulfur dioxide, even at severe dosage levels (Nelson 1958). However, if storage fruit is re-treated every week with the proper dosage of the fungicide, the infection can be contained within the berry. Plate 4-I shows such a berry after 2 months of storage at 0°C (32°F). The fungus is still viable within the berry, but no adjacent berries have been infected. Such "brown bombers" are indicative of effective sulfur-dioxide treatment as contrasted with the infected berry in plate 4-J where the fungus has spread into several surrounding berries. At storage temperatures, the fungus produces few spores so the mycelium is white as contrasted with the gray color of vineyard infections (plate 4-H). Without effective sulfur-dioxide treatment, the fungus nest can and may infect a whole cluster (plate 4-K); if unchecked, the entire pack may become a mass of moldy fruit.

Occasionally *Botrytis* may invade the stem from an infected berry and spread to other berries by this route. Plate 4-L shows part of the stem structure in a brown water-soaked condition indicative of decay. This stem rot commonly develops under the conditions shown in plate 4-H. The fungus can invade the stem from the infected berry, then subsequently spread throughout the stem structure in storage. Although the fungus can be contained within a berry, it is difficult, if not impossible, to prevent its spread in stems; hence the importance of trimming out all infected parts, such as those shown in plate 4-H, during packing.

These illustrations suggest the insidious nature of *Botrytis* as a postharvest mold. The threat of undetected field infections in storage grapes is the primary reason why sulfur dioxide must be applied weekly as long as the grapes are stored. Even complete containment of the infections with the fungicide may not be adequate if too many infected berries are present to begin with. For example, a tolerance limit of 0.5 percent decay by weight represents about 12 normal-sized Emperor berries per box. Obviously, if the number of infected berries packed in each container exceeds this number, the pack could not pass a condition inspection later in storage, no matter how near-perfect the decay control program had been.

Fortunately, some precautions can alleviate the problem of *Botrytis* mold in storage. The fungus is most apt to infect grapes after they are ripe, and even then moisture on the berries or a high relative humidity must persist for a day or two to allow time for conidia to germinate and establish infections (Nelson 1951b). Such conditions are usually brought about by rain, dew, or fog. Heavy-cover crops and rank vine growth may aggravate the problem by causing the moist conditions to prevail until infections can be established. If infections are suspected under these conditions it is wise to suspend harvesting for at least 2 or 3 days. By that time infections that would otherwise be undetected will now be more apparent and can be trimmed out before the grapes are packed (Nelson 1956).

Botrytis may cause decay of storage grapes that have never been exposed to wet conditions before harvest. This decay may result from infections that have been latent in the berry. The fungus has been reported capable of infecting the berry through the style during bloom, then remaining dormant during the growing season (Hewitt 1974). As maturity approaches the fungus may reactivate to cause rot easily discernible at harvest, or it may not cause symptoms until the grapes have been packed and stored. Plate 4-M shows two berries in the summer bunch-rot phase of this fungus. These berries were not in close contact with the other berries in the cluster, so the rot had not spread. Drying conditions have caused both to shrivel, one almost to the mummy stage when photographed. Had these berries been in the interior of the cluster, they likely would have caused summer bunch-rot of the cluster either by contact infection or by the decay traveling through the stem structure from infected to uninfected berries.

At least three fungi cause a form of storage decay called *black spot.* In some years the most trouble is caused by *Cladiosporium herbarum* (Pres.) Lk. (Dufrenoy and Genevois 1935). It can infect uninjured grapes much in the same manner as *Botrytis* (Hewitt 1974), which makes it particularly significant. The incidence of decay by the fungus varies widely from year to year, but does seem to be most severe following early fall rains (Delp, Hewitt, and Nelson 1951). It is most troublesome in Emperors, especially those harvested late in October or early in November.

Whether it infects through the uninjured skin or through wounds, the fungus grows slowly in storage causing characteristic black spots (plate 4-N). These spots may not appear for several weeks. The decay is not confined to the epidermal layers as with *Botrytis*, but macerates the pulp tissue, often to the seeds. The decayed tissue has some integrity and can sometimes be lifted from the berry leaving a deep hole, in comparison to the decay caused by some other fungi that turn the pulp tissue to a watery consistency. If not contained by weekly sulfur-dioxide treatments, the fungus can spread slowly to other berries by contact infection. Eventually the mycelium may erupt through the skin, white at first, then appearing as an olive-colored felt covering over the berry (plate 4-O). The fungal infections are usually not detectable at harvest; hence the storage fruit should be closely monitored, especially if there has been wet weather before harvest.

Black-spot decay is also caused by species of *Alternaria* and *Stemphylium* (Harvey and Pentzer 1960). The growth patterns and appearance of the lesions of these fungi are similar to those for *C. herbarum.* However, these fungi can infect the berry only through wounds. As a result, it is commonly these fungi that are associated with the black-spot decay of the stem-attachment area (plate 4-P). An injury at the base of the pedicel caused by handling probably allowed either or both of these fungi to infect the two decayed berries shown in the illustration. These fungi (as well as *Cladiosporium* if it does infect the pedicel area) will usually rot the vascular strands so that, if the berry is detached or sloughs off, there is no wet brush left on the pedicel. The pedicel on the right in plate 2-E was affected in this way. Early fall rain increases the incidence of Alternaria and Stemphylium rots just as it does that caused by *Cladiosporium.* Wet conditions probably encourage growth of these fungi on dead organic matter or injured fruit, which build up a spore load in the vineyard. With more spores present, infections through wounds caused by postharvest handling are more likely to increase.

Species of *Penicillium* (blue mold) can infect grapes but are rarely a postharvest problem. They require a wound for entrance into the berry, which limits their infection capability. Moldy harvesting equipment such as field lugs can be a source of inoculum and, if berries rub against the bottom and sides of the containers, infection can result. Subsequent rough handling causing further injuries increases the possibility of blue-mold infection. *Penicillium*-infected berries can be detected by the watery consistency of the contents and a pronounced moldy odor. If the fungus grows on the surface, it will appear as tufts of white mycelium, which rapidly turn blue or green as a dense mat of spores is produced (plate 4-Q).

Aspergillus niger v. Tiegh. is frequently encountered in the vineyard as a part of a hot-weather bunch-rot complex. Although not a true smut fungus, it is frequently called *smut* because of the black sooty appearance of infected berries caused by the black conidia of the fungus (plate 4-R). The rot, like that produced by *Penicillium* sp., reduces the pulp tissue of the berry to a watery consistency. The fungus grows very slowly or not at all at normal transit and storage temperatures; therefore the presence of *Aspergillus* infections in harvested table grapes indicates one of two things: (1) poor trimming so that field infections of the fungus were not eliminated from the pack; (2) gross temperature mismanagement so that high temperatures prevailed long enough for the fungus to become established. Under normal circumstances, then, this fungus is not a postharvest problem. However, in the market, if displayed fruit is allowed to remain at or above 20°C (68°F) for a day or more, this fungus may appear. If sporulation takes place, the spores have the added nuisance effect of soiling sound berries as they are smeared about during handling.

What has been said for *Aspergillus* sp. applies generally to *Rhizopus* sp. This fungus is a common hot-weather bunch-rot organism, which if trimmed from harvested fruit does not become a postharvest problem with normal handling. This fungus grows rapidly under warm, moist conditions producing a coarse gray mat of mycelium. Distributed in this mat are numerous sporangia (spore balls), which gives the mycelium the appearance of having been sprinkled with fine black pepper (plate 4-S).

The fungus *Uncinula nectrix* does not produce rot of grapes, but can seriously detract from their quality. During the growing season, if not controlled, it invades the epidermal cells of the green surfaces of the vine, including the cluster stems and berries. It does not spread further on the stems and berries after harvest, especially after the first treatment with sulfur dioxide. However, it leaves a characteristic lacy scarring pattern on the berries (plate 4-T). Heavy infections, especially later in the season, may show the presence of the external mycelium and conidia as a powdery covering on the berry; hence the name *powdery mildew* (plate 4-U). The berries may even be deformed or cracked as a result of severe infection, leading to invasion by mold organisms that cause decay (plate 4-V). The stems may also be affected, showing the same appearance (plate 4-W). A serious problem is that these infected stems shrivel and break readily causing shatter of the berries when the clusters are removed from the lug.

A type of scarring similar to that caused by powdery mildew is caused by thrips, a very small insect that scars the surface of the berry in early development (plate 4-X). Commonly, the insects will remain under dead floral parts at the calyx end of the berry shortly after fruit set and their feeding on the berry in this area will cause rather coarse scarring, not the delicate lacy pattern of that caused by mildew (Jensen and Luvisi 1973).

Chemical Composition of the Berry

The principal components in the ripe grape are carbohydrates—chiefly sugars. Glucose and fructose are present in about equal amounts. Normally, there is less than 1 percent sucrose and practically no starch. The total sugar content in most table-grape varieties, when considered commercially mature, ranges from about 14 percent to 18 percent. The degree-Brix is often called the sugar percentage but, as will be explained later, other compounds affect the degree-Brix value, although usually to a small extent. These sugars accumulate rapidly only during the 21 days to 60 days before harvest. Heavy cropping, disease, or inadequate sunshine will slow the rate of this increase, sometimes drastically (Winkler et al. 1974).

The organic acids, although present in small amounts compared with the sugars, contribute markedly to the overall taste. They do not ordinarily exceed 1 percent by weight of the juice and may be as low as 0.4 percent. Tartaric is usually the dominant acid, although malic may be present in significant quantities. Citric, succinic, and other acids may also be present, but only in very small amounts.

The acid concentration increases rapidly early in the season, often to as much as 3 percent shortly after berry set, then declines until harvest. However, the *total amount of acid per berry* increases until the berry is nearly full size (Winkler et al. 1974).

The phenolic compounds in grapes are significant in many ways. The anthocyanins in the subepidermal cells of colored grapes are synthesized in the berry as it reaches maturity. The simpler complexes of malvidin, cyanidin, petunidin, and delphidin-3-monoglycosides impart the bright-red color characteristic of Flame Tokay and Emperor grapes. Additional compounds such as these pigments acylated with p-coumaric and caffeic acids, and peonidin-3-monoglucoside, impart more intense pigmentation ranging from deep red to jet black as in Ribier (Winkler et al. 1974).

Tannins, the condensation products of phenolic compounds, are found chiefly in the epidermal-cell layers and the seeds. They cause the astringent taste. Further, they impart the brown color to injured or senescent cells. Italia berries bruised by lid pressure commonly show this symptom. Sometimes this browning develops in the area of the rudimentary seeds of Thompson Seedless, commonly referred to as *internal browning* (plate 3-X, 3-Y). Tannins are formed when the enzyme polyphenoloxidose is released into the vacuoles of the cells from injured or senescent cytoplasm, there complexing the phenolic compounds into the brown tannin end product.

Characteristic varietal flavors appear to be produced by many compounds, present for the most part in very small amounts. Only two have been identified as being at least the dominant flavor component—terpene linalool, which causes the characteristic flavor of muscat grapes, and methyl anthranilate, which is the flavor of the Concord variety (Winkler et al. 1974).

Physiology of the Grape

Grapes as living tissue respire, although the rate is low compared with that of most other fruits (Lutz and Hardenberg 1968). Very small amounts of sugar and organic acids are slowly converted into CO_2, H_2O, and heat. There are few other significant chemical changes. Since there are no starches to convert to sugar, there is no increase in sweetness. Any softening of the tissue is due to flaccidity from water loss as there is little, if any, hydrolysis of the intercellular pectic compounds. The grape, then, can live a relatively long time after harvest if protected from water loss, decay by microorganisms, and injury from rough handling. This life can be extended to as long as 6 months or more (depending on the variety) if the temperature is kept as low as possible without freezing. The low temperature minimizes the respiration rate, which prolongs the normal metabolism of the fruit and thereby its useful postharvest life.

The Table-grape Vineyard

Trellising and Training

Trellising and training are more important for a table-grape vine than for either raisin or wine-grape production, because greater emphasis is placed on *appearance* as well as total amount of the fruit. A well-trellised vine can produce more usable table fruit partly because more clusters are attractive and of uniform maturity. This happens because the clusters hang isolated, free of being rubbed by leaves, shoots, or trellis wires. Highest production can be obtained only if the leaf canopy is spread out so that a maximum number of leaves *see* the sun. Only in this green chlorophyll tissue are the sugars synthesized, and only if exposed to sunlight. A green leaf traps about 90 percent of the radiant energy of the sun, leaving only about 10 percent for the leaf in its shadow (Kliewer, Lider, and Schultz 1967). In fact, densely shaded leaves are a liability to the vine, consuming more energy in growth than they provide in the trapped energy of synthesized sugars.

Leaves should *see* the sun, but the fruit should not. Exposed berries frequently sunburn in the severe temperature and light-intensity conditions of California vineyards (plate 3-U, 3-V). At the same time, pigmented varieties such as Emperor and Tokay grapes will not color satisfactorily in deep shade (plate 1-O). Such fruit will color though if the leaf canopy is thin or if a reasonable amount of reflected light reaches the berries from the sky (plate 1-L). How extensive a trellis can be to provide these conditions often is limited by cost or cultural operations. Most California grape growers favor a crossarm type. Figure 1A shows a sloping-crossarm trellis. This system provides good exposure of the leaf canopy to the sun, yet the fruit is well shaded to minimize sunburn. Also, the clusters are isolated from the leaves and easily accessible for harvest (fig. 1B). However, if the crossarm is offset and slopes rather steeply as shown in figure 1A, the fruit of a cordon-trained vine will frequently be excessively crowded under the lower end. Further, deep shade in this area often results in poorly colored fruit of red and black varieties (plate 1-O, 1-S). Less slope and less offset will alleviate these problems. Favored by many table-grape growers is a horizontal-crossarm system of either one or two crossarms (fig. 1C). This trellis provides easier access to the fruit from both sides of the vine, and the distances from the head of the vine to the trellis wires are more uniform to facilitate tying the canes of Thompson Seedless vines to the wires. Also, for a cordon-trained vine, there is more uniform spacing of clusters and uniform coloring of red and black varieties than with a sloping-offset trellis.

The number of crossarms, their length, height from the ground, and angle of slope varies depending on several factors: (1) vigor of vine growth; (2) whether the vines are cane or cordon pruned; (3) the need for shoot and leaf removal so clusters hang free; (4) the need for berry thinning; (5) growth regulator and pesticide applications of sprays or dusts that are required; (6) irrigation system used; and (7) cover-cropping program followed. The vines are usually spaced 10 to 12 feet between rows and 6 to 8 feet between vines in the row. Rows are seldom longer than 220 yards, so irrigation runs are not excessively long and harvesting crews do not have to haul fruit long distances to the avenues.

More elaborate trellis systems are used in other table-grape districts of the world, especially where labor costs are lower. In South Africa, the sloping crossarm may be so long that the higher ends are supported from the next row giving a "factory-roof" appearance to the vineyard (fig. 2D). In Spain and Chile, a horizontal-overhead trellis of beams or wires is commonly used (fig. 3E). Such systems facilitate more intricate hand-thinning and uniform applications of growth regulators, which further improve the appearance of the fruit. For example, in South Africa, meticulous hand thinning of the normally tight clusters of the Barlinka makes this variety feasible to grow, whereas in California labor costs would make it prohibitive. In Chile, often clusters of Thompson Seedless are hand-sprayed individually several times with gibberellic acid. Such treatments not only increase berry size, but the increase is more uniform.

Cultural Practices before Harvest

Precautions should be taken in preparing the vineyard for harvest to facilitate the operation and retain the attractive appearance of the fruit. The avenues should be treated to prevent dust clouds created by moving vehicles from settling on the clusters and detracting from their appearance. The space between the rows should be prepared to facilitate movement of vehicles between the vines for distributing picking containers and to pick up those that are filled. This preparation necessitates withholding irrigation water long enough to stabilize the soil for such traffic. Irrigation furrows may have to be leveled and high-cover crops removed. Even some pruning of long shoots or leaf stripping may be necessary so that the pickers will have easy access to the fruit.

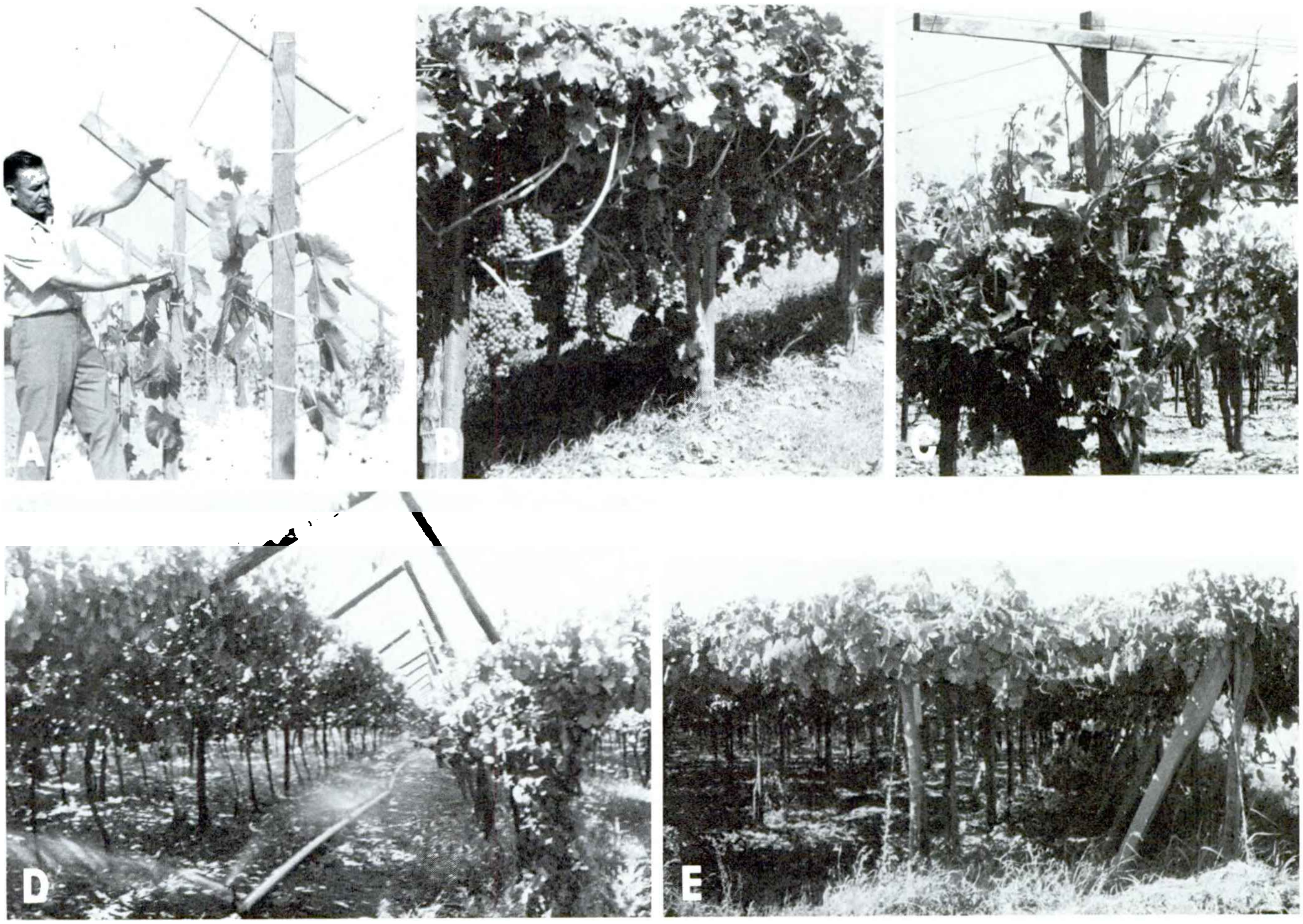


FIGURE 1. Table-grape vineyards.

A. Young California vineyard with a sloping-crossarm trellis system. The wire, at a 42-inch (108-cm) height, supports the arms of a horizontal-bilateral cordon, while the wires on the sloping crossarm support the shoots or, if Thompson Seedless, the canes and shoots. Rows are oriented east and west if possible, with the high ends of the crossarms pointed north to provide maximum shade for the fruit and exposure of the leaf canopy to the sun. The fruit clusters hang in the zone indicated by the outstretched hands for easy accessibility for thinning, leaf pulling, and harvesting because it is relatively isolated from the leaf canopy.

B. Row of California vines on a sloping-crossarm trellis ready for harvest. Rows are usually 12 feet (3.7 m) apart. Note that leaves and lateral shoots have been stripped from the lower parts of the primary shoots to minimize leaf rubs on the berries, to improve exposure to light, and to make the clusters more accessible for harvest.

C. Young vine being trained on a horizontal-crossarm trellis. The lower crossarm, at a 42-inch (108-cm) height, is 18 inches (45 cm) long and supports two or three wires onto which canes can be tied (four to six canes per vine). The upper crossarm, at a 60-inch (154-cm) height, is usually 36 inches (93 cm) long and supports two or three wires. As the shoots grow upward from the cordon or canes, they are restrained by these wires from bending over and covering the fruit.

D. Typical vineyard in the Republic of South Africa with the vines trained on a factory-roof type of trellis. The rows are usually 10 to 12 feet (3.3 to 3.7 m) apart and the vines 6 to 8 feet (2 to 2.5 m) apart in the row.

E. Typical Chilean vineyard with the vines trained on a horizontal overhead-wire trellis. The supporting poles are usually spaced 13 feet by 13 feet (4 m by 4 m) apart, each 6.5 feet (2 m) high with a vine trunk trained to the top. The arms, canes, and shoots (as well as fruit) are supported by a lattice of wires spaced 1.5 to 3 feet (0.5 to 1 m) apart. Six- or eight-gauge wire is strung across the tops of the poles in both directions and 10- or 12-gauge wire is interlaced between to complete the lattice.

Factors Affecting Time to Harvest Table Grapes

When to Harvest Table Grapes

Table grapes should not be harvested until mature. Unlike many fruits, grapes do not ripen after harvest, so they should be picked only after they reach the optimum stage of acceptability in appearance, flavor, and texture.

Color and Maturity

Appearance is determined chiefly by color, especially for red and black grapes (plate 1-A–1-L). In fact, standards for color (white varieties excepted) are specified in the *United States Standards for Grades of Table Grapes* (USDA 1971). These standards may be supplemented by higher standards set by local marketing groups, such as the Tokay Marketing Agreement in Lodi, California. The United States standard grades for table grapes include U.S. No. 1 Table, U.S. Fancy Table, and U.S. Extra Fancy Table. The U.S. No. 1 grade requires that for red varieties each bunch have at least 60 percent of the berries showing characteristic color for the variety, and for black varieties at least 75 percent. For U.S. Fancy, each bunch of a red variety must have at least 66⅔ percent of the berries showing good characteristic color but Flame Tokay and Cardinal bunches must have at least 75 percent of the berries showing good characteristic color. For black varieties, each bunch must have at least 85 percent of the berries showing good characteristic color. For U.S. Extra Fancy, each bunch of a red variety must have at least 75 percent of the berries showing good characteristic color, and for black varieties at least 95 percent. The minimum requirements of the desirable attributes of the grapes, such as color and bunch size, are usually progressively higher from U.S. No. 1 to U.S. Extra Fancy. At the same time, the permissible limits of most undesirable attributes (defects) such as crushed, scarred, or shot berries, are progressively lower.

Three aspects of color are considered in determining whether a bunch of grapes meets the minimum standard for color. First, what is the lowest limit of color intensity considered characteristic for the variety? Second, what percentage of the berry surface must have this minimum intensity to be considered colored? Third, what percentage of the berries of the bunch need to fulfill these first two requirements for the bunch to meet the color standard for the grade?

The requirement *characteristic color* specifies that for red varieties the color may be pink to dark red, except that for Flame Tokay the color may range from light pink to dark red, and for Cardinal light pink through purple. For black varieties, the color may range from reddish purple to black. The requirement *good characteristic color* specifies that for red varieties the color may range from light through dark red, except that for Flame Tokay it may be pink through dark red, and for Cardinal light red through purple. For black varieties, the color may range from purple to black (no reddish tint). For both good characteristic color and characteristic color, at least two-thirds of the berry surface must show the kind and intensity of color specified for the berry to be considered colored. The term *fairly well colored* is used when the bunch meets the color requirements of the U.S. No. 1 grade. For the U.S. Fancy grade, the term *reasonably well colored* is used, and for the U.S. Extra Fancy grade the term *well colored* is applied.

The complex relation of color to maturity standards for red table grapes is shown by the Queen clusters in plates 1-L[1], 1-M, 1-N, and 1-O. On the basis of characteristic color, these clusters would rate 95, 65, 60, and 50 percent colored berries. Only clusters 1-L[1] and 1-M would definitely qualify for U.S. No. 1 Table (fairly well colored). Cluster 1-N would be questionable because 60 percent colored berries is the minimum for this grade, and cluster 1-O would definitely not qualify with only 50 percent. If the clusters were rated on the basis of good characteristic color, the percentages of colored berries would be slightly less for clusters 1-M, 1-N, and 1-O because there are a few berries in each that are pink instead of light red—berries that would pass the characteristic color, but not the good characteristic color standard. Cluster 1-L[1] with 95 percent colored berries would definitely pass the standard for U.S. Fancy (85 percent good characteristic color), but would be questionable for the U.S. Extra Fancy grade (95 percent good characteristic color).

Plate 1-T shows six Queen berries with the percentage of the berry-surface color ranging from 100 to 0. The upper three berries would qualify both for good characteristic color and for more than two-thirds of the surfaces so colored. However, if the lower-left berry had at least two-thirds of the surface colored, it would qualify as characteristic color, but possibly not as good characteristic color because of the very light red color. The middle berry in the lower row (if at least two-thirds of the surface were colored) would definitely not qualify for good characteristic color and possibly not even for characteristic color because of the faintness of the pink color.

Emperor grapes show a wide range of intensity of color, from light pink to deep purple. All berries in plate 1-Y can be rated good characteristic color; however, those on the left with the bright-red color would be considered more attractive than those on the right with the reddish purple color.

Equally interesting is the relation of color to maturity standards for black table grapes as shown by the Ribier clusters in plates 1-P, 1-Q, 1-R, and 1-S. On the basis of characteristic color, these clusters would rate 85, 75, 70, and 65 percent colored berries. Cluster 1-P and probably cluster 1-Q would qualify for U.S. No. 1 grade (fairly well colored), whereas clusters 1-R and 1-S would not. If the clusters were rated on the basis of good characteristic color, the rating for cluster 1-Q would drop from 75 percent to 65 percent because of several reddish purple berries—not acceptable for this higher-color-intensity standard. Cluster 1-P with 85 percent colored berries might pass the U.S. Fancy grade; however, the very slight reddish color on two berries could introduce doubt.

Plate 1-U shows six Ribier berries with the percentage of the berry-surface color ranging from 100 to 0. The upper row of berries would qualify as characteristic color. It is doubtful that the lower left berry could. Only the left and middle berries in the upper row would qualify as good characteristic color—the berry on the right showing too much reddish purple color to qualify for this standard.

Total Soluble Solids and Maturity

The total soluble solids of the expressed juice of the berry contains acids as well as sugars in solution. However, the acid fraction is usually very small compared with the sugar fraction—so small, in fact, that for practical purposes the soluble solids are considered as the sugar content. It is measured on a degree-Brix (or Balling) scale—a scale based on grams of sucrose in 100 grams of a sugar-and-water solution.

The minimum standard degree-Brix, like that for color, varies depending upon the variety. Degree-Brix and the Brix/acid ratio are specified for all varieties whether colored or white. The minimum also may vary depending upon the district in which the grapes are produced. For several varieties, this minimum is 1°B less if the grapes are produced in the Coachella Valley rather than the San Joaquin Valley (Calif. Dept. Food and Agr., Bureau of Fruit and Vegetable Standardization 1971), the argument being that the higher ripening temperatures of the Coachella Valley depress the acid content more than the less-severe temperatures of the San Joaquin Valley. The result is that the Brix/acid ratio may be the same for the fruit from each valley even though the degree-Brix may differ by 1. The net effect is that both lots may taste the same because taste response correlates more closely with the Brix/acid ratio than with degree-Brix alone (Winkler 1948; Nelson et al. 1963). This is especially true for the higher-acid grapes early in the season.

Cluster Stems and Maturity

Cluster stems may vary from those quite woody with advanced maturity (called *cured*) to those more succulent. The cured stems have a lower water content than the succulent ones, hence will shrivel less with dessication. Further, they are tougher, break less easily, and their pedicel attachments are usually stronger. Such stems have much better storage potential and therefore are an especially significant quality factor for extended storage grapes such as Emperor, Calmeria, Almeria, and Ribier.

Sampling Methods to Determine Maturity

The table-grape crop, unlike that for raisins or wine, is seldom harvested all at one time. In early districts, the first harvest may start when as little as 10 percent of the crop is ready in order to take advantage of early-season high prices. Also, starting early and repeating a picking every week or less allows the harvest to be completed without some of the crop becoming overmature. As many as five pickings may be necessary to do this. Light crops, as from severe thinning, and even heavier crops in later districts may be harvested with as few as one or two pickings.

As harvest time approaches, the progress of fruit maturity can be monitored roughly by sampling a few berries from clusters selected at random. Three to six berries should be taken from the middle area in order to secure an average for the cluster, because the least mature berries are on the lower end and at the tips of the laterals, and the most mature near the base of the laterals at the top. Each berry should be squeezed between the thumb and finger until a few drops of juice can be deposited on the glass prism of a hand refractometer so that the reading is taken immediately. The instrument should not be rinsed between readings because residual water will dilute the juice of the next sample. If rinsed, the instrument should be wiped dry before reuse.

A more critical assessment of maturity can be made by crushing entire clusters in a container, straining the juice through cheesecloth, then securing one or more readings from this more representative sample. If there is enough juice to float a Brix hydrometer (200 ml to 300 ml in a tall slender cylinder), maturity can be determined this way rather than with a refractometer. However, the industry (including inspectors) now use the hand refractometer almost exclusively because of its portability, speed of operation, and durability (Calif. Dept. Food and Agr. Regulations 1972).

Precautions should be taken that refractometer readings are accurate. The effect of temperature must be considered because the juice expands as temperature increases. With fewer sugar molecules between the prisms, the refractive effect is less and readings will be lower. Conversely, readings increase as the temperature is lowered. Instruments are available with temperature compensation built into the optical system. Others have a small mercury thermometer attached to the instrument that senses the temperature of the instrument (and hence that of the thin film of juice) and indicates the plus or minus correction factor to be applied to the indicated reading (fig. 6A). Still other refractometers rely on zeroing the instrument with distilled water. Subsequent readings are valid as long as the instrument does not change temperature. To be effective the instrument should have a degree-Brix range no greater than 0° to 30°B and be graduated to 0.1°B divisions if possible, or at most 0.2°B.

Although the hand refractometer is relatively durable, it is a precision instrument and should be handled as such. A severe shock such as dropping it on a hard surface can damage the optics—either the prism or eyepiece mechanism. It should be kept clean by rinsing the prism end with clean water, and carefully removing dust from the eyepiece with lens paper or a soft cloth. Juice should not be allowed to evaporate from the prism surface because evaporation concentrates the sugars and will result in a high reading. Conversely, residual water from rinsing will dilute subsequent samples and result in low values.

Sometimes it is necessary to determine the total titratable acid (expressed as grams of tartaric acid per 100 ml of juice) of the grape sample. This becomes necessary when minimum standards permit grapes to pass at some degree-Brix less than the qualified minimum standard, provided the acid content is low enough so that the Brix/acid ratio is above a specified level. This ratio denotes the number of parts sugar (as percent soluble solids) to one part acid (as percent total acid). This value has been shown to be superior to the degree-Brix alone in predicting the palatability of grapes because it takes into account both the acid and sugar levels as taste factors. Winkler (1932) in early studies showed acceptance more closely correlated with the ratio than with degree-Brix. This was confirmed in later studies with taste panels (Nelson et al. 1963) and supermarket customers (Nelson, Allen, and Schultz 1972; 1973). This determination is most commonly used early in the season when the acid level is still relatively high. The procedure is more laborious and requires more equipment than the soluble-solids determination. Its application is usually restricted to early-season grapes to screen out high-acid fruit when ripening temperatures have been relatively cool, while permitting shipment of lower-acid fruit if higher temperatures prevailed before harvest.

Needed for the determination is a supply of distilled water, some sodium-hydroxide solution standardized preferably to 0.1333 Normal, phenophthalein indicator, and an assortment of glassware consisting of a 10-ml burette, 10-ml pipette, and one or two 250-ml Erlenmeyer flasks.

In practice, a sample of 10 ml of clear juice is placed in a flask with the pipette. This juice is diluted with about 100 ml of distilled water and 2 to 3 drops of indicator are then added. The sodium hydroxide is added slowly from the burette until a persistent faint pink color is reached. If 0.1333 N sodium hydroxide is used, the number of milliliters needed can be converted directly to grams total acid per 100 ml (percent of total acid) by dividing the value by 10. The Brix/acid ratio can then be derived by dividing the degree-Brix by the total acid value.

Effect of Weather on Time of Harvest

The grape harvest is seldom interrupted by adverse weather conditions until late in the season by fall rains or frost. If rain does wet the clusters thoroughly, it is prudent to suspend harvest for at least 3 days. If the rain does cause fungus infections to take place, this period will allow symptoms of the infection to develop to the extent that pickers can detect and trim out infected berries (plate 4-H). Even so, fruit picked this soon after a rain should be sold immediately or if stored kept segregated and monitored closely for any development of decay (plate 4-I, 4-J).

On rare occasions, grapes can be frozen late in the season. A light freeze may damage only the stems, but a hard freeze will damage the entire cluster. Freezing damage can first be detected by a blackening and rapid shriveling of stems. If the berries are affected they become mushy and exude (leak) juice (plate 3-Q, 3-R, 3-S, 3-T). Harvest should be suspended for at least a day for these symptoms to be expressed. Clusters with freezing damage should not be packed—even those with damage restricted to the stems—because blackened stems are unsightly and will break easily if dry, and are subject to decay if wet.

Harvesting and Packing Table Grapes

House or Shed Packing

Part of the California table-grape crop is packed in sheds or specially designed packing houses. The operation can have advantages over the other primary method of packing in or beside the vineyard. Packing personnel are exposed less to the somewhat severe working conditions of the vineyard. Many sheds are air-conditioned adding further comfort. More advantage can be taken of mechanization in shed packing, which can make handling operations more efficient. Quality control can be close since supervision of packers on a packing line is more centralized. Further, with the shed system it is more feasible to pack more than one quality grade or to use more than one type of shipping container.

The system consists of distributing empty field lugs under the vines from trucks moving between the rows (fig. 2A). The pickers select suitable clusters, cut them from the vine with harvesting shears, then place them in the lugs one layer deep without further trimming (fig. 2B, 2C). The filled lugs are loaded onto the trucks for transport to the shed. Many grape growers have mechanized this stage of the operation (fig. 2D). The elevator being pulled behind the truck eliminates the high lift from ground to truck bed and even to the top of palletized stacks of lugs. At the shed, the palletized lugs are handled by forklift to bring them to the head of the packing line where each lug is placed on a conveyer either mechanically or by hand (fig. 2E, 2F).

As the packers take the grapes from the field lug, they trim the clusters with shears to remove defective parts, then pack them into the shipping container (fig. 3A, 3B, 3C). The packed lugs are moved by conveyor through a lidding machine (fig. 3D), stacked on pallets, then strapped for stability in preparation for fumigation and cooling. As the packer empties the field lugs, they are diverted to another conveyor and moved to where they are repalletized and loaded on the vineyard trucks.

Field or Vineyard Packing

A large part of the California grape crop is packed in the vineyard. This method has some advantages over the house-pack method: (1) less capital investment in packing facilities; (2) only a vineyard crew to manage rather than a picking and packing crew whose production must be coordinated; and (3) no large inventory of field lugs.

There are two types of operations depending on where the packing takes place. A very small part of the crop is packed under the vine with the shipping container either on a small stand or propped against the vine trunk. Here the picker is also the trimmer and packer. Supervision is difficult, and frequently quality control is a problem. The method is usually used by small operators or for small lots of grapes that require special handling.

The avenue pack is far more popular. Figure 4A is an overall view of an avenue-pack operation, with several packing stands, each at the head of a row of vines. In between two rows is one harvesting crew that services one packing stand (fig. 4B). Here the grapes are picked, trimmed, and placed in lightweight trays (fig. 4C). Four to ten trays are placed on a lightweight hand cart and transported to the avenue (fig. 4D). Packing is done on the portable packing stand with enough space for a few of the trays, one or two packing scales, a rack for packaging supplies, and a canopy for shade (fig. 5A). Figure 5B shows a completed pack of Ribier grapes in an expanded polystyrene lug. Just above the upper end of the lug is the scale dial with a needle that indicates the weight of the packed container. To the left is a strip of pressure-sensitive labels that the packer places on the containers as they are packed showing producer, variety, net weight, brand, and so on. This is a special convenience in a field-pack operation; otherwise the containers would have to be prelabeled, which poses a problem as the crew is switched from one variety to another or to different brands.

A crew operating as a unit usually consists of four to six workers. One is the packer at the stand, another the hauler, and the rest pickers. An attractive feature of this method is that the crew commonly operates as a cooperative unit. The packer is the key person of the crew, being responsible for not only the packing, but handling the packaging materials, placing the required markings on the lugs, lidding them with snap-on lids, and stacking them at the side of the avenue (fig. 5C). The lugs are palletized on trucks as soon as possible and transported to the cooling and fumigation facility (fig. 5D).

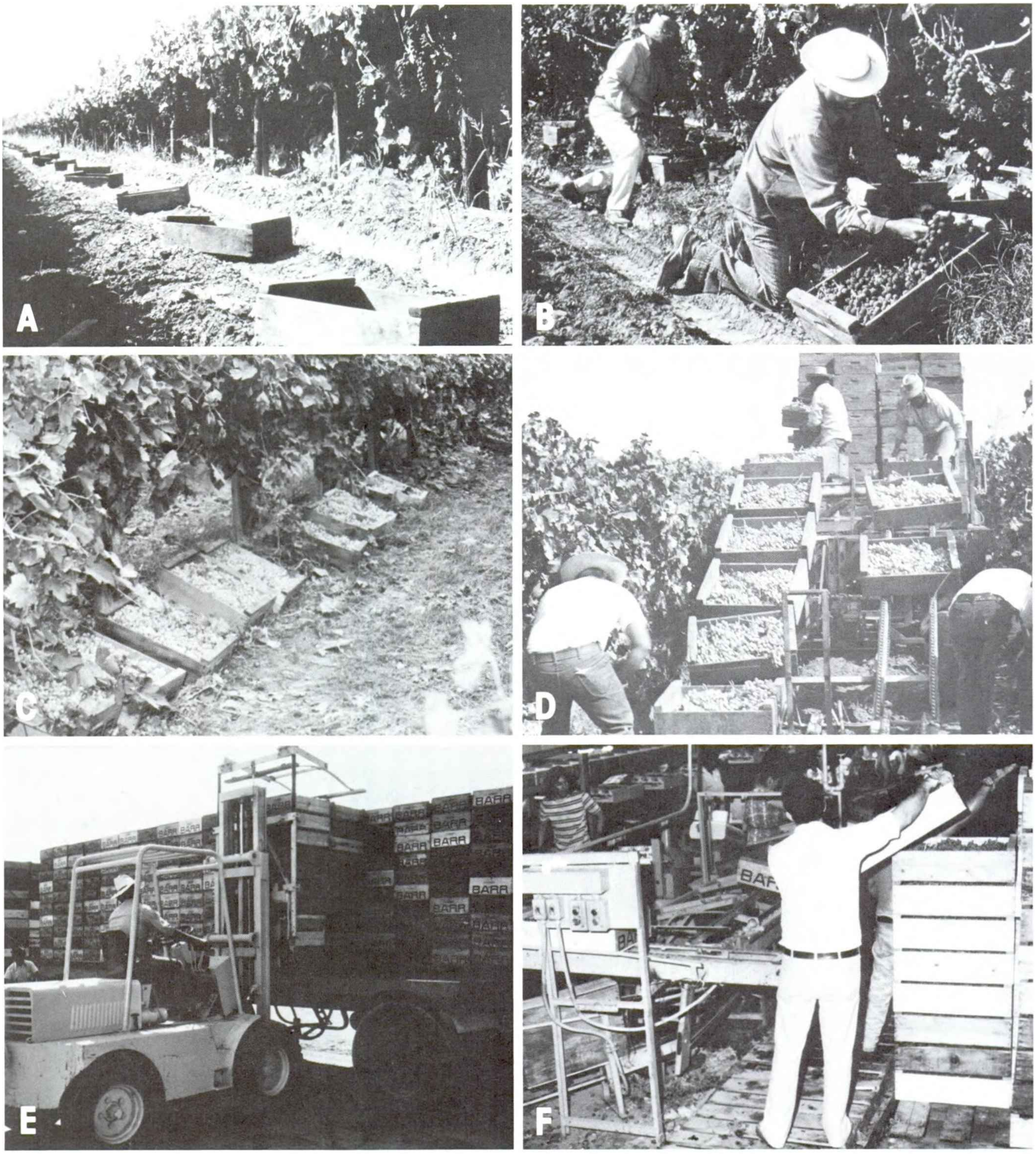


FIGURE 2. Harvesting and handling table grapes for a house-pack operation.

A. Field lugs distributed in the row for the pickers.

B. Pickers selecting suitable clusters, cutting them from the vine, and placing them one-cluster deep in the lug without trimming.

C. Filled field lugs placed back under the vines to be in the shade and out of the way for the hauling crew.

D. Field lugs being elevated mechanically to the truck bed for palletization and transport to the house-packing shed.

E. Forklift transferring filled field lugs from the truck to the packing-shed floor. Note pallet clamp to prevent lugs from falling during transport—an effective precaution because these palletized lugs are not strapped.

F. Field lugs being transferred to the conveyor that moves them to the packers.

There may be as many as 20 such crews operating under a supervisor (fig. 4A). As a crew finishes its row, it moves to the next unoccupied row taking along the equipment. Thus the crews proceed "leap-frog" fashion along the avenue. Although supervision may not be as close as in a house-pack operation, it is considerably better than with the in-row method, especially considering the volume of fruit packed. A significant breakthrough that popularized this method was the adaptation of the snap-on lid, eliminating hand-nailing or moving a bulky nailer about in the vineyard.

Precautions before Packing Grapes

The anatomy of the grape cluster requires special techniques of handling to prevent many problems of poor market quality of table grapes. Several phases of handling may be considered, the first being that of careful selection. Few clusters are so near perfection that they require no trimming before packing. At the same time, there are others so imperfect that it is immediately obvious that they should be rejected. The first major decision, then, is how much trimming is economically

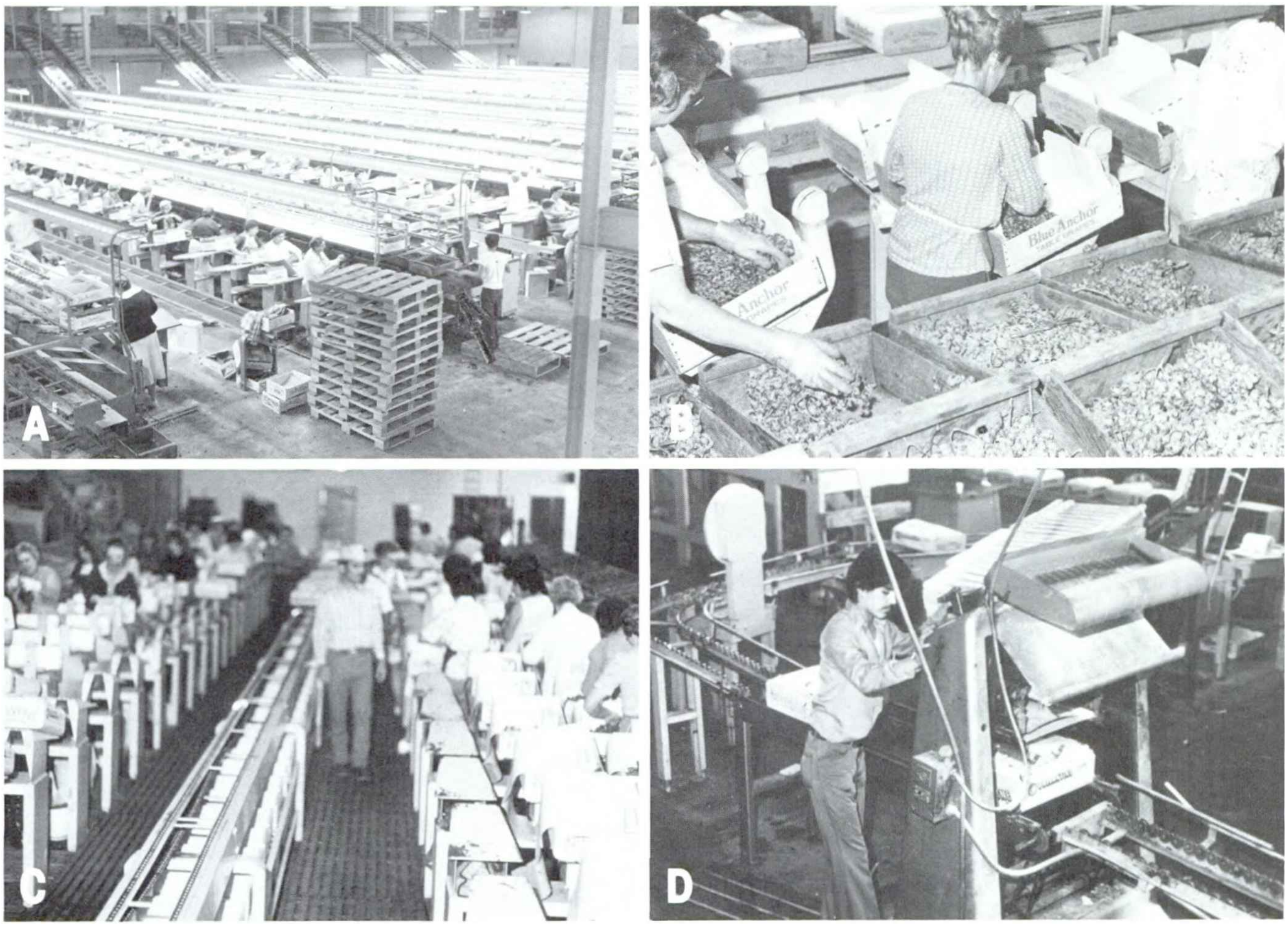


FIGURE 3. House-packing table grapes.

A. Overview of a multiline house-packing facility. Empty shipping containers (two labels) are being delivered from the left on high conveyors to the packers, while filled field lugs (*arrow*) are being delivered from the right.

B. Close-up of packing operation. Packers are removing clusters from the field lugs, trimming them of defective berries, and then packing them in the shipping containers. Note the center packer's trimming shears with curved blades on the grapes in the center field lug. Each packer can pack two quality grades (labels) simultaneously, each on a separate scale as indicated by the weight indicator just above the upper end of the container. When a packer has finished with a field lug, the container can be tilted slightly so that it will drop down onto a conveyor below to be carried to where it can be repalletized and returned to the vineyard. In the meantime, cull grapes are collected on another conveyor for disposal.

C. Two packing lines being served by one conveyor for the packed shipping containers (*center*). As each pack is completed by the packer, the container is transferred by a swamper (*center*) to the conveyor, which then moves it to the lidding machine at the far end of the lines.

D. Lidding operation. The operator positions a lid in the machine over the container that has just been positioned by the conveyor, then activates the machine by a foot pedal. Six nails attach the lid to the container with one cycle of the machine. This machine can lid as many as 30 containers a minute.

feasible to bring a less-than-perfect cluster up to acceptable standards by removing defective parts. Labor costs and market value of the fruit will largely determine the amount of trimming economically acceptable.

Clusters rejected as not feasible to trim are those that are: (1) inadequately colored (plate 1-O); (2) so compact that the interior parts cannot be examined for defective berries or stems (plate 1-V); (3) so straggly that the exposed stems make them unattractive (plate 1-W); (4) so filled with shot berries as to detract seriously from the appearance; (5) too small, at least $\frac{1}{4}$ pound for U.S. No. 1 and $\frac{1}{2}$ pound for U.S. Fancy (plate 1-X); (6) filled with excessively sunburned, scarred, mildewed, decayed, raisined, cracked, crushed, irregular-shaped or undersized berries (plates 2, 3, 4); and (7) sunburned, decayed, mildewed, shrunken, or blackened in the stems (plates 2, 3, 4). The occasional defective berry or part should be removed with special harvesting shears with curved blades (fig. 6B).

The cluster should always be held by the peduncle or stem, to avoid touching the berries as much as possible (fig. 4C). Rubbing between berries or with the hands destroys the "bloom" or luster making the berries appear shiny (plate 2-R). Further, excessive rolling of the cluster during trimming causes flexing of the stems, which can result in breakage of laterals and injury to the pedicel attachments of the berries (plate 2-G). Points of greatest stress are at the junctions of the laterals and pedicels. Bending of these parts crushes the stem tissue, which subsequently turns brown, dries, becomes brittle, and breaks easily (plate 2-D). It takes

FIGURE 4. Field-packing table grapes.
A. Avenue scene in a typical avenue field-packing system. Each packer at a portable stand in the avenue packs the output of four to six picker-trimmers operating between two rows of vines to as far as 100 yards (90 m) from the avenue. Empty shipping containers and packaging materials are delivered to these stands as needed, while packed containers are stacked at the side of the avenue for pickup later.
B. Picking-trimming operation between the rows of vines. Note that each picker is filling a special lightweight tray with trimmed clusters.
C. Close-up view of a picker trimming a grape cluster before placing it in the tray. These trays are usually placed on the ground during filling, but sometimes may be mounted on portable stands to reduce stooping. Note that the cluster is being held by the stem, as defective berries are removed with the shears—effective techniques to minimize rubbing the berries and destroying the bloom.
D. Worker delivering a load of filled trays on a special type of wheelbarrow to the packer in the avenue.

little twisting stress during rough handling to rupture the skin at the junction of the pedicel and the berry. Such injuries (usually not visible at the time of packing) are common causes of wet shatter of berries or breakage of lateral stems of clusters. In addition, SO_2 can penetrate readily into the broken pedicel attachment, causing bleaching and wetness (plate 2-G). The bleaching is good in that it indicates the wound is at least sterilized and will not be a source of decay. However, such injured berries are unattractive and probably inedible because of off-flavors and stickiness.

Shipping Containers

Most California table grapes are packed in lug boxes 16⅛ inches long (inside dimension) with widths of either 13½ inches or 14 inches (outside dimensions) and with depths ranging from 4½ inches to 5½ inches (inside dimensions). The net weight of fruit packed without the clusters being individually wrapped is 22 pounds (10.5 kg) for Coachella Valley grapes and 23 pounds (11 kg) for fruit packed in the San Joaquin Valley (Calif. Dept. Food and Agr. Regulations 1972). The container may be tapered up-and-in along the tops of the sides or down-and-in along the bottom sides to facilitate packing and cooling. The lug may be constructed either of all wood or with only the ends being solid wood, and the sides and bottom being a paper-wood laminate (Technical Kraft Veneer [TKV]) (fig. 5A, 5C).

The volume of grapes packed in expanded polystyrene containers has been increasing (fig. 5B). The inside dimensions are 18 inches long, 11½ inches wide, and 6 inches deep. They are packed to the same net weight. Other than a bottom cushion pad, no curtains or paper liners are used as the polystyrene does not have the abrasive properties of wood that can scuff or bruise the grapes.

Grapes are no longer packed for export in all-wood chests 18⅝ inches by 14¹⁵⁄₁₆ inches (outside dimensions) by 7¾ inches deep (inside dimensions), and then embedded in sawdust just before shipment (fig. 18). With the high cost of this container with sawdust, the unattractive appearance of the sawdust particles on the berries, the woody flavor imparted to the fruit, and problems of disposal of the sawdust, the chest has been phased out in favor of the standard domestic containers. Further, the advent of palletization has reduced drastically the need for the durable protective features of the sawdust pack. No longer do the containers have to be manhandled across the docks (dropped, slammed into place, and even pilfered) if secured in a pallet handled by a forklift, or, better yet, further protected with the pallet secured in the more favorable environment of a refrigerated container designed for transport either on trucks or ships.

Some grapes are packed in lugs 15¾ inches by 19¹¹⁄₁₆ inches (outside dimensions) with depths of 4 inches to 5⅕ inches. Each cluster is wrapped completely in tissue paper and packed one-cluster deep.

Fiberboard has shown considerable promise for shipping containers for table grapes. Extensive tests have shown the feasibility of this material if wax-dipped, curtain-coated with a plastic-wax emulsion, or treated with polyphenolic resin to resist the weakening effect of moisture uptake during storage and transit (Nelson 1970). Systems of handling have been devised to use full- or half-telescope containers. The problem of designing cartons is to design them to withstand three-pallet stacking. However, pallet corner supports or racks could largely solve this problem (fig. 9). Cooling is generally slower with these containers than with lugs; however, as cooling techniques are improved, especially by the use of forced air, this problem can be largely eliminated. To date, use of this packaging method has had limited acceptance for table grapes, although the corrugated carton is widely used for tree fruits.

Cluster Arrangement in the Container

The clusters are packed in a stems-up arrangement in all the aforementioned containers, except the wide shallow cluster-wrapped pack. Most common is the so-called *naked pack,* but to a significant extent individual clusters are *chimney wrapped* (fig. 7B). This pack, like the cluster wrap, does keep the stems fresher in appearance than the naked pack because the wraps protect them from drying, especially during long-term storage. Further, the wraps retain berries that may shatter and otherwise be lost when unpacked. However, problems of rapid cooling and SO_2 penetration during gassing are increased. The cluster-wrap pack has the additional disadvantage of making it more difficult to examine the fruit after packing.

When packing the naked pack, the lug is first equipped with a bottom cushion pad, which may be part of a one-piece liner that protects the fruit from the ends and even the sides of the lug. Vents in a one-piece liner are provided to register with those along each side at the bottom. The lug is oriented with the label end toward the packer and tilted at an angle of about 15° for ease of packing. The trimmed clusters are placed in the lug starting at the lower end, holding the cluster by the stem in an upright position at the desired height, then inserting other clusters underneath as necessary (fig. 5A). Packing continues toward the upper end maintaining a slight crown, so that when the lid is fastened the pack is compressed slightly. After placement of the last cluster, the pack is usually covered with a curtain. It may be either a separate unit with ends that tuck down inside of each side of the lug or be a part of the liner. Along each side are vents to facilitate cooling and penetration of SO_2 during fumigation (fig. 7A). Some grape producers provide a top cushion pad in lieu of, or in addition to, the curtain. This precaution is especially significant for Ribier and

Cardinal packs whose berries crack easily during pressure of lidding—especially early in the day when the berries are extremely turgid.

The chimney-wrap is made in the same manner except that the trimmed cluster (or two small ones) is first laid on a pad of tissue wraps, then rolled into the top

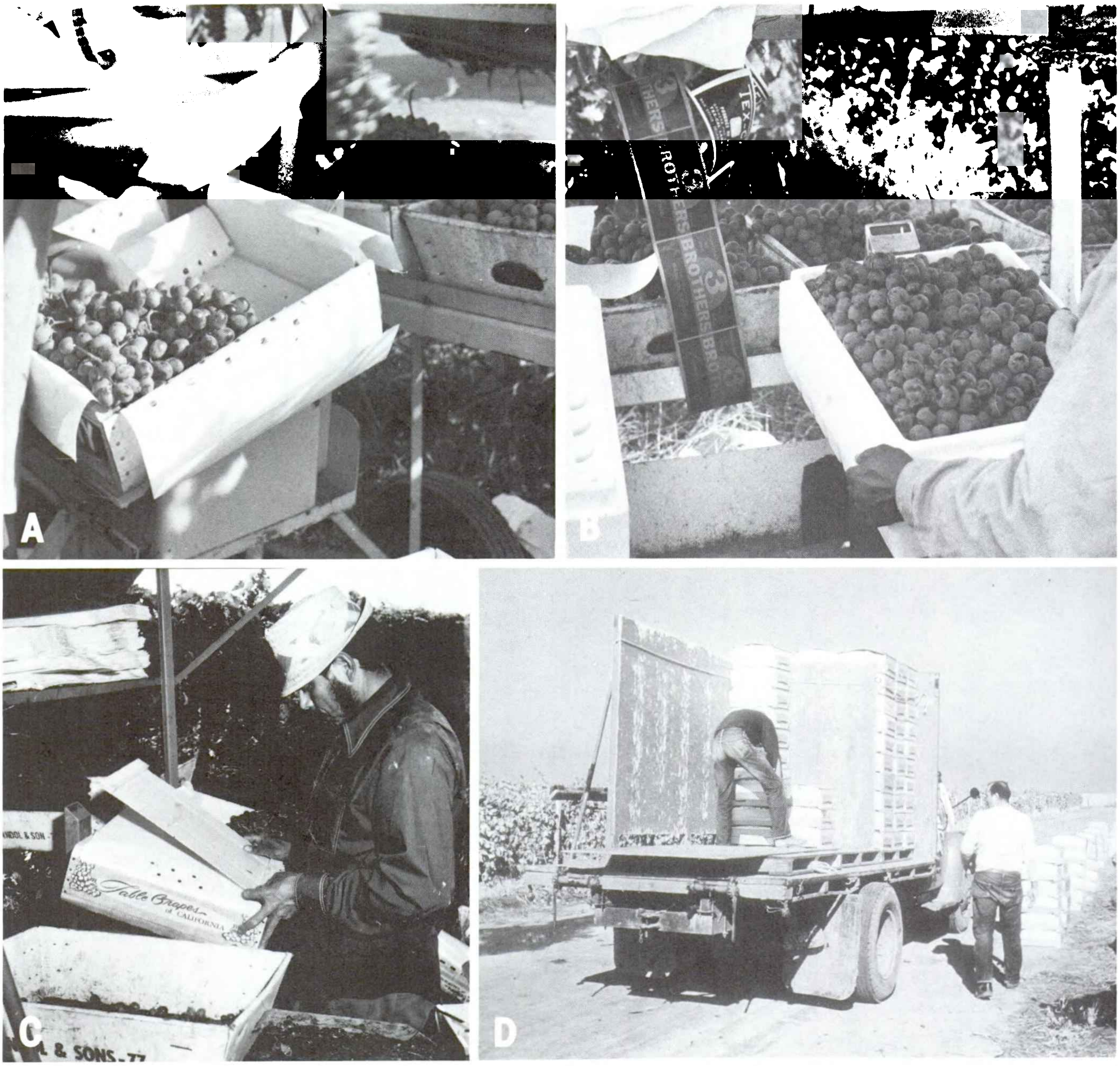


FIGURE 5. Avenue-packing operation.
A. Packer at the portable stand is transferring a trimmed cluster from the tray to the shipping container (a TKV lug). Note that the liner is one-piece (including a cushion pad for the bottom), and has end guards and side guards that can be extended over the pack forming the curtain.
B. Completed naked pack of Ribier grapes in a polystyrene container. A cushion pad is usually used in this container and occasionally a top pad. However, liners are seldom used. Note vented bottom of part of empty container at lower left. The lid is likewise vented. Also note the weight indicator just above the lug to assure correct gross weight.
C. Packer installing a snap-on lid onto a TKV lug. Nails partly driven into the top edge of the heads of the container match slots in the cleats of the lid. Once the cleat is engaged at the end of the lug nearest the packer, the middle of the lid can be bowed upward, and the nails in the opposite end then can engage the slots in the other cleat.
D. Packed containers being lifted by hand and palletized on the truck bed for transport to the cooling facility.

wrap to form a cup. When in place in the pack, the edge of the wrap is slightly higher than the top lateral of the cluster (fig. 7B). For the cluster-wrap, the wrap completely encloses the cluster.

Miscellaneous Packs

Specialty packs of grapes, such as those prepared for the holiday season or special trades, are very limited. Great emphasis is placed on appearance for these packs, exhibiting the fruit in an attractive or even dramatic manner. Stems may be concealed so that only the berries show (face pack). Contrasting patterns of red, black, and white grapes may be used to produce special designs or effects. For such packs, the labor input is high. Clusters with uniformly large berries of bright red, white, or black colors are selected, sufficiently loose so that they can be bent, turned, or twisted to form attractive designs for the surface of the pack. Great skill is needed to accomplish this without removal of the bloom from the berries or harmful flexing of the stems that could result in shatter.

Consumer Packs

Considerable attention has been given to the feasibility of consumer packaging of table grapes at the shipping point. During the late 1950s and early 1960s, numerous

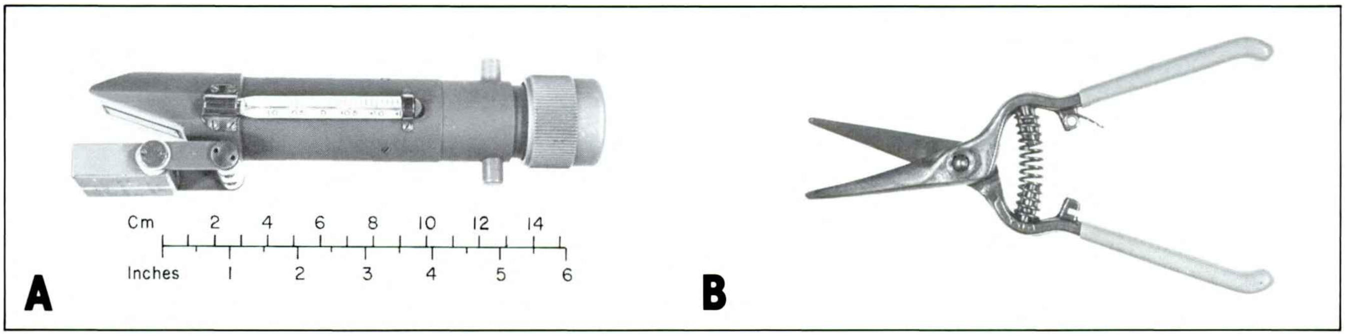


FIGURE 6. Two essential tools for harvesting table grapes.
A. Hand refractometer equipped with temperature-correction thermometer for determining the total soluble solids (maturity) of the fruit. There are instruments with built-in temperature-compensation capability and others that have to be zeroed with distilled water.
B. Harvesting and trimming shears. Other types have curved (not shown) blades to facilitate trimming out defective berries without injuring others.

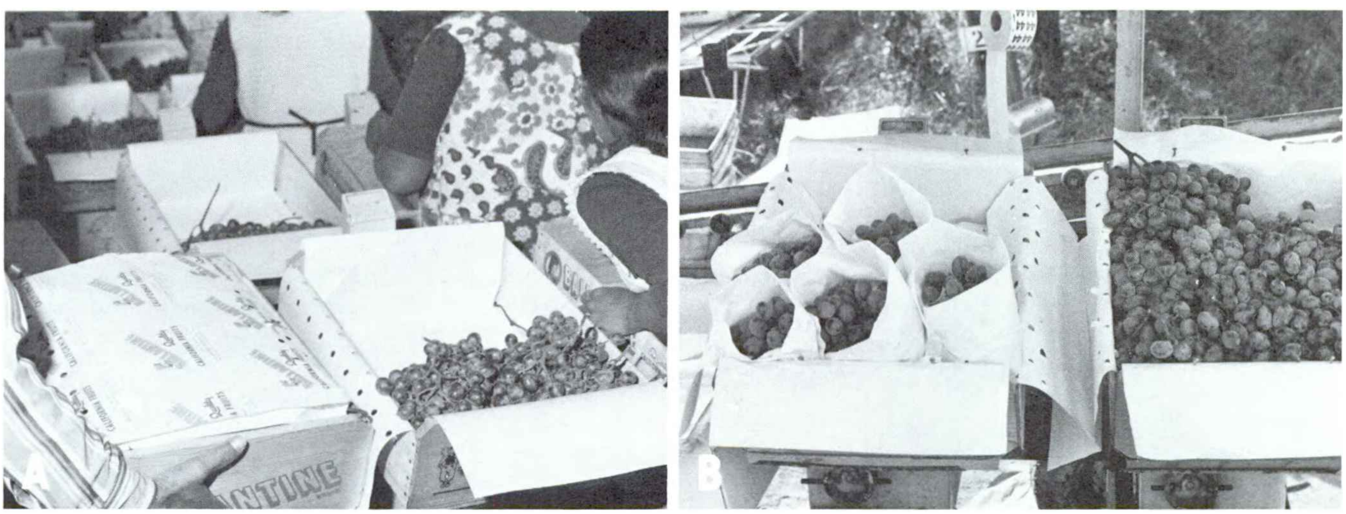


FIGURE 7. Popular types of packs of table grapes and packing materials.
A. Partly completed pack in a TKV lug equipped with cushion pad, end guards, and vented curtain (*right*). Pack with curtain in place (*left*). Note double rows of vents along each top edge to facilitate cooling and fumigation.
B. Nearly completed chimney-wrap pack (*left*) and naked pack (*right*). Note the three rows of vents in the curtain for the chimney-wrapped pack—a wise precaution because the wraps are a significant barrier to sulfur-dioxide penetration during fumigation and to cold air during cooling. Often the curtain is not used for the chimney-wrapped pack for this reason as the curtain itself is a significant barrier.

shipments were made of grapes packed in consumer units of 1½ pounds and 2 pounds each. The units were consolidated into shipping cartons or crates of 12 units or 16 units each. Various types of plastic film windows or overwraps were provided to display the grapes within, as well as convenient methods of opening and closing the units (Hale and Stokes 1960). It was difficult to pack grapes in these units largely because clusters could not be easily sized to fit and meet the weight tolerances of these small packages of fixed net weight. Further, the cost of packing and packaging materials for this system was very high. It soon became evident that problems of effective SO_2 fumigation and fast cooling were increased as well. Finally, once packed, there was little or no opportunity to recondition the fruit at a distribution point if decay or other adverse quality factors developed during transit.

As a result, attempts to consumer-package grapes at the shipping point were largely abandoned. However, to meet the strong demand for consumer-packaged produce (particularly in eastern supermarkets) efforts were shifted to using this packaging system at distribution points near the markets. The system of packing the consumer units in a distribution center servicing as many as 150 supermarkets is probably the most effective. The volume of produce is large enough to justify extensive mechanization with sophisticated equipment. Packing lines can be designed to handle different kinds of produce as the traffic dictates. For grapes, many of the problems encountered at shipping point are practically eliminated. The fruit can be packaged easily in simple, yet attractive units, consisting of a plastic or wood-pulp tray overwrapped with plastic film (fig. 8A, 8C). They can range in weight from 1 pound to 4 pounds depending on trade demands. Quality control is effective because the clusters can be checked closely when removed from the shipping container and before being packed in the trays. A mechanizing feature of significance is that the overwrapped units can be passed through a machine that automatically stamps the package with the name of the commodity, its weight, and even its price since now it is only a day away from the produce counter (fig. 8D). The units can be consolidated into reusable trays for the short haul to the market, eliminating the need for further expensive packaging and the difficulty of disposal of shipping containers at the retail store (fig. 8E).

Although many problems are solved by this system, some are created. Condensation of moisture on the berries after removal of the lugs from the refrigerated carrier can detract from the appearance of the fruit. This problem may be compounded by the handling necessary in repackaging. As the berries rub against each other or against other surfaces, the condensate is smeared about accentuating this wet effect. Also, any juice from crushed, detached, or SO_2-injured berries is likewise smeared, which gives the berries a sticky texture and, upon drying, a varnished appearance.

Fortunately the wetness problem can be alleviated by controlling the environmental conditions and by using particular methods of handling the fruit. If possible, the air temperature of the packing area should be kept above the dew point. If the temperatures and relative humidity are low enough, no condensation will occur on the berries. Even if condensation cannot be avoided, it can be reduced by keeping the shipping containers under cold dry conditions until the fruit can be repacked. Once moved to the packing line and opened, the exposed fruit should be repacked and overwrapped quickly to minimize condensation.

During the operation, the clusters should be handled as gently and as little as possible. This can be accomplished by removing them from the lug in reverse order to that used when packed. To do this, the lug should first be placed with the label end toward the packer. The first cluster removed should be from the far end, usually from a corner. If it was the last one packed, it can be lifted out easily holding it and succeeding clusters only by the main stem. As an alternative, the packed lug can be emptied by turning it over into a tray or onto a selection table (fig. 8F). In this way, the packer has an assortment of clusters to choose from when packing the trays. This can be done by restraining the fruit in the lug with the unfastened lid while inverting it, then gently lifting the lug from the fruit. The lug should not be merely turned upside-down allowing the clusters to tumble about, which will cause excessive injury and smearing of wetness.

Handling Juice (Wine) Grapes

Although juice grapes are intended for wine, handling is included here especially for home wine makers in the eastern United States and Canada, because the technology is similar to that used for table grapes. Also, many shippers pack both kinds of fruit and handle it in the same facilities.

Juice grapes may be shipped in Container No. 38L when greater than 5½ inches deep, Container No. 38Q when 8¼ inches deep, and Container No. 38M. The net weight must be either 36 or 42 pounds (Calif. Dept. Food and Agr. Regulations 1971). Standards of quality are similar to those for table grapes except that limits for defects are more lenient, especially for those that affect appearance only—raisining, scarring, and misshapen berries (Calif. Dept. Food and Agr., Bureau of Fruit and Vegetable Standardization 1971). Specifications for maturity, for example, are more stringent because an adequate sugar content is essential for a stable and balanced wine.

Many wine-grape varieties cannot be shipped successfully because the skins are too tender and berry attachments are too weak—such as Burger and Semillon. Such grapes crush easily and tear from the pedicels causing excessively wet packs. Zinfandel, Carignane,

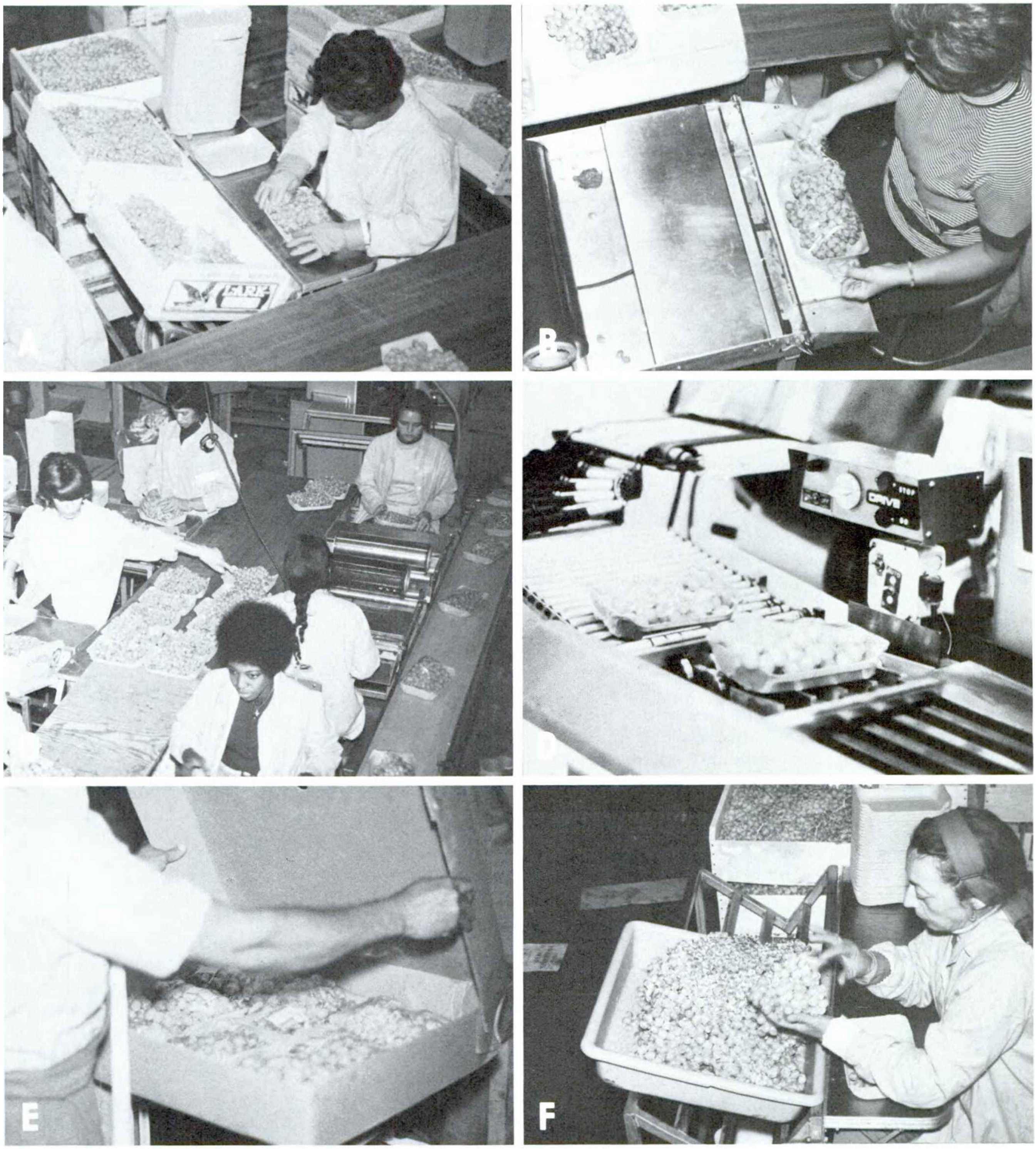


FIGURE 8. Consumer-packaging of table grapes at a wholesale distribution center.

A. Worker filling a plastic or wood-pulp tray with clusters or parts of clusters from the shipping container on the left.

B. Another worker completes the plastic film overwrap of the consumer unit, which will be heat-sealed on the hot plate.

C. Overview of the packing line and belt carrying the packages to the weighing-pricing machine in the background.

D. Overwrapped units being labeled with name of the commodity, weight, price per pound, and total price of the unit.

E. Labeled units in a lightweight master tray ready for transport to a retail store.

F. Clusters of grapes that have been transferred from the shipping container to a tray for easy access in packing consumer units.

Muscat of Alexandria, French Colombard, and Alicante Boushet are popular varieties that will juice badly if not handled carefully before, during, and after lidding.

The clusters are jumble packed: that is, placed in the containers with no special orientation. Trimming is minimal—clusters not meeting the quality standards are more quickly rejected than table grapes would be. Container liners are not used; at most a cushion pad is placed on the bottom of the lug.

Juice grapes are either house or field packed. Field packing is done under the vines, so the packer picks and trims the fruit as well as packs it. Once packed, juice grapes are handled in essentially the same way as table grapes.

Palletization

Before World War II, nearly all California table grapes were handled either by hand, one lug at a time, or with hand trucks capable of carrying as many as 12 lugs. Cooling and storage rooms were typically only high enough for convenient hand-stacking of lugs—12 feet or less. Field lugs of grapes for house packing and field-packed shipping lugs were hand stacked onto auto trucks in the vineyard, then unloaded later at the dock with hand trucks. This necessitated that all unloading docks be at a truck-bed height. Following World War II, forklifts capable of carrying one or more tons of lugs on a pallet rapidly replaced the hand truck. New facilities were constructed to take advantage of the potential efficiencies of this innovation. Packing-shed floors were often placed at ground level for greater ease of moving traffic of fruit and personnel. These floors were made of concrete, partly to sustain the heavy loads of the forklifts. The height of cooling and storage rooms was increased to 30 feet or more to accommodate three- and four-pallet stacking (fig. 18).

FIGURE 9. Stacking of containers and lugs in cooling rooms.
A. Palletized TKV and polystyrene containers in a conventional cooling room.
B. Palletized TKV lugs in a cooling room equipped with stacking racks.

Several pallet sizes have evolved, each with some advantages. The 51½-inch by 42-inch (nine-stack) pallet and the 35-inch by 42-inch (six-stack) pallet both accommodate the standard shipping lugs with no open space on the pallets. These sizes have the advantages that no modifications of dimensions of shipping containers were needed (or the size of the containers could be adapted to these pallet sizes), and the palletized lugs had good stability when loaded solid and strapped. The larger pallet has the added advantage of greater efficiency when handling large quantities of fruit with 50 percent more lugs per pallet than can be stacked on the smaller one. The six-stack pallet became the preferred size where fast cooling was critical. Even the clipped corners of the lugs, which provide air channels through the pallet, did not suffice for rapid and uniform cooling of the nine-stack configuration using the conventional parallel-flow method of handling the cooling air. The center stack, especially, cooled slowly and was the most difficult to treat effectively with sulfur dioxide. Further, in periodic inspections of the fruit during storage, the center lugs were the most difficult to retrieve and examine—the specific lugs in which the fruit was most apt to have problems from inadequate cooling and sulfur-dioxide exposure for decay control.

The stacks of lugs on both sizes of the pallets required some restraining system to maintain stability during movement of the pallets. In the field-packing system, the palletized lugs on the trucks were simply cinched in place with overhead ropes and restraining bars. At the shed, the house- and field-packed lugs were held in place for movement in and out of cooling and storage rooms, with one or more tapes or straps that encircled the palletized unit. These could be removed quickly later for hand-loading into vans and reefers.

During the late 1960s and early 1970s, there was a marked transition from hand-loading and bracing of lugs in carriers to the one-way pallet system of transit handling. Both labor input and time could be substantially reduced by using this system. Figure 10A shows a forklift unloading field-packed lugs from a vineyard truck. These lugs were hand stacked on a one-way pallet in the vineyard (the last hand-stacking the lugs will need until they reach the market). In figure 10B, the field-packed lugs are being transferred from the vineyard truck to the loading dock for strapping. This forklift is capable of handling an entire truckload of lugs at one time. Figure 10C shows the placing of corner strips to maintain lug alignment in preparation for strapping. Figure 10D shows details of the strapping mechanism for rapidly threading straps around the palletized lugs to maintain vertical alignment of the palletized unit. Before shipment, additional straps will be added in a vertical direction to prevent up-and-down movement of the lugs during transit. This operation eliminates the need for a gravity conveyor to transport the lugs one at a time from the shed into the carrier for hand-stacking. Or, if the forklift could enter the carrier, the palletized unit no longer had to be dismantled and the lugs restacked. Now it is usual for a forklift driver and a bracing operator, equipped with a pneumatic nailing gun, to load and brace a van or reefer in as little as 45 minutes. Formerly a loading crew of four or five men required 2 to 3 hours (Nelson, unpublished data).

Figure 11A shows a forklift placing the first six-stack pallet in a container van. The load, two pallets wide, is immobilized from lateral shifting by cross strips attached with a pneumatic hammer (fig. 11B). With all pallets secured, the rear gate is placed in such a way that no longitudinal shifting is possible after the doors are closed and locked (fig. 11C, 11D). The same loading procedure would be used for all vans. Figure 12A shows a forklift placing a six-stack pallet in a mechanical rail reefer. Figure 12B shows the arrangement of three pallets across but with the lugs crosswise in the load instead of lengthwise, as in the container or van that accommodates only two pallet widths. When loading is completed in the reefer, steel gates on each side of the doorway can be swung into place and locked, which secures the load in each end from longitudinal shifting.

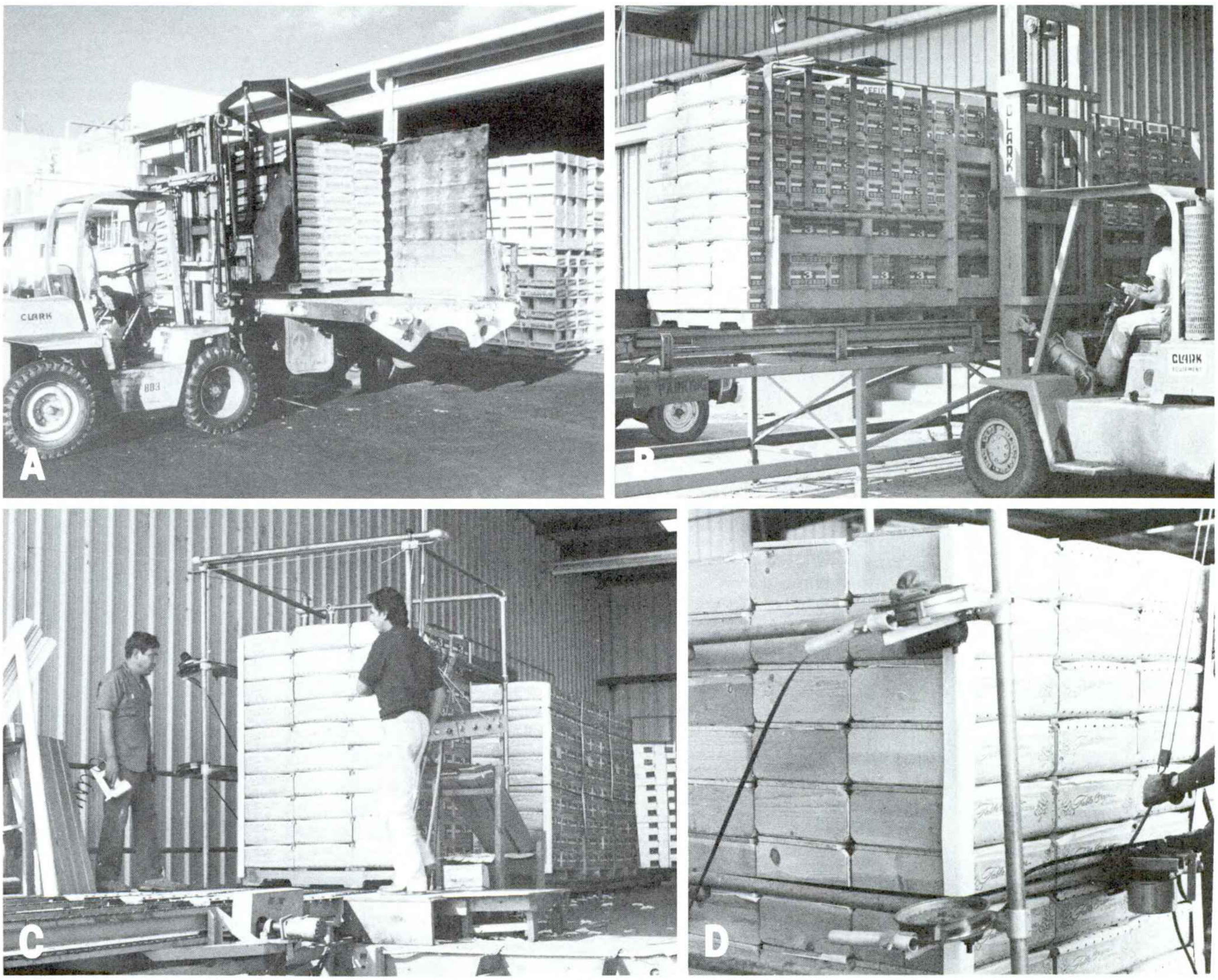


FIGURE 10. Handling of field-packed containers at the cooling facility.
A. Palletized containers being unloaded from a vineyard truck with a forklift truck for transfer to the dock.
B. Forklift placing load on the dock conveyor. This forklift is capable of handling five pallets (over 400 containers) at a time.
C. Palletized TKV containers on the dock conveyor being strapped in preparation for forklift handling during cooling and fumigation.
D. Close-up view of a mechanized strapping operation. Note that the straps are threaded automatically around the palletized containers before being cinched tightly. The operation can be done vertically as well to secure the containers to the pallet frame itself.

Minor problems have been encountered in fitting the two pallet sizes into all van containers and rail reefers without wasteful space between pallets—space that requires bracing to prevent shifting of pallets during transit. The chief problem has been small variations in inside widths of the carriers.

With these loading and bracing systems, it is essential that the grapes be thoroughly cooled before loading, because there is little opportunity for air to circulate in reefers from top to bottom and in vans from back to front through the load. Reefers no longer have spaces between each tier of lugs provided by the braces of the old gate load for cold air to flow down readily past both sides of every lug and return under the floor racks to the refrigeration unit. Vans no longer have horizontal channels between lugs (as provided when hand-stacked lengthwise) for the cold air to enter at the rear of the load and come in contact with nearly every lug as it moves forward to the refrigeration coil at the front of the van.

The question of whether the industry should convert to the 40-inch by 48-inch pallet has been controversial.

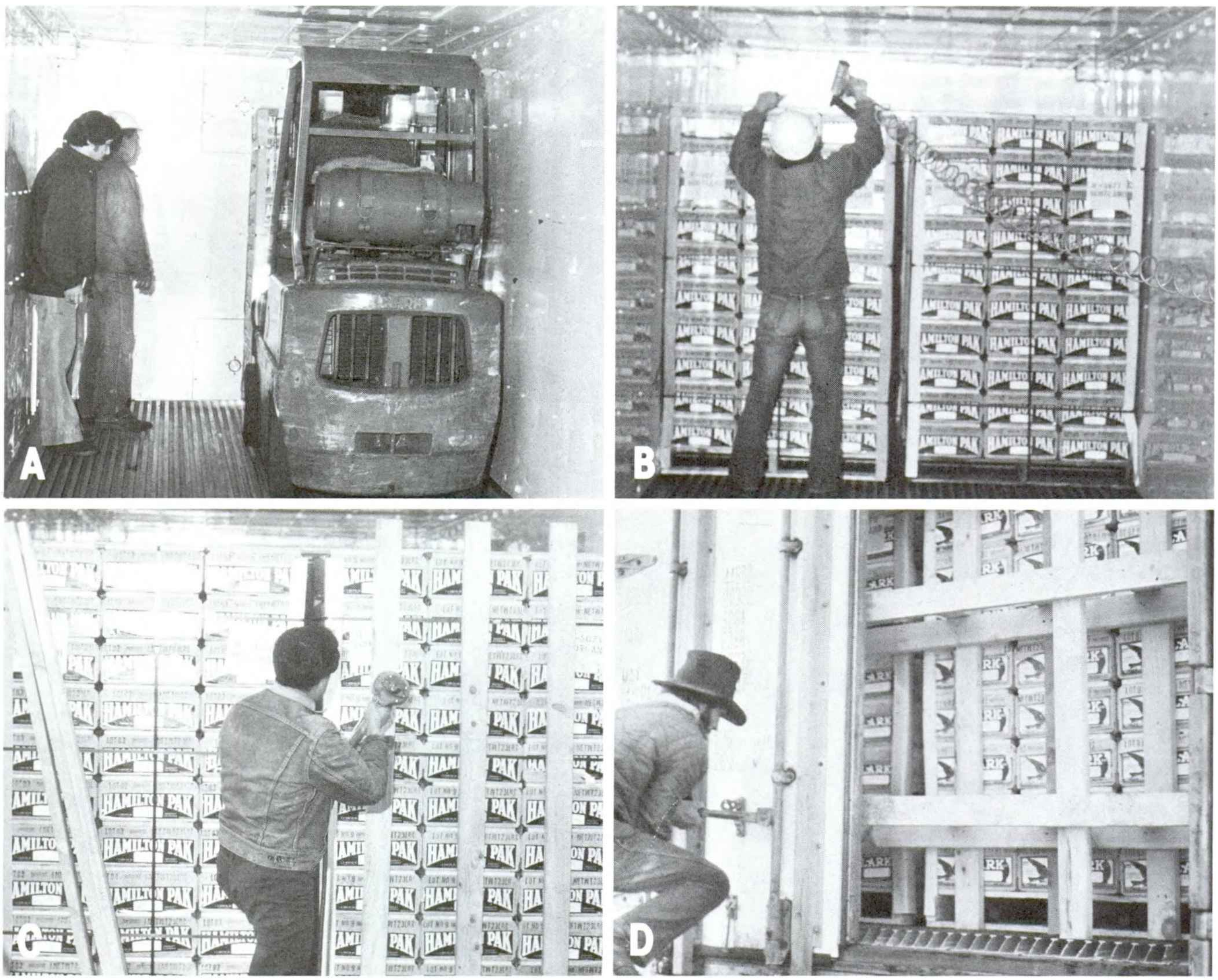


FIGURE 11. Loading an insulated highway van with palletized grapes.
A. Forklift is positioning the first pallet of fruit in the front end of the van.
B. Worker is nailing dunnage strips across the pallets with a pneumatic hammer. These strips prevent lateral shift of the pallets if the van sways or turns direction suddenly. Note that the van accommodates six lug-widths across (two pallets).
C. All pallets have been loaded and the worker is nailing a heavy gate brace against the rear of the load.
D. A second heavy brace has been added with spacers so that this brace will press firmly against the back doors when closed. The forklift ramp has been removed, and the worker is closing and locking the left door of the van.

This size is standard for chain-store warehousing and therefore attractive for consideration since a high percentage of the table-grape crop is merchandized through this distribution outlet. This size of pallet has become more feasible to use in recent years as a result of two trends: First, more than 90 percent of the table grapes now are transported in vans, either over the highways or on railroads as *TOFC* (trailers on flat car). Second, improvements in insulation have made it possible to reduce the thickness of van walls so that the 40-inch by 48-inch pallets can fit the inside dimensions using a *pinwheel* configuration—four pallets with one crosswise and its "mate" lengthwise followed by two more in reverse arrangement. This leaves an 8-inch vertical channel in the center of each four-pallet unit, which causes no additional problems in bracing. As a result, several shippers now use this size of pallet, even though it requires altering the dimensions of the shipping container. The 38R grape lug ($15\frac{3}{4}$-inch by $19\frac{11}{16}$-inch) fits this pallet in a six-stack arrangement.

Once the one-way pallet system was adopted, strapping of the palletized units needed to be more extensive to minimize shifting of the lugs during transit in the carriers. Two, and even three, steel or reinforced-plastic straps are cinched tightly around each pallet and often two straps encircled the pallet vertically securing the lugs to the pallet itself (fig. 12). Corner strips are often used to further maintain alignment of the pallet and to prevent the straps from crushing into the corners and sides of the lugs (fig. 11B).

FIGURE 12. Loading a railroad reefer with palletized grapes.
A. The forklift is positioning a pallet against the left wall of the reefer. A reefer must be loaded, first one end then the other, through doors in the middle.
B. Loading has been completed for one end of the reefer. Note that the width accommodates six-lug lengths since it is wider than that of a van. As a result, six-stack pallets are loaded lengthwise in a reefer but crosswise in a van.

Characteristics of the Table-grape Varieties of California

The 12 table-grape varieties discussed account for about 95 percent of California's table-grape production. Several varieties of minor importance include Beauty Seedless, Exotic, Red Malaga (Molinera), Malaga (White Malaga), Olivette blanche, Rish Baba, and Kandahar. Some new varieties with varying degrees of promise are Superior Seedless, Centennial Seedless, Dawn Seedless, Blush Seedless, Redglobe, and Christmas Rose. There are two others with a mild labrusca flavor: Niabel and Early Niabel.

EMPEROR (Plate 1-A)

This variety accounts for about 20 percent of the table-grape production of California. There are about 22,000 acres of vines, largely limited to a belt near the foothills of the Sierra Nevada in Kern, Tulare, and Fresno counties. The clusters are large, conical, and well filled with large red to reddish purple berries that have seeds. With thick, tough skins, the berries are elongated obovoid or ellipsoidal, and are neutral in flavor. The texture of the berries is moderately firm. The stems are strong and the berries adhere very strongly. The harvest season extends from September 15 to November 1. It is the foremost storage variety and can be marketed until March. Gibberellic acid is sometimes applied to the clusters 2 weeks after fruit set to reduce shriveling. Ethephon is often applied at the first sign of pigmentation to enhance color.

CARDINAL (Plate 1-B)

This variety is a cross between Flame Tokay and Ribier. It accounts for about 2 percent of the table-grape production of California in 1982. Production is in the Coachella Valley and in the San Joaquin Valley south of Fresno. The clusters vary from medium to large in size and loose to compact in density. The very large berries are somewhat round in shape, dark red to reddish black in color with advanced maturity, and are seeded. Ethephon is often applied to enhance color and the vines sometimes are girdled to advance maturity. The variety is harvested in the Coachella Valley during the first 2 weeks of June, and in the San Joaquin Valley during the first 2 to 3 weeks of July. Because the berry is thin-skinned and the stem attachment is weak, the clusters must be handled carefully to avoid injury to the fruit.

RIBIER (Alphonse Lavallee) (Plate 1-C)

This variety accounts for 4 percent to 6 percent of the table-grape production of California. It is produced largely in the lower San Joaquin Valley. The short, conical clusters are of medium size and vary from loose to compact. The seeded berries are very large, oblate to short ellipsoidal, black in color, and moderately tough skinned. The stems are tough, with the berries firmly attached. A few vines are girdled at fruit set for larger berries and often at 4 percent color to advance maturity. The berries are prone to cracking from lid pressure if packed when very turgid. Careful packing alleviates this and the polished appearance caused by the berries' rubbing against each other. It is a mid-season grape and stores well.

RUBY SEEDLESS (Plate 1-D)

This variety is a cross between Emperor and Pirovano 74. Introduced in 1968, it produces less than 0.5 percent of California's table-grape production but is increasing slowly. The clusters are very large, conical, and well-filled with seedless, medium-sized berries that are ovoid in shape and have tender skins reddish black to dark red. The variety ripens mid- to late season in the lower San Joaquin Valley. Berry attachment is firm and the clusters resist damage well during postharvest handling.

CALMERIA (Plate 1-E)

Introduced in 1950 from an open-pollinated seedling of Almeria (Ohanez), it produces over 4 percent of California's table-grape production. The big clusters are well-filled with large, greenish berries that are ovoid and elongated, and have seeds and tough skins. The stems are tough and berry attachment is strong. The variety matures late and is well adapted to extended storage. The harvest season is during late September to October, and marketing extends until the end of December into January. It is replacing the Almeria as a storage white grape.

ALMERIA (Ohanez) (Plate 1-F)

This variety now accounts for only about 0.5 percent of California's table-grape production, being slowly displaced by the Calmeria. The compact clusters are medium to large, with white, seeded berries with thick, tough skins and strong stem attachments. The berries are subject to heat injury (Almeria spot). Harvest season extends from mid-September through October.

ITALIA (Plate 1-G)

This variety produces less than 0.5 percent of California's table-grape production. The clusters vary from medium to large in size and are well filled with large, oval, white, seeded berries that have a slight muscat flavor when very mature. The skin has a pronounced astringent taste. The berries are subject to brown discoloration, especially from abrasion during handling. The harvest season extends from mid-August through September.

FLAME TOKAY (Plate 1-H)

This variety now produces only 2 percent to 4 percent of California's table-grape production. The clusters are big and well filled with large ovoid, truncate, seeded berries that are bright red in color. The berries are subject to sunburn and often fail to color adequately, especially during extremely hot weather in the Lodi district where they are produced almost exclusively. The harvest season is from mid-August through September.

FLAME SEEDLESS (Plate 1-I)

This variety is a descendant of three crossbreeds: the Cardinal and Red Seedless; the Red Malaga and Tifahfi; and the Muscat of Alexandria and the Thompson Seedless. It was introduced in 1973 and has increased from no production 5 years ago to 4.4 percent of California's production during the 1982-83 season. It appears to be displacing the Cardinal. Current production is chiefly in Kern, Tulare, and Fresno counties, starting the first part of July. There is also some production in the Coachella Valley a month earlier. The clusters are medium in size with small, bright red, crisp seedless berries. To achieve larger berries, the vines are girdled and treated with gibberellic acid at fruit set. At the first sign of color, the vines are treated with ethephon to advance maturity of the fruit.

PERLETTE (Plate 1-J)

This variety is a cross between Queen of the Vineyard and Thompson Seedless. It produces about 6 percent of California's table-grape production. Introduced in 1946, it is the earliest commercial variety and is grown almost entirely in the Coachella Valley, where it comprises 74 percent of the acreage. The harvest season extends from late May to the middle of June. It has large clusters and requires heavy thinning by a combination of "brushing" during the prebloom stage and cluster thinning at the fruit-set stage. Berry size is enhanced by girdling and application of gibberellic acid at the fruit-set stage. The white, seedless berries are medium sized, thin skinned, and crisp.

THOMPSON SEEDLESS (Plate 1-K)

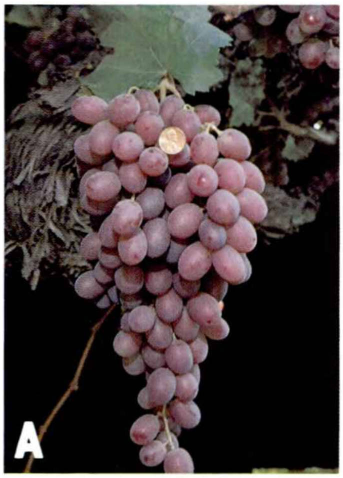
This variety, although officially classified as a raisin variety, produces about half of California's table grapes. It is extensively planted in the Coachella Valley where its harvest season extends through late June. Much larger plantings are in the San Joaquin Valley from Madera southward to Arvin. For successful table-grape production, the vines are usually treated at bloomtime with gibberellic acid for thinning and again at fruit set to increase berry size. This program is supplemented with girdling for berry size and cluster thinning at the fruit-set stage. This program results in a moderately loose cluster with berries ranging from 4 to 6 grams in weight, instead of about 2 grams for a "normal" berry for raisin production. With a fairly thin greenish skin, the berries are seedless and are oval to elongated with a pedicel attachment that sometimes is very weak, resulting in a heavy "shatter" of abscissed berries during postharvest handling.

QUEEN (Plate 1-L)

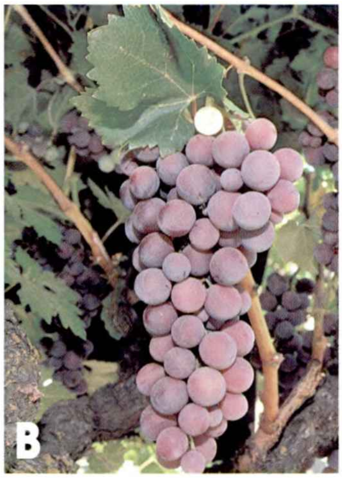
This variety was introduced in 1954 from a cross between Muscat Hamburg and Sultanina. It now produces about 0.5 percent of California's table-grape production. The large clusters are loosely winged, and filled with big berries ellipsoidal in shape and firm with seeds. The color is dark red. The fruit matures during September in the San Joaquin Valley. The vines are often girdled at 1 percent to 5 percent color to advance maturity, and are frequently sprayed with ethephon at the same stage to enhance color.

Plate I.

Varieties of California Table Grapes, and the Relation of Color and Cluster Conformation to Quality

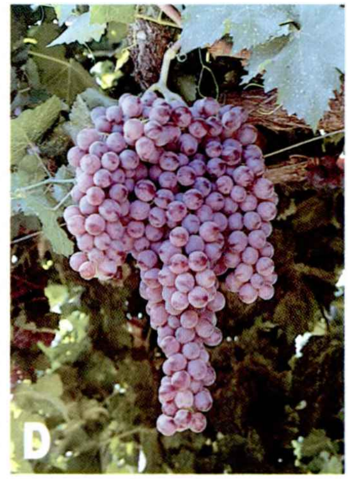


EMPEROR



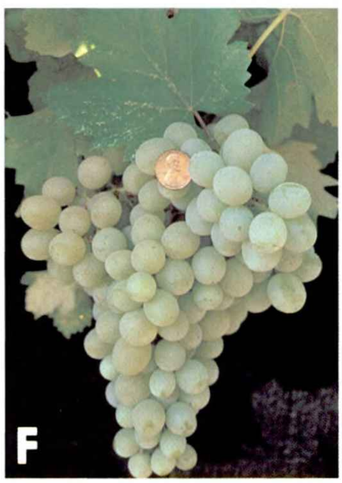
CARDINAL

RIBIER (Alphonse Lavallee)



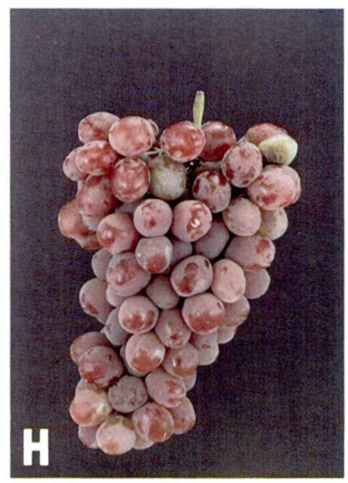
RUBY SEEDLESS

CALMERIA



ALMERIA (Ohanez)

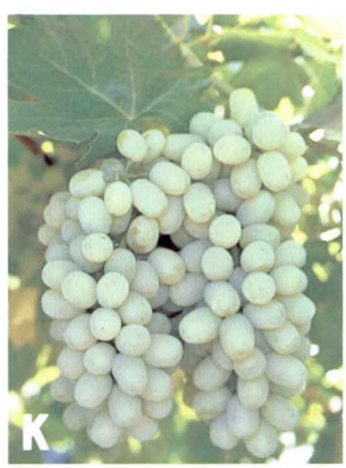
ITALIA



FLAME TOKAY

FLAME SEEDLESS

PERLETTE



THOMPSON SEEDLESS

QUEEN

L1

Queen cluster with 95% characteristic color berries.

M

Queen cluster with 65% characteristic color berries.

N

Queen cluster with 60% characteristic color berries.

O

Queen cluster with 50% characteristic color berries.

P

Ribier cluster with 85% characteristic color berries.

Q

Ribier cluster with 75% characteristic color berries.

R

Ribier cluster with 70% characteristic color berries.

S

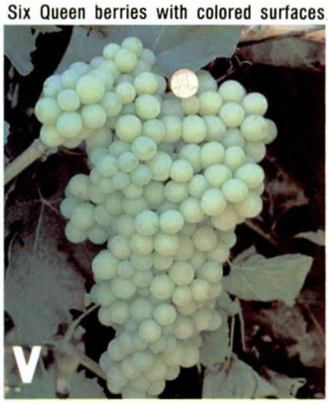
Ribier cluster with 65% characteristic color berries.

T

Six Queen berries with colored surfaces ranging from 0% to 100%.

U

Six Ribier berries with colored surfaces ranging from 0% to 100%.



V

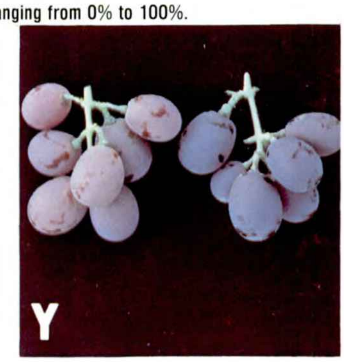
Excessively tight (compact) cluster of table grapes.

W

Emperor clusters: *left*, adequately filled; *right*, inadequately filled with excessively open stems (straggly).

X

Size of clusters and quality: *left*, ½-pound minimum for U.S. Fancy grade; *right*, ¼-pound minimum for U.S. No. 1 grade.



Y

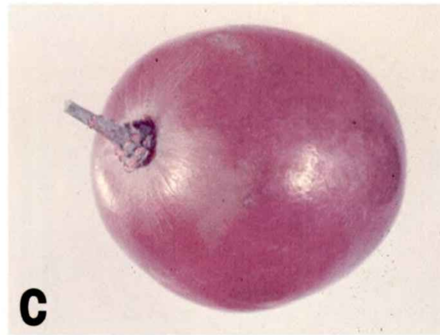
Well-colored berries of Emperor with desirable bright-red-colored berries on the left and less desirable reddish purple berries on the right.

Plate II.

Anatomy of the Grape Cluster and the Impact of Handling on Structure

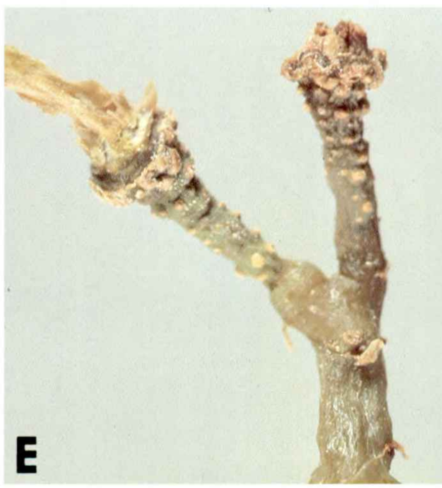
Cluster of Thompson Seedless table grapes with top berries removed to show the main stem (rachis), branches (laterals), the part of the rachis above the first branch (peduncle), pedicels (capstems), and berries.

The same cluster after 6 hours at 20°C (68°F) showing drying and browning of the stems, especially at the junctions of the laterals with the rachis, and the pedicels with the laterals.

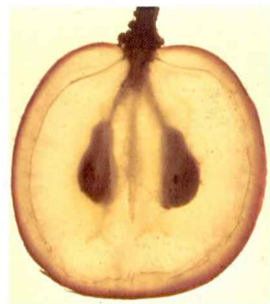


Mature Emperor berry showing the pedicel, torus (enlarged area of the pedicel at the junction with the berry), and the shiny waxy appearance of the cuticle.

Parts of two laterals showing pronounced shrinking and browning at the junctions of the laterals with the rachis, and the pedicels with the laterals. Handling that flexes the laterals and pedicels excessively causes greatest stress at these points resulting in crushing of the tissues and rupture of the cuticle. Subsequent rapid water loss from these areas causes brittleness and increases the likelihood of stem breakage (shatter) of these parts.



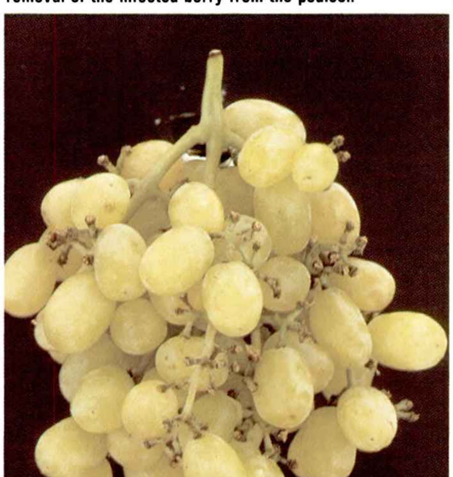
Two pedicels: the one on the left showing a wet brush, which is composed of the vascular strands torn from the inside of the berry; the one on the right showing no vascular strands because the strands had been decayed before removal of the infected berry from the pedicel.



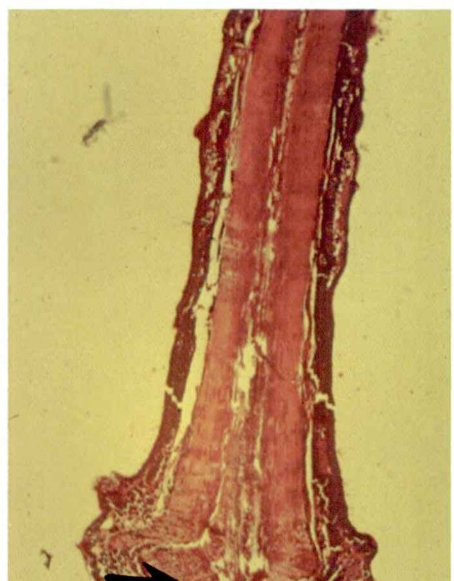
F

View of the center of an Emperor berry cut in a longitudinal plane showing the pedicel, torus, and central vascular system through the center of the berry; two seeds attached to this system; a peripheral vascular system situated just inside of the skin and enveloping the pulp; and the red skin composed of four to six epidermal-cell layers in which the anthocyanin pigments are situated.

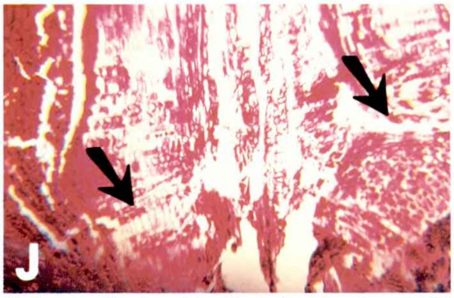
View of the pedicel-attachment area of the berry showing the torn skin and partly ruptured vascular strands resulting from rough handling (wet shatter).



Cluster of Thompson Seedless showing several pedicels from which the berries have abscissed during handling leaving no wet brush (dry shatter).



Photomicrograph of the pedicel of a berry showing the beginning of an abscission zone across the pedicel in the area of the torus (x 16).

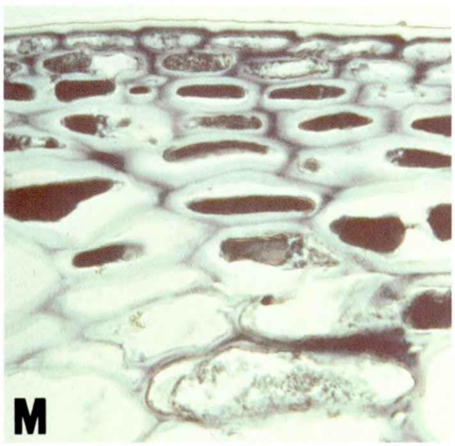


Higher magnification of the abscission zone shown in 2-I, showing the transverse zone of cell separation on each side of the core of vascular strands (x 40). Very slight stress results in a clean separation leaving the berry relatively intact (dry shatter).

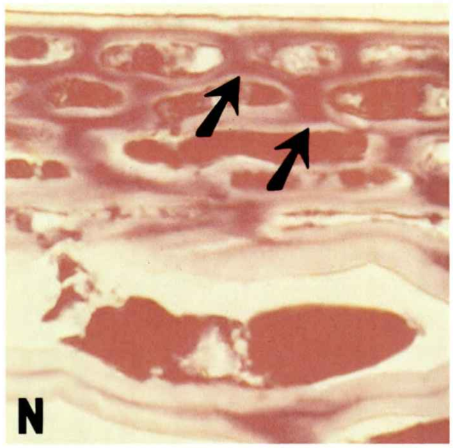
K

Partly peeled Emperor berry showing the network arrangement of the peripheral vascular system just under the skin. Peeling removed four to six epidermal-cell layers containing all the anthocyanin pigments.

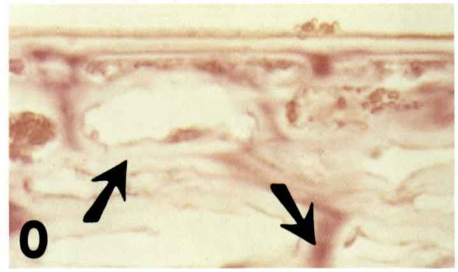
Longitudinal center section of a Thompson Seedless table grape showing the same structures as in 2-F except that there are no normal seeds—only one very small rudimentary seed just to the left of center, the result of an aborted embryo at a very early stage of development.



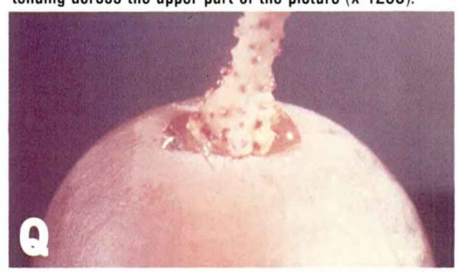
Cross section of the berry skin showing the epidermis and five subepidermal layers of cells (x 600).



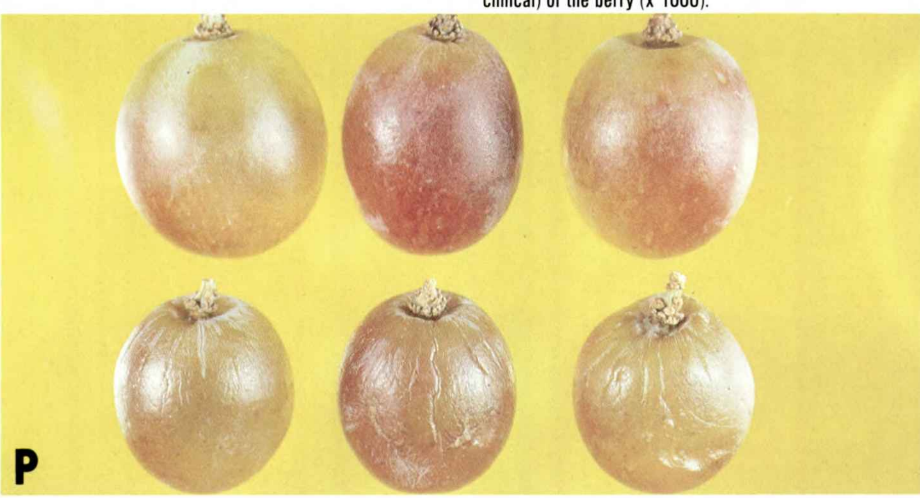
Enlarged view of 2-M showing the middle lamella (stained dark red) between the cell walls parallel to the surface (periclinal) and those perpendicular to the surface (anticlinal) of the berry (x 1000).



Further enlarged view of 2-N showing the greater density of the pectic compounds of the middle lamella between the anticlinal as compared with that between the periclinal walls. The cuticle is the light-colored (unstained) band extending across the upper part of the picture (x 1200).



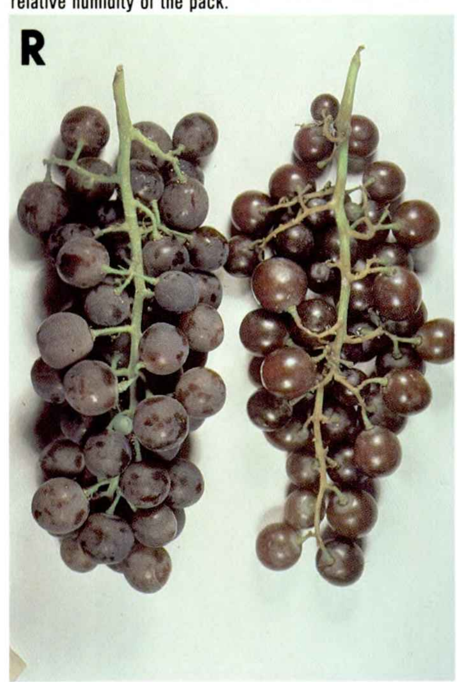
Emperor berry from storage with pedicel attachment injured during packing handling. Juice exuding through the injured area has collected at the base of the pedicel in the high relative humidity of the pack.



Symptoms of water loss from Emperor berries. Upper left berry with no loss is still turgid and bright in appearance. Upper middle berry with 3% weight loss is slightly dull in appearance, and softness of texture is detectable. Upper right berry with 4% loss is distinctly dull and soft. Lower left berry with 5% loss is very dull in appearance with very fine wrinkles radiating outward from the pedicel, and the texture is very soft. Lower middle berry at 6% loss shows deeper and more wrinkles over most of the berry surface and is flabby in texture. Lower right berry with 8% loss shows even deeper and more wrinkles over the entire surface with sunken areas clearly visible. The berry is now very flabby.

Portion of the surface of a Thompson Seedless berry showing two prominent lenticels as brown mounds embedded in the cuticle.

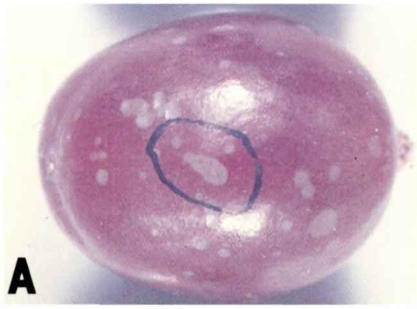
Thompson Seedless berries from storage showing no bleaching, *left*, and with bleached areas under unsuberized lenticels and as a halo around the pedicel area caused by sulfur-dioxide treatment during storage, *right*.



Cardinal clusters with bloom intact, *left*, and with the bloom polished from excessive rubbing of berries against each other and against the hands of the harvesting handlers, *right*.

Plate III.

Chemical Injury and Physiological Disorders of Table Grapes



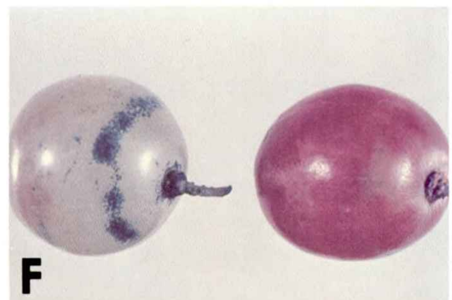
Tokay berry from storage with many bleached spots—one encircled with India ink.

The same berry after being submerged in a saturated methylene blue solution for 2 hours. The dye has penetrated into the underlying tissue through microscopic openings in the cuticle—openings that are at the center of the bleached spots, indicating that through these same openings the sulfur-dioxide gas penetrated during storage treatments and bleached the anthocyanin pigments.

Emperor berry from storage with a large bleached area on which are droplets of exuded juice. The high concentration of openings in this area through which the gas penetrated and the juice subsequently escaped from the injured tissue underneath was probably caused by abrasion during handling.

Emperor berry from storage, which had been in contact with the lid of the container in the area encircled by the ink line. Gas and dye penetration appear to be through openings made in the skin by lid abrasion.

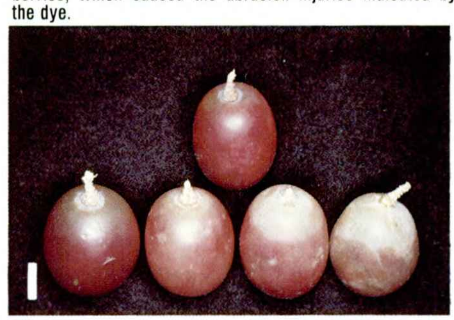
Emperor berry from storage, which had been split by lid pressure. Subsequent sulfur-dioxide treatments have bleached the edges of the split—often a useful symptom indicating whether adequate gas has penetrated to the fruit during treatment.



Emperor berries from the top of a pack subjected to simulated transit vibration. The berry on the right had been kept immobile, that on the left allowed to rotate loosely on the axis of its pedicel thereby rubbing against adjacent berries, which caused the abrasion injuries indicated by the dye.

Emperor berry from storage. The crater-like depressions here and in 3-B indicate accelerated water loss through small openings, probably aggravated by underlying tissue injured by the gas.

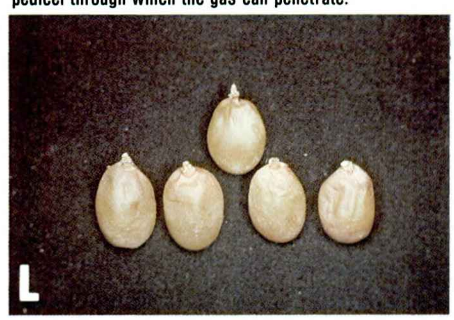
Pedicel of a stored Emperor berry showing a droplet of juice on the tip of each lenticel. This suggests that the lenticels were incompletely suberized, and the gas penetrated here to injure the tissue below, which in turn released juice to exude to the surface.



Emperor berries from storage with sulfur-dioxide bleaching injury ranging from none to very severe. Typically bleaching is most severe around the pedicel because of the high concentration of openings in and around the base of the pedicel through which the gas can penetrate.

The same five berries after 3 days at room temperature and in relatively dry air. The rate of water loss is apparently directly related to the severity of the bleaching injury.

The same type of injury apparent on stored Thompson Seedless berries as that shown in 3-I for Emperor grapes.



The same five berries after 3 days in dry room air. The response to drying conditions is the same as that shown in 3-J for Emperor grapes—sunken pedicel area which coincides with the bleached area.

Thompson Seedless berries from storage. Those on the right have mild ammonia injury as indicated by bluish spots and bluish brown stems; those on the left are unaffected.

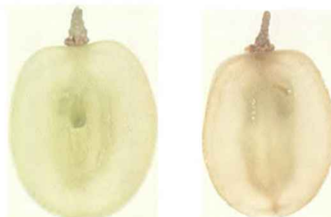
Severe ammonia injury of Thompson Seedless berries, *right*, indicated by bluish black berries and stems; the berries on the left are unaffected.

O

Cardinal (red) grapes with severe ammonia injury, *right*, showing purplish berries and blue-black stems—symptoms characteristic of ammonia exposure.

P

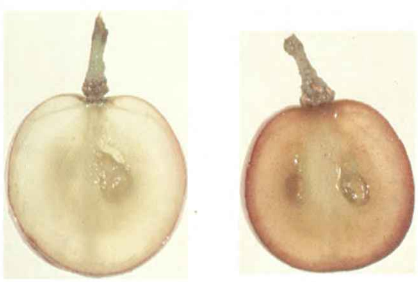
Enlarged view of Cardinal berries with severe ammonia injury, *right*. Berries may "leak" and the tissue may have a water-soaked appearance.



Q

Freezing injury of Thompson Seedless white berry, *right*. The cut surface shows the characteristic water-soaked appearance and beginning of browning of the injured tissue as contrasted with the firm translucent green tissue of the unaffected berry on the left.

Thompson Seedless berries that had been frozen, then thawed. Note the rapid onset of browning and leaking of juice from the berries.



S

Freezing injury of a Cardinal berry, *right*. A center slice of the affected berry shows with transmitted light the characteristic onset of browning and a water-soaked condition.

T

Freezing injury of Cardinal grapes, *right*, indicated by a brownish-red color and leaky berries.

Tokay cluster with many shriveled berries caused by excessive heat during the growing season (probably from direct sunlight).

Calmeria berries showing Almeria spot characterized by sunken, brown leathery spots caused by pulp temperatures exceeding the thermal death point during the growing season.

Waterberry of Thompson Seedless grapes. Affected berries are soft, immature in appearance, and watery and sour when tasted. Sometimes the symptoms are so subtle that they do not become apparent until several hours after harvest.

Browning of Thompson Seedless stored grapes indicated by the gray-brown color of the berry on the right and less so by that on the left. The center berry is unaffected.

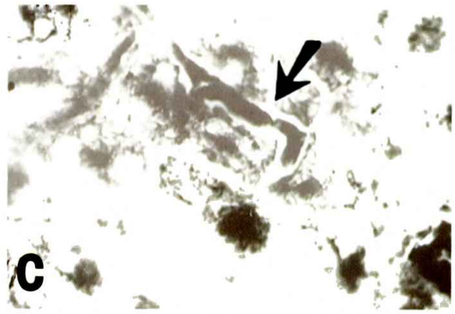
The same three berries cut in half showing strong internal browning symptoms in the rudimentary seed area, *right*, and browning of one shoulder of the berry on the left (probably the result of a bruise inflicted during handling).

Plate IV.

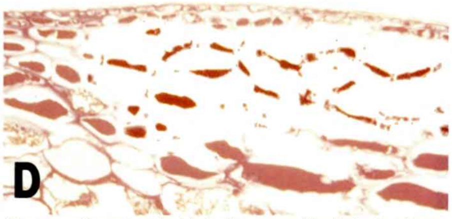
Symptoms and Signs of Pathogenic Organisms on Table Grapes

Shown is a side view of a conidium of *Botrytis cinerea* that has germinated on the surface of the cuticle (orange band) of a berry and has produced an attachment body (appressorium) below which is a very slender infection peg that has penetrated the cuticle (x 1200).

A subcuticular vesicle (mycelium) is just beginning to form below the appressorium indicating that infection has been established through the uninjured cuticle (x 400).

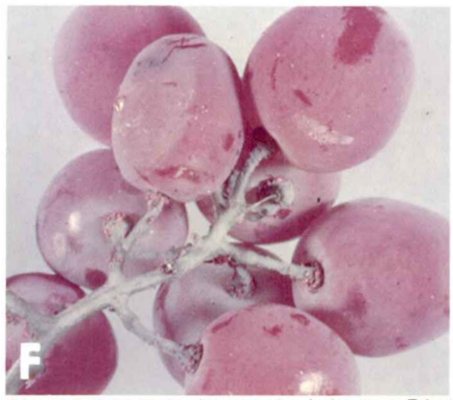


Top view of intercellular mycelium taken in the plane of the epidermal-cell layer just below the cuticle. The center of the picture shows a segment of subepidermal mycelium of the fungus growing between the cells of the epidermis (x 400).



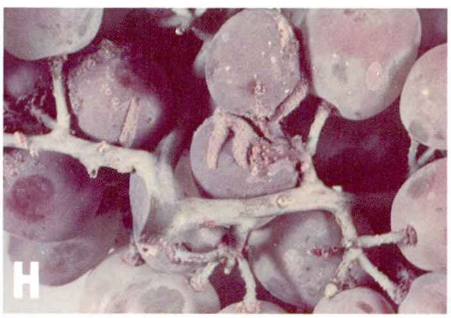
Cross-section of a slipskin lesion caused by *Botrytis cinerea* (x 40). Ruthenium red, a stain specific for the middle lamella, has imparted a dark red color, especially dense at the left side of the picture beyond the edge of the lesion. In the lesion area to the right is the cleared effect resulting from breakdown of the pectic compounds of the middle lamella by the fungus. Note the "sheets" of subepidermal cells whose periclinal walls have separated with the anticlinal walls for the most part still attached. The pulp cells below are unaffected and the epidermal-cell layer remains attached to the cuticle. This type of maceration, where the epidermis and cuticle slide easily from the pulp, gives rise to the term *slipskin*, a unique symptom of early infection by this fungus.

Advanced infection by *Botrytis* on Calmeria berries as indicated by the conspicuous brown areas in contrast to the green unaffected tissue.



Advanced stage of development of a lesion on a Tokay berry, *center.* The gray-brown area on the left side of this berry is difficult to detect in contrast to the red pigment of unaffected tissue.

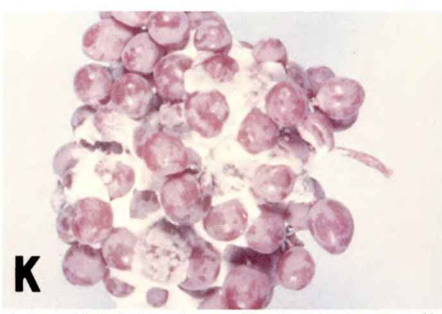
A slipskin lesion shows on each of two Tokay berries; that on the right has been ruptured by very slight pressure, that on the left is still intact. It is difficult to detect these lesions; if overlooked they can be sources of decay later in the packed fruit.



The Botrytis infection has advanced to the stage that the mycelium forms ridges of conidiophores and conidia in the cracks of the weakened epidermis. The gray color suggests the name *gray mold* for this later stage of infection.

Botrytis-infected berry in a pack of Emperor grapes after storage for more than 2 months. Effective weekly treatments with sulfur dioxide have kept the fungus contained within the berry thereby allowing no contact infection to take place.

In this pack, inadequate sulfur dioxide has allowed the fungus to spread from the field-infected berry into adjacent unaffected berries by contact infection.



A nest of infected berries resulting from inadequate sulfur-dioxide exposure. The *Botrytis* mycelium is white as it produced few conidia at the low temperature in the high relative humidity in the pack. In the vineyard, abundant conidia impart a gray-brown color to the fungus as shown in 4-H.

Botrytis infection of the stem of the cluster as indicated by the brown color of the affected tissue, *upper right.* This type of infection is dangerous as the fungus can move through the stems and infect berries through the pedicels.

Summer bunch-rot phase of Botrytis infection. Infection took place in the spring during bloom in the dead floral parts, then remained dormant as a latent infection until the berries started to ripen in late summer. Decay may develop before harvest or in transit or in storage (Hewitt 1974).

Emperor berries from storage infected by *Cladiosporium herbarum* (black spot).

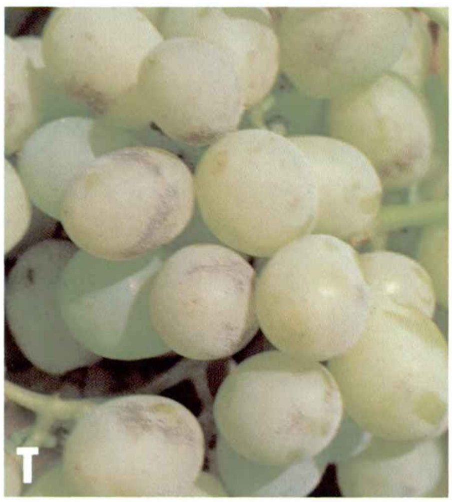
Later stage of black-spot infections showing mycelial development on the surface of the berries, white at first, then becoming olive green in color as many spores are produced.

Two Emperor berries showing black-spot infections, probably caused by *Alternaria* sp. or *Stemphyllium* sp., because infection appears to have taken place at the stem end. These fungi usually need a wound to gain entry and a torn pedicel attachment is a common court of infection. In contrast, *Cladiosporium herbarum,* like *Botrytis cinerea,* can infect berries directly through the uninjured skin.

Emperor berries infected by *Penicillium* sp. The blue-green color of the sporulating surface and maceration of the contents of the berry to a watery consistency are characteristic.

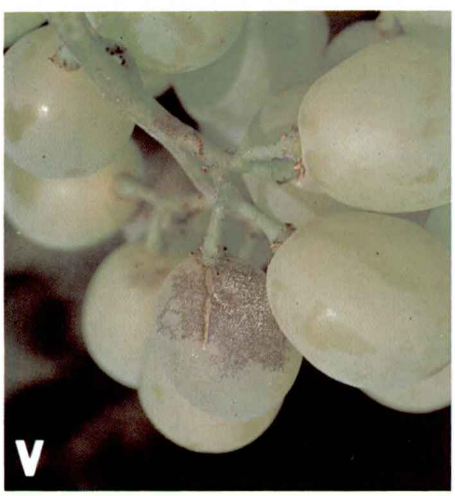
Thompson Seedless berries infected by *Aspergillus niger.* The brown sooty soiling of the fruit, often called *smut* in the industry, is distinctive. Like *Penicillium,* it liquefies the contents of the berry.

Thompson Seedless berry infected by *Rhizopus arrhizus.* A mat of dense coarse gray mycelium with many spores that look like finely ground pepper is characteristic.



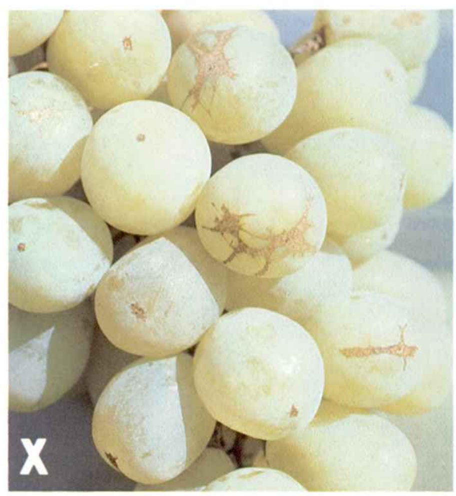
Thompson Seedless berries that were infected by *Uncinula necator* (powdery mildew) before harvest. This ectoparasite caused the characteristic lacy scarred pattern on the berries.

Thompson Seedless berries scarred by contact with leaves or other parts of the vine or trellis during growth.



Heavy infection of powdery mildew is shown on the middle berry as a dense gray mat of mycelium and conidia. Cracking of the berry indicates an early infection before the berry had attained full size. The infection so damaged the skin that splitting occurred as the berry enlarged.

Heavy mildew infection that has involved the stems as well as most of the berries.



Scarring of Thompson Seedless berries caused by thrips feeding on the berry, while sheltered by floral parts that adhered to the surface just after berry set. This type of scarring is restricted largely to the calyx end of the berry and is less lacy in pattern than that caused by powdery mildew as shown in 4-T.

Cooling Table Grapes

The Need for Cooling Table Grapes

Table grapes are available in most major markets of the world for most of the year. This can be ascribed largely to the application of modern technology of postharvest handling of the fruit. Production of this fruit is highly seasonal and limited to relatively small areas of the world. As a result, the grapes must often be transported over long distances and in seasons several months after they have been harvested. To meet the demands of distant markets, much of the grape crop must be kept fresh and attractive for several weeks or even months after harvest. No phase in the postharvest-handling procedure to maintain quality is more critical than that of cooling—removal of the sensible or field heat from the fruit after harvest.

Development of effective methods of temperature management for table grapes has been especially significant in production areas distant from major markets. A large share of the California crop is marketed in the northeastern part of the United States and Canada 3,000 miles away, with a smaller share exported to Europe, South America, and southeast Asia. The Republic of South Africa markets the major part of its crop in the northern countries of Europe, and much of the Chilean crop is exported to other South American countries and the United States.

There are three compelling reasons why table grapes should be cooled promptly and thoroughly after harvest to maintain satisfactory quality: (1) minimize water loss from the fruit, (2) retard development of decay caused by fungi, and (3) reduce the rate of respiration of the fruit. Probably the most urgent reason to cool the grapes promptly is to reduce the rate of water loss. This phenomenon is strictly a physical factor related to the evaporative potential of the surrounding air. It may be expressed directly as *vapor-pressure deficit* (VPD), a term indicating the combined influence of temperature and relative humidity, and is the one factor related directly to the rate of water loss from the fruit. The equation may be expressed as follows:

$$VPD = VP \times \frac{100 - RH}{100}$$

where VPD = vapor-pressure deficit (mm or inches of Hg [mercury]),

VP = vapor-pressure of water at a given temperature (mm or inches of Hg), and

RH = relative humidity (percent).

It is apparent from the equation that the VPD increases as the VP increases (which would occur with a rise of temperature of the grapes, since VP is related directly to temperature of water and since the juice of the berries is largely water). Further, the VPD will increase as the RH is lowered. It is expected, then, that the VPD would be especially high during the typically hot, dry conditions that prevail during harvest of California table grapes. Reducing the temperature of this hot fruit promptly and rapidly will therefore drastically reduce the amount of water loss.

Temperate Effects on Water Loss

Figure 13 is a generalized overview of fruit temperatures during a typical postharvest-handling operation for California table grapes. The relatively high fruit temperatures prevail from the time the grapes are harvested until cooling is well under way. Especially critical are temperatures during the summer season. Significant, then, is the length of this phase before cooling when the fruit is deteriorating most rapidly. This phase may range from 1 to 12 hours, which can spell the difference between top-quality and unacceptable fruit. Once cooling has started, the length of this phase, which may range from 3 to 24 hours, can also have a significant effect on the market quality of the fruit.

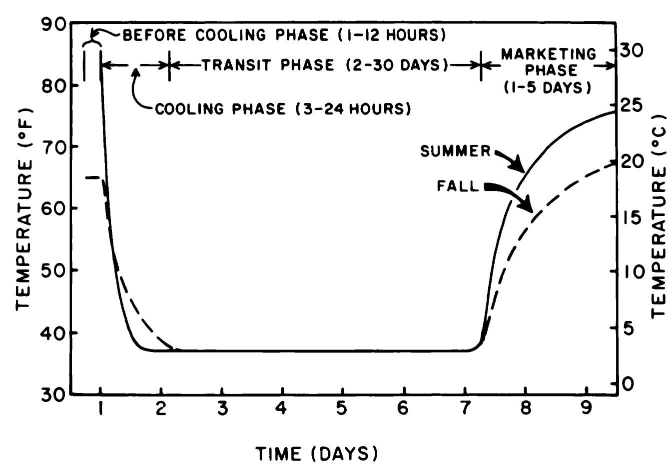


FIGURE 13. Typical temperature environment of California table grapes from the vine to the consumer.

The transit phase, too, can be an important factor in the postharvest-handling chain, mainly because of the length of the period. It may be only 2 to 8 days for domestic shipments, but as long as a month for export grapes. A typical transit temperature of 2° to 2.5°C (36° to 38°F) is shown, which may be acceptable for the period of a week or less, but for a month this transit temperature should be nearer 0°C (32°F). Although not shown in the figure, there could be a storage period of as many as 6 months starting at the end of the cooling phase. Since the length of this period is great, the temperature should be near ideal (−1.0°C [30°F]).

Finally, the temperature environment during the marketing phase can be of utmost importance. It is by nature a severe phase as the fruit normally warms up during distribution handling. It is the end of the line—all of the deterioration of the preceding phases is additive, so market quality may appear to drop quickly, especially if good temperature management is not maintained and the marketing period is extended excessively.

Some techniques can be used to avoid the higher fruit temperatures during harvest. Fruit picked early in the morning will be considerably cooler than fruit picked later in the day. Cooler fruit means less deterioration, and means that less cooling is needed. Further, exposing the picked fruit to the sun can cause a drastic rise in fruit temperature. Figure 14 illustrates that this temperature can actually be as much as 7°C (11°F) *above* that of the air while shaded fruit remained no less than 3°C (6°F) *below* the air temperature. A difference of 9°C (17°F) in this temperature range can very quickly mean the difference between fruit that is still acceptable and fruit that is useless, because of drying. Harvested grapes, then, must be kept shaded until cooling can be started. Also, the earlier in the day the fruit is harvested and cooling started, the lower the initial temperature, which shortens accordingly the length of the period required to bring the fruit to transit temperatures. In the Coachella Valley where these data were obtained, it is common practice to start harvesting in the morning as early as visibility will permit, then suspend picking operations at noon.

There are least three symptoms of water loss from grapes. First to appear are shriveled stems that usually become brittle and break easily when handled (plate 2-A, 2-B). With grapes, unlike other fruit, the stems serve as a handle to move the fruit. When this handle is broken, the fruit is lost for all practical purposes, even though the shattered berries themselves still look and taste good. Such losses can be very considerable. Figure 15A shows how rapidly the stems can dry, especially if temperatures are high. Not only is the rate of drying related directly to temperature, but the rate increases logarithmically. For example, the increase in the rate of drying is much greater from 27° to 32°C (80° to 90°F) than from 21° to 27°C (70° to 80°F), and greatest from 32° to 38°C (90° to 100°F).

The second symptom of water loss to appear is browning of the stem. Such stems detract seriously from the appearance of the grapes. The brown-stem syndrome follows closely that for dry stems and shows the same response to temperature (fig. 15B). In fact, the rate of stem browning increases more rapidly with temperature than does the rate of stem drying (Nelson 1955). From 21° to 38°C (70° to 100°F) there is a three-fold increase in stem drying after 8 hours whereas for stem browning it is more than a four-fold increase.

The third symptom of water loss is shrinkage of the berries. Grape berries do not *show* symptoms of water loss until shrinkage is quite evident on the stems. However, at about 3 percent loss in weight, the berries start to appear dull as the taut condition of the skin slackens. At 4 to 5 percent loss the berries feel definitely soft, and above a 5 percent loss fine wrinkles start to appear radiating out from the pedicel (plate 2-P). Market quality is significantly impaired when the berries feel soft, and the berries border on being unacceptable when they show distinct wrinkles. As in the case of the stems, the rate of berry softening is related directly to temperature before cooling (fig. 15C). Grapes held 8 hours at 38°C (100°F) had 75 percent of the berries rated

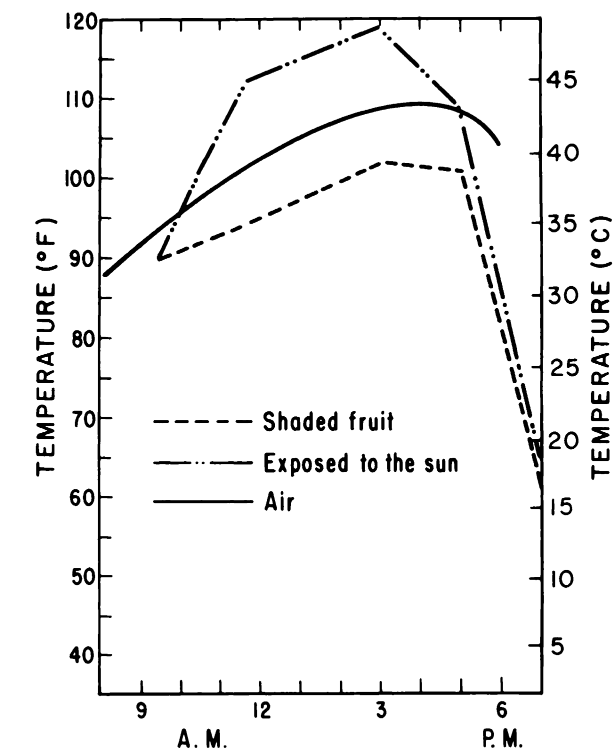


FIGURE 14. Effect of shade on the temperature of harvested grapes before packing.
The fruit was harvested at 9 a.m. and cooling started at 5:30 p.m.

"soft," whereas the lot held at 21°C (70°F) had only 45 percent soft berries. Weights were determined for these lots of grapes during the delay period (fig. 15D). The lot at 38°C (100°F) lost 3 percent of the initial weight during the 8-hour period whereas that held at 21°C (70°F) lost 0.3 percent—only one-tenth as much.

That these high temperatures before cooling are relatively severe may be illustrated by comparing the rate of deterioration of the fruit with that after cooling. The general conclusion can be made that harvested grapes will deteroriate *more in 1 hour* at 32°C (90°F) than they will in *1 day* at a common transit temperature of 4°C (39°F) or in *1 week* under storage conditions of 0°C (32°F). Good temperature management then is essential, considering the appalling effect the relatively short period before cooling can have on the postharvest life of the grape.

Temperature Effects on Decay

Decay is an ever-present hazard in the postharvest handling of table grapes. Surface contamination by fungus spores and even field infections should be assumed to be present in the berries. Two effective tools are available to minimize this danger. First is prompt and complete cooling of the fruit; and second, timely and thorough fumigation with sulfur dioxide—supplemented with weekly treatments if the fruit is stored (Nelson and Baker 1963).

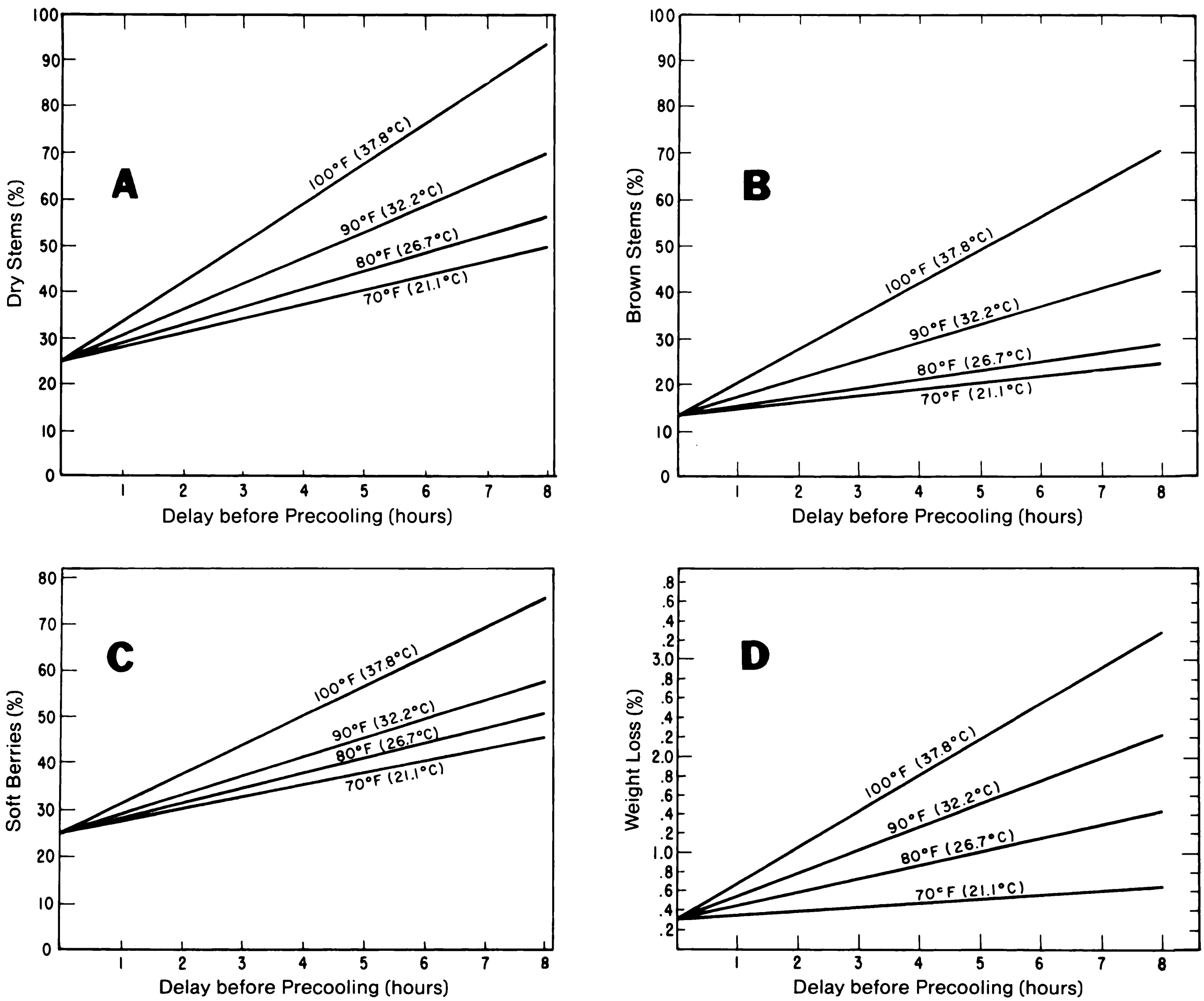


FIGURE 15. The effect of four different temperatures between harvest and cooling on the rate of deterioration of quality of table grapes.

A. Drying of stems.
B. Browning of stems.
C. Softness of berries.
D. Weight loss.

Several fungi can incite postharvest decay of grapes, the most important being *Botrytis cinerea.* This fungus grows across nearly the entire temperature range in which grapes are handled. However, growth is slowed as the temperature is lowered until it is *almost* stopped at the optimum storage temperature of −0.5°C (31°F). It is important, then, that the fruit temperature be lowered promptly and as rapidly as possible to this temperature. In addition to fumigation, an effective supplement to temperature management in controlling decay is careful handling of the fruit at all times to minimize injury. Broken berries are not only unsightly but are favorite courts of infection by fungi.

Temperature Effects on Respiration

Table grapes like all other fresh fruit are alive and remain so during postharvest handling and marketing. Being alive, they respire using stored chemical constituents, primarily sugar, and oxygen from the air to produce carbon dioxide, water, and energy (heat). Respiration is a deteriorative process; the heat produced must be removed to prevent a rise in temperature that would accelerate deterioration. Relative to most fruits, grapes have a very low respiration rate. Although low, the process requires significant quantities of refrigeration to remove this heat as well as the sensible heat during cooling. Further, after transit or storage temperatures are attained, heat is still being evolved that must be removed in order to maintain the desired temperature. Figure 16 shows that this amount can be significant. If the grapes have been cooled to 4°C (40°F) before being stacked such that no heat enters or leaves the fruit, the rise in temperature in 8 days is 2°C (4°F). However, if the initial temperature is 20°C (68°F), then the rise is about 10°C (18°F). This is a very substantial increase—certainly sufficient to aggravate problems of decay. Loading inadequately cooled grapes into mechanically refrigerated carriers (either rail or truck) can cause such problems since these carriers cannot adequately cool grapes, partly because of lack of refrigeration capacity and partly because of lack of air circulation throughout the load.

History of Cooling Grapes

Until about 1950, most table grapes destined for distant markets were transported in ice-refrigerated rail cars. These cars had bunkers in each end with a total capacity for about 5.5 tons of ice. When properly used, the refrigeration capacity was sufficient to cool adequately the approximately 15 tons of grapes. The cars became relatively efficient coolers when fan systems were installed during the 1930s and 1940s (Pentzer 1945). These fans reversed the natural convection causing the air to rise in the bunkers, flow out over the load, down between the braced packages, and back under the floor racks to the bunkers. Greater efficiency of cooling was attained when provisions were made to power these fans with electricity at the loading dock, starting them immediately after the car was loaded with warm fruit and then running them continuously for a day before releasing the car. The alternative was to release the car when loaded, with the result that the fans would run only when the car was in motion. In practice, during the first day or two of the transit period, the cars stood still in reicing stations or switching yards as trains of these cars were assembled for the transcontinental trip. Unfortunately, these long delays occurred precisely when the need for uninterrupted cooling was most critical.

After 1950, more and more of the fruit was transported by carriers equipped with mechanical refrigeration. Refrigerated highway vans carried an increasing share of the grapes. At the same time, the railroads shifted gradually to mechanically refrigerated cars *(reefers),* until by 1970 the ice-refrigerated car was essentially phased out. These changes had a marked effect on methods and location of grape cooling. It became evident that these cars could not adequately cool grapes because of the limited capacity of the refrigeration unit and the much heavier loads being hauled. The units in these carriers were able to hold satisfactory transit temperatures *provided* that the fruit had been

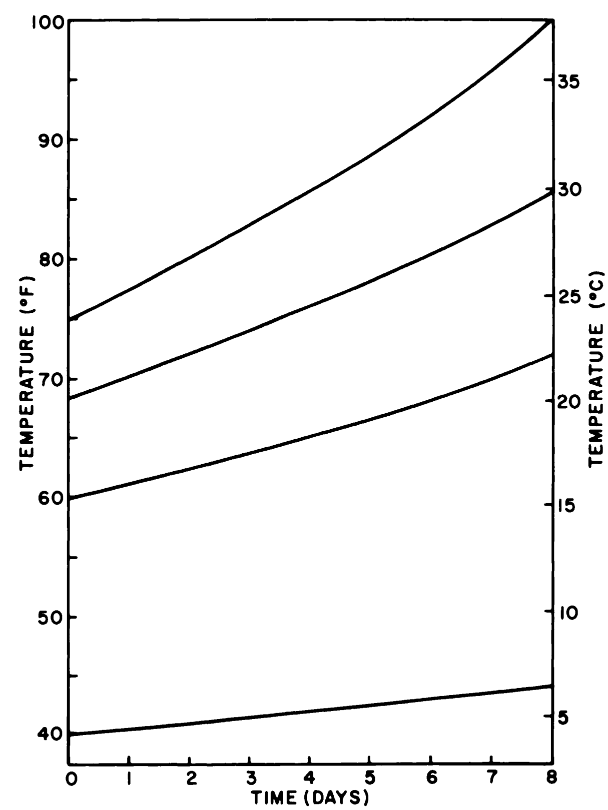


FIGURE 16. The effect of initial temperature and the heat of respiration of table grapes in the increase in temperature.
It is assumed that heat neither escapes from nor enters the space occupied by the fruit.

brought to transit temperature *before* loading. Even for shipments to points within California, only very limited quantities of table grapes are moved without cooling. Such movements are usually overnight hauls from the Coachella or San Joaquin valleys into Los Angeles and San Francisco Bay markets. Unless marketing is very prompt, the practice can be hazardous because of rapid deterioration of this warm fruit.

Methods of House-cooling Grapes

There are three general methods of house-cooling grapes based on how the cooling air is brought to the fruit: (1) *parallel flow* when cooling air is delivered by fans on the side of the room to palletized fruit with two sides of each pallet exposed to the air flow, or when the air is delivered downward from ceiling jets between pallets with four sides exposed; (2) *forced air* when the air is delivered directly to the fruit by establishing a pressure gradient *across* the lugs in the pallet; and (3) *conduction* when the air is delivered to the *unvented* lug. The parallel-flow methods may be regarded as approaching natural-convection cooling—the velocity of the air along the sides of the containers causing turbulence that results in air exchange through the vents of the package. The forced-air method may be considered as simply forced-convection cooling. The conduction method is just that: the berries in contact with the cold unvented liner are cooled by conduction, and they in turn extract the heat from those deeper in the pack by the same process with no air movement involved. Actually all the methods involve at least some degree of conduction in heat transfer to the cooling air. Each method has advantages and disadvantages; however, they do differ widely in the rate of cooling the grapes (fig. 17). There is a close relation between the cooling rate and the accessibility of the fruit to the cooling air. Exposing the containers reduces the cooling time, but when the fruit itself is brought into close contact with the air (forced air), the cooling time is drastically reduced.

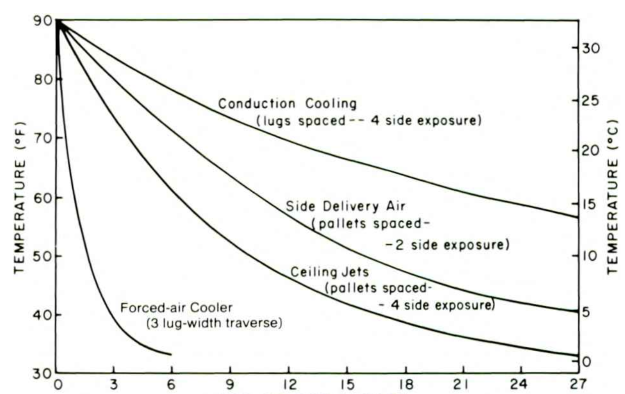


FIGURE 17. The effect of method of air-handling during cooling on the rate of decrease in temperature of table grapes.
The conduction method involves packages with no vents and would be used only with in-package sulfur-dioxide generators.

Parallel-flow Cooling

Figure 18 shows pallets of grape lugs and chests stacked in a conventional cooling room. Although not shown, fans direct the air across the top of the room, after which it flows downward and back through the channels between pallet stacks. The air is then pulled up through the refrigerated bunker by the fan to start the cycle over again. Several means are used to make the fruit as accessible to the air stream as possible. Channels through the stacks of TKV lugs in the center stack (appear as diamond-shaped holes) help in cooling the center of the pallet, especially if the pallets are spaced with 1 or 2 inches between pallets in the row. Channeling within pallets not only shortens the total cooling

FIGURE 18. Palletized export chests and TKV lugs stacked in a typical cooling room.
The stack of pallets on the left has the chests stacked squarely on each other with spacers between so that the cooling air can reach the fruit. The stacks on the right are in an offset-stacking pattern for the same reason.

time, but, more significant, it reduces the range in temperature between the least and most exposed fruit in the pallet (Richardson, Nelson, and Meredith 1971). Thick cleats on both ends of the lids or bottoms of the lugs are effective. These provide channeling between the layers of lugs in the pallet. Lack of such channels nearly doubled the time required to cool a pallet of TKV lugs in a nine-stack pallet. Interior channeling becomes even more significant if packing materials within the lugs block air movement. Vented curtains will increase the cooling time three- to fourfold as compared with no liners (Ryall 1952). Chimney wraps and wraps that completely enclose the clusters have as much or more effect on blocking the cooling air (Nelson, unpublished data). The outer lugs of the pallet are cooled by the ram jet effect of the turbulent channel air, which forces cold air through the side vents along the top and bottom of the lugs. The velocity of the air in the channels should be at least 200 feet per minute (fpm) to assure satisfactory cooling. To the left and right of the TKV lugs are stacks of export chests. Since chests do not have vents, they are stacked in an offset pattern on the right, and on the left are stacked squarely on each other with spacers between chests. In this way, the cold air has access to the fruit as well as the sulfur-dioxide-laden air during fumigation. A conventional room such as this shown here should have a fan capacity to deliver 6,000 to 8,000 cubic feet per minute (cfm) of air per 1,000 lugs of grapes (Ryall and Harvey 1959). Also, since about 3½ tons of refrigeration are required to cool 1,000 lugs (22 pounds net) of grapes 22°C (40°F) in 24 hours, the capacity should be adjusted not only to the amount of fruit to be cooled but also to the time required for cooling. For example, if the room holds 4,000 lugs, the amount of refrigeration would be 14 tons for a 24-hour cooling period. However, if the cooling is to be completed in 12 hours, the refrigeration capacity of the room must be twice that, or 28 tons. A ton of refrigeration is that required to freeze one ton of water at 0°C (32°F) into ice at the same temperature in 24 hours.

Some table-grape operators place the fruit to be cooled in the same room with storage grapes. This practice is not as desirable as that using a separate room just for cooling because the rapid air movement required for good cooling dries excessively fruit that has already attained the storage temperature. The objection to this practice can be overcome somewhat by designing the cooling room into *bays,* each separated by a wall that extends part way across the room. If each bay is served by a fan or damper system that can be controlled independently, the air environment of this bay is semi-isolated from that of other bays. As long as the temperature of the fruit is being lowered, high-velocity air conditions can be maintained without affecting materially the environment of adjacent bays, such as passing warm air over fruit that has already been cooled. For a cooling bay to operate properly, the cold air must be delivered to the back of the bay where it then can move through the stacks of fruit to the center of the room. Once storage temperature is attained, either the rate of air movement may be reduced or the fruit moved to a storage bay.

Cooling rates can be increased in a parallel-flow system if the air is brought to the pallets of fruit through jets in the ceiling (fig. 19). Faster rates are possible, largely because the air is brought to all four sides of the pallet directly beneath the jet, rather than to only two sides in a channel-flow situation (fig. 18). However, the faster cooling benefit of this system is offset somewhat by the elaborate systems of plenums needed and the problems of balancing the air-distribution pattern. Further, since cross, as well as longitudinal, channels must be provided, the pallets must be positioned so that each intersection of the channels is precisely under a ceiling jet.

Forced-air Cooling

The feasibility of forced-air cooling (pressure cooling) as a rapid method of removal of field heat from grapes was first demonstrated at the Earl Fruit Company in Lodi, California (Guillou and Nelson, unpublished data 1954). Later the method was reported by Guillou and Parks (1956). Figure 20 shows the principle of this method. The rate of cooling with this system is greatly increased over that of the parallel-flow system (fig. 17) because the cooling air is brought directly to the *fruit* in the package rather than just to the *package.* By setting up a pressure gradient *across* the package, there is a positive flow of cooling air *through* the container from one side to the other providing direct contact with the packed fruit. Figure 21A shows one unit of a forced-air system in operation. In place are six-stack pallets with the pressure gradient across three containers. The negative pressure is causing the flexible

FIGURE 19. Cooling room with ceiling jets for air distribution.
Channels are left in both directions between the pallets with the intersection of the channels directly under a ceiling jet (Winkler et al. 1974).

baffle to be pushed slightly into the channel between the two walls of pallets of the unit. This type of unit has several merits. The pallets can be quickly moved into place with forklift trucks and the baffle can be installed easily. When cooling is completed 3 to 9 hours later, the unit can be easily dismantled. Or, if it is not necessary to move the fruit, the baffle can be lifted and the pallets left in normal parallel-flow air. It is important that the baffle be removed because, when the desired temperature is attained, further air flow through the containers will needlessly dry the fruit.

Figure 21B shows another method of handling pallets efficiently in a forced-air system. As a pallet is pushed into place against the wall, a trigger near the floor opens vents in the wall behind the pallet, which starts air flow through the pallet. When cooling is completed, the pallet can either be removed or moved back a few inches, which closes the vents stopping further air flow through the pallet.

Maintaining high efficiency of a forced-air system requires close monitoring of several factors. The room temperature should be checked frequently during the day to verify that it does not rise above the permissible level (fig. 25). This is especially important during the afternoon and evening, when larger and larger quantities of fruit that were brought in earlier in the day need to be cooled. Forced-air systems can make enormous demands on the refrigeration capacity because they extract heat from the fruit at a rate many times that of a parallel-flow system. As the temperature of the cooling air rises because the demand for refrigeration

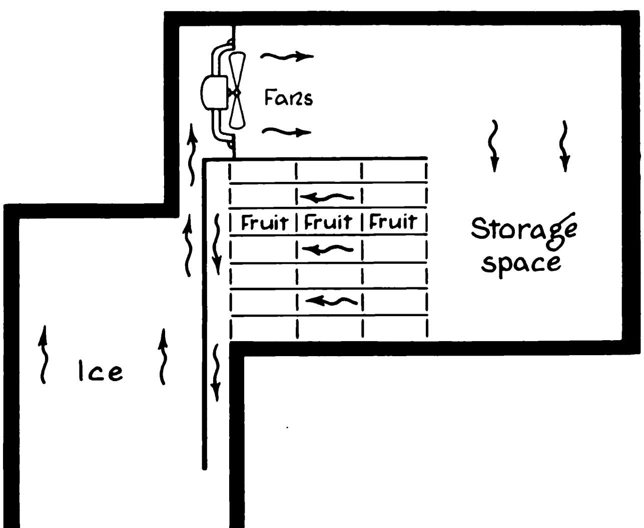


FIGURE 20. Diagrammatic illustration of the principle of forced-air cooling.
Air pulled by the fan from the refrigeration compartment (ice, coils, spray, or packed column) is forced through the fruit packs from one side of the lug to the other before returning to the compartment (Winkler et al. 1974).

exceeds capacity, the cooling rate of the fruit decreases correspondingly. This prolongs the cooling period and thereby increases the dehydration of the grapes.

In a well-operated forced-air system, both the static-pressure and the air-volume parameters are critical. Operating either parameter beyond certain limits results in slower cooling and/or excessive use of power for the air-handling system. Generally, the system should be designed to deliver about 1 cubic foot of air per pound of fruit a minute ($ft^3/lb/min$ or 0.128 $m^3/kg/min$). However, this volume will vary depending on the length of the cooling period desired. The fan capacity required to deliver a given volume of air depends on the static-pressure difference across the packed fruit. In turn, the static-pressure difference required to deliver a given volume of air depends on (1) the length of the channels through the packs, as determined by the width of the containers in the pallet and the number of containers across which the channels extend; (2) the area and length of channels between containers, pallets, and baffles that allow the air to bypass the packed fruit; (3) the area, number, and exposure of vents in the packaging materials and containers; and (4) the resistance of the fruit and packaging materials, such as liners and cluster wraps, to air flow. Close monitoring of the pressure differential will indicate whether there is excessive air leakage due to faulty placement of pallets or baffles. An effective means for checking static pressures is a manometer calibrated in hundredths of an inch water pressure (fig. 35C).

As channel length is increased, the pressure differential must be increased greatly to keep the air volume constant. This means correspondingly more fan power. For a pallet where the air must traverse three package widths, a differential of 0.25 inch of water was found sufficient to cool naked packs of grapes covered with vented curtains (Guillou 1960).

The cooling rate within the pallet may be uneven, especially when the air channels are long. It takes 1 to 2 hours longer to cool the downstream fruit in a pallet three packages wide than it does to cool the upstream fruit. This problem may be overcome somewhat by allowing some room air to bypass the upstream packages, as shown in figure 22. The mixing of cold room air with air that has traversed the upstream packages permits more uniform cooling of the entire pallet of fruit. Careful monitoring of the temperature of upstream and downstream fruit will indicate the best channel width to use for mixing the air streams to obtain the most uniform cooling rate. In all instances, the warmest location in the pallet would be monitored and the temperature of its fruit should be used to determine when cooling is adequate.

The size, number, and placement of vents in the packages may have a significant effect on the length of the cooling period. For example, with a static pressure of

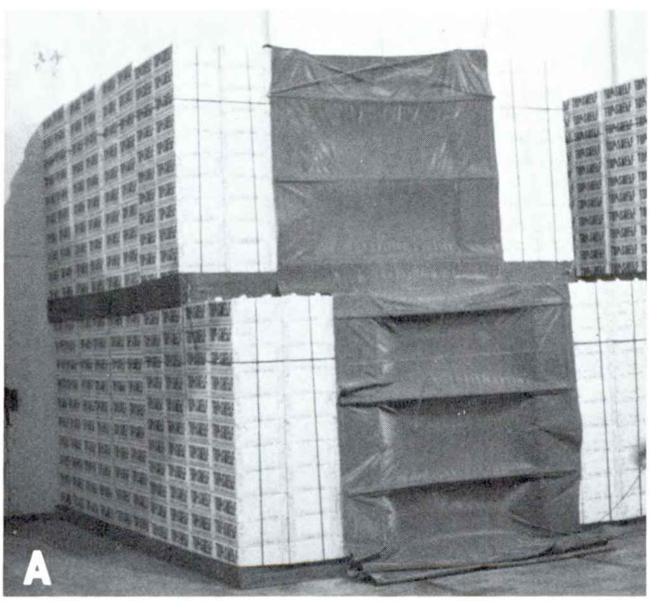
0.25 inch and with the grapes packed without cluster wraps in vented liners, increasing the vented area in the sides of the package from 1 to 3 percent shortened the cooling period by about 1 hour. With cluster-wrapped grapes and no liner, the cooling period was shortened about 2 hours. With the average package, 2 to 5 percent of the area of the sides should be vented for effective forced-air cooling. The precise percentage will depend on the length of the cooling period desired and on the presence of packaging materials that may limit the rate of air flow through the fruit pack.

The orientation of polystyrene packages in the pallet can have a significant effect on the length of the cooling period because of the difference between the vented area in the sides and the vented area in the ends of the packages. Because these packages are commonly stacked in an interlocking pattern in the pallet, the air in a forced-air system flows lengthwise through some packages and crosswise through others. Cooling takes about 2 hours longer for the lengthwise packages than for the crosswise ones because there is less vented area in the ends than in the sides. Increasing the number or size of the end vents in the bottoms and lids of packages would correct this deficiency.

Vents are especially critical in the polystyrene package since the field heat in the fruit must be extracted almost entirely through them. The walls of this package have such effective insulative properties that practically no heat is transferred through the material itself. This is one reason why the forced-air system for fast cooling of grapes in this package is especially preferred over the much slower parallel-flow system. This preference also exists when using corrugated cartons, which are usually stacked with only the sides exposed to the cooling air, leaving very little surface through which conduction cooling can take place. Here, too, size and placement of the side vents are critical, regardless of whether the cooling system uses parallel flow or forced air.

The resistance to air flow and insulative properties of packaging materials markedly affect the length of the cooling period. A vented liner with curtains in the TKV package lengthens the cooling period by about 1 hour, as compared to that for cluster-wrapped grapes in the same package. Incorporating both cluster wraps and a a liner almost doubles the cooling period of cluster wraps only.

Air that bypasses the fruit pack does little cooling and therefore has no significant effect on the length of the cooling period. However, even relatively small openings around the packages can increase significantly the fan capacity required to maintain a given static-pressure difference. For example, whether or not TKV containers have cleats on the bottom makes no significant difference in the length of the cooling period; however,



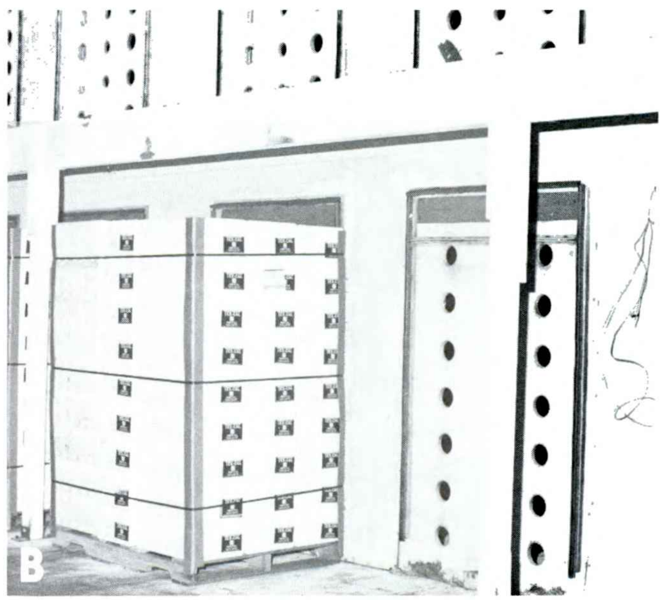


FIGURE 21. Effective methods of forced-air cooling palletized table grapes.

A. Through a wall opening, air is drawn from the plenum between two rows of pallets. Note that the negative pressure in the plenum is drawing the flexible baffle inward even as the cold air of the room is being drawn through the fruit packs from each side of the cooling unit. The number of pallets in the unit is determined by the length of the plenum and by height, although seldom are pallets stacked more than two high in such a cooler.

B. Single-pallet forced-air cooling. The holes in the wall are closed until opened by a trigger near the floor that is activated when the pallet is moved into position. When cooling is complete, the pallet can either be removed to a holding room or simply be moved back slightly to stop the air flow through the fruit. Note that a second row of pallets can be cooled on the shelf above the pallet in position.

¼-inch cleats can almost double the volume of air required to maintain a given static-pressure difference; ½-inch cleats can triple the volume needed. This large increase in volume requires a great increase in fan capacity to cool a given quantity of fruit. Since more power is needed, the cost is greater. Bottom and top cleats may increase the rate of cooling in a parallel-flow system by exposing more package surface to the cooling air for conduction, but they are detrimental in a forced-air system because of the waste of energy for fan power. For maximum efficiency in a forced-air system, the only air that should be permitted to pass through the pallet is that which comes into direct contact with the fruit.

Forced-air cooling has the advantage that the short length of the cooling period makes it possible to cool and ship fruit the same day that it is harvested and packed. Until a reliable cooling period could be reduced to 9 hours or less, it was necessary to carry over the last fruit harvested until the next day so cooling could be completed during that night. This situation aggravated problems of congestion in the cooling facility and also delayed by at least 1 day the fruit reaching the market.

Schedules usually become exacting in a well-run forced-air cooling facility owing to the rapid turnover as warm fruit is placed on line and cooled fruit removed. As a result, it is often helpful to predict when a given lot of fruit will be cooled adequately and can be removed for storage or shipment. For this, the half-cooling method of calculating cooling rates is useful (Guillou 1960). This method may be defined as the time it takes to reduce the temperature of the commodity halfway from its initial temperature to that of the cooling medium (air in this case). The utility of this method may be illustrated by the data shown in figure 23. If, for example, at 2 p.m. after 2 hours of cooling, the temperature of grapes on the forced-air cooler is 13°C (56°F), using 0°C (32°F) air for cooling, and the initial temperature of the fruit was 27°C (80°F), it can be predicted that this fruit will reach 3.5°C (38°F) in 4 more hours or at 6 p.m. In this way, the arrival of refrigerated carriers can be closely scheduled to the time the fruit is adequately cooled and ready for loading.

For practical purposes, the length of the cooling period may be expressed in terms of the *⅞-cooling time.* Figure 23 shows a typical cooling curve for grapes that were packed at a temperature of 26°C (80°F). When the fruit was "⅞-cooled," the temperature was down to 3°C (38°F), which is within the range for satisfactory transport or for transfer to storage. However, when only "half-cooled," the temperature was still 13°C (56°F), which is well *above* a suitable temperature for shipment or storage.

Conduction Cooling

A third method of cooling is by *conduction,* which is the transfer of heat only through the walls and liner of the package. This method is widely used by the Chilean and South African table-grape industries, but certain packaging requirements must be met. The cold air is circulated around the *unvented* (or nearly unvented) packages. Cooling takes two to three times longer than good room cooling does, yet can be done with practically no drying of the stems or berries (Gentry and Nelson 1964). However, it is necessary to provide a water-vapor barrier completely around the fruit to retain this freshness. Further, a cushion pad (preferably of excelsior) must be included, not only for physical protection of the fruit, but also to absorb that moisture

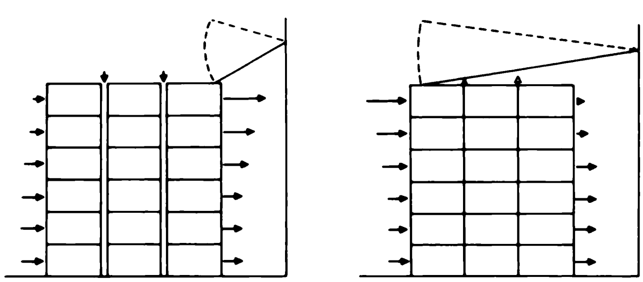


FIGURE 22. Stacking arrangement of containers on the pallet and location of the baffle.
A. This arrangement allows the air entering the channels between the stacks of containers to mix with the upstream air in order to hasten cooling of the downstream fruit.
B. In this arrangement, little cooling of downstream fruit takes place until the upstream fruit is completely cooled (Mitchell, Guillou, and Parsons 1972).

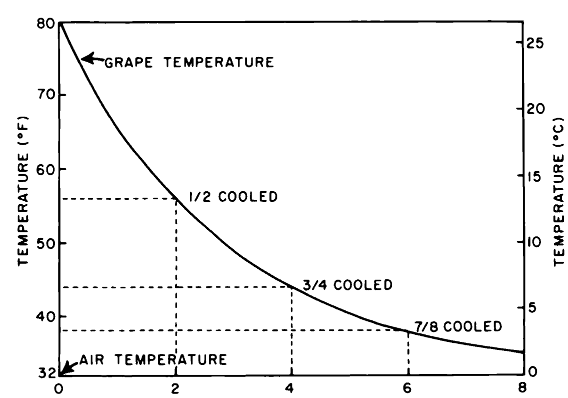


FIGURE 23. Illustration of the principle of half-cooling time.
When the fruit has been cooled halfway from its initial temperature to that of the cooling medium (after 2 hours in this case), it can be predicted what the temperature will be at any time thereafter as long as all factors of the cooler remain constant.

that condenses on the inside of the unvented vapor barrier during cooling and would otherwise collect on the bottom of the liner, soaking the bottom berries (Nelson and Gentry 1968). Indispensable to control decay are in-package sulfur-dioxide-release devices that must be placed one just under and one over the fruit inside of the vapor barrier (Nelson and Ahmedullah 1978). Figure 24 shows the sequence of packing a lug of grapes equipped with top and bottom two-stage sulfur-dioxide generators: (*A*) the lug box is first lined with an unvented liner, preferably including a water-vapor film, followed by a cushion pad; (*B*) a two-stage generator is placed on the cushion pad with the first stage uppermost next to the fruit; (*C*) the fruit is packed in the usual way, either as a naked pack or with chimney wraps; (*D*) the top generator is placed on top of the fruit with the first stage downward next to the fruit; (*E*) an unvented curtain, preferably with a water-vapor barrier film is installed over the top generator; and (*F*) the unvented liner is completed and the end guards are being bent in for lidding.

These two-stage generators simulate to some extent the initial and weekly sulfur-dioxide applications generally used, except that the fumigant is generated *inside* the unvented container. The first-stage component (functioning as the initial application) starts generating sulfur dioxide within minutes after packing and is exhausted after 3 days to 5 days. The second-stage component (functioning as the storage application) starts generating the gas after 3 days and maintains a low concentration for extended periods. This type of pack can be stored for as long as 2 months without further treatment except that of keeping the temperature at or near 0°C (32°F). The storage period should not be extended, though, beyond the time needed to market the fruit within the 2-month time limitation because there is little assurance that in-package sulfur-dioxide generators currently available will afford protection from decay for longer than this. When the generators cease to evolve the fumigant, the fruit becomes vulnerable to attack by decay organisms in the nearly saturated atmosphere of the unvented package (Nelson and Ahmedullah 1976).

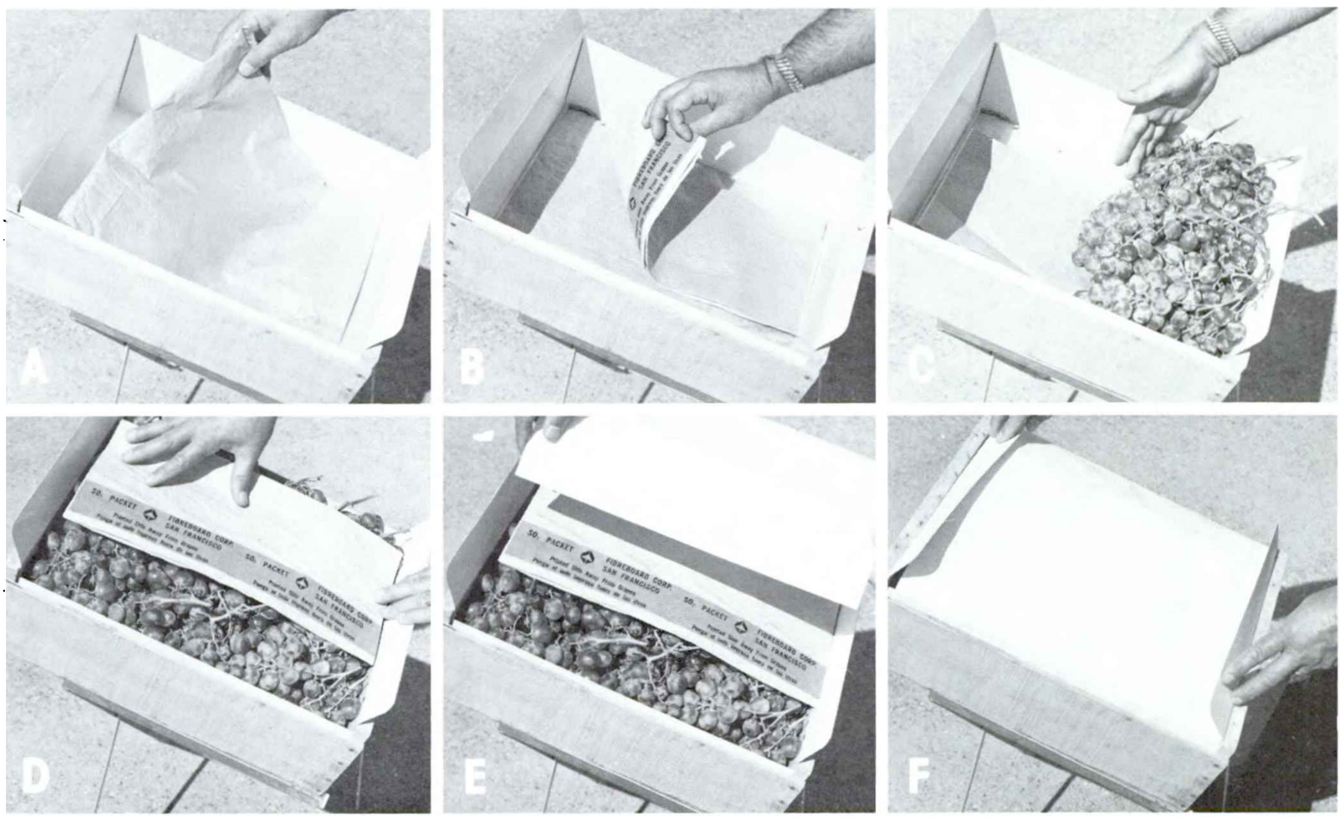


FIGURE 24. Sequence of packing grapes with an unvented liner and in-package two-stage sulfur-dioxide generators.

A. Lug with unvented liner and cushion pad. In lieu of an unvented liner, either a TKV lug or corrugated carton may be used if unvented and coated on the inside with a water-vapor barrier.

B. Two-stage generator in place with the first stage (fast-release rate) uppermost to be next to the fruit.

C. Naked pack half completed. Chimney wraps may also be used.

D. Pack completed and another two-stage generator being placed into position with the first stage downward next to the fruit.

E. Unvented curtain being placed into position. Greater freshness of the fruit is retained if the curtain is coated with a water-vapor barrier such as polyethylene.

F. Pack completed and ready for lidding.

The first stage of the two-stage sulfur-dioxide generator shown in figure 24 consists of a sheet of kraft paper, 8 inches by 16 inches (20 cm by 40 cm), to which 1.5 grams of sodium bisulfite ($NaHSO_3$) is affixed. The second stage is composed of two sheets of kraft paper, each faced with a very thin film of polyethylene. These sheets are placed with the polyethylene film of each in contact, then heat-sealed together. This forms 12 pockets in the generator unit, each pocket containing $NaHSO_3$ in powder form. The pockets contain a total of 5.5 grams of $NaHSO_3$ (Nelson and Ahmedullah 1972). The two stages may be obtained either loosely fixed together to be used as one unit as shown in figure 24, or separately and used independently. Either or both stages may be obtained from Uvas Quality Packaging, Inc., P.O. Box 369, Antioch, California 94509.

Various combinations of the generators can be used depending on several factors: (1) the length of the protection period needed; (2) the temperatures that will prevail during cooling, storage, transit, and distribution; (3) the decay potential in the grapes; (4) the depth and quantity of grapes in the package; and (5) the type of venting required for the gas-barrier liner of the package (e.g., vents through which methyl bromide can penetrate to the fruit to fulfill insect-quarantine requirements).

The maximum protection period of 2 to 3 months can be expected only if the other factors are favorable. After the container is closed, cooling must be started promptly to lower and maintain the fruit temperature at 0° or −0.5°C (32° or 31°F). The distribution phase —when the temperature of the grapes usually rises— must not be over 3 days. The decay potential must be low; that is, the grapes must be relatively free of field infections by *Botrytis cinerea* that develop as a result of rainy weather before harvest. The quantity of grapes in the package must not exceed the capacity of the generator. The two-stage generator described will protect up to 23 pounds (11 kg) of grapes if packed, one underneath and one above the fruit. No fruit should be further than 4 inches (10 cm) from a generator surface since the concentration gradient of the SO_2 decreases by about a factor of 50 percent for every inch (2.5 cm) of distance from the generator. If the pack is deeper than 4 inches (10 cm), both top and bottom generators should be used. If the pack is shallower, but wider and longer, both generators may be used side by side on top of the grapes. It is usually in the corners of the pack—at the greatest distance from the generator— that decay is most apt to develop.

The first stage alone will protect the grapes for as long as 10 to 15 days if all factors are favorable. Compromises on temperature or venting in the gas barrier will shorten this period. With no cooling, the grapes can be protected from decay for up to 6 days (Nelson 1983).

The second stage may be used alone *only* if the grapes can be fumigated with SO_2 from outside the containers in a fumigation room. This requires that the containers be vented to admit the gas to the grapes. Further, the vented containers must be promptly and thoroughly cooled after packing with either a parallel-flow or a forced-air system. When the fruit is at or near 0°C (32°F), the containers must be unvented to confine the SO_2 produced by the second-stage generators. If the containers are palletized, the entire pallet may be enclosed in a polyethylene film cover to confine the gas. Otherwise each container must be converted to the unvented mode that uses packaging components designed with this capability.

Venting of the gas barrier (as when required for methylbromide treatment to fulfill insect quarantine requirements) significantly reduces the efficiency of the in-package SO_2 generator (Nelson 1983). Even the minimum venting of ¼-inch diameter (6 mm) on a 4-inch (112 mm) spacing pattern can allow enough loss of SO_2 to increase decay slightly. Further, loss of water vapor through these vents is enough to cause measurable drying of stems and berries. If cooling does not start immediately after packing, excessive amounts of SO_2 will be lost from the first-stage generator. Allowing the packed containers to remain in warm still air accelerates the evolution of the gas from the first-stage and, since there is some aeration, the concentration of the SO_2 does not build up to levels that are effective in controlling decay.

Cooling Rates and Refrigeration Capacity

A common cause of slow cooling is inadequate refrigeration capacity. A typical grape-cooling facility will normally have high demands placed on its capacity during the afternoon and early evening hours as increasing volumes of warm fruit are placed on line for cooling. Figure 25 shows what can happen to cooling rates in a facility with adequate (as contrasted with inadequate) refrigeration capacity during a typical 24-hour cycle. Assumed is an initial fruit temperature of 27°C (80°F), a half-cooling time for the facility of 3 hours (if not overloaded), and a refrigeration capacity adequate to keep the cooling air at 0°C (32°F) throughout the cycle (again, if not overloaded). Grapes placed in the cooler at noon can be expected to reach 4°C (39°F) before 9 p.m. However, fruit placed in the facility, if it had the inadequate temperatures shown, would not reach this temperature until after 4 a.m. the next morning—a needless loss in quality caused by more than 7 extra hours of cooling and a whole day's delay in shipment to market.

Ice is an excellent refrigerant to use to meet this fluctuating demand for refrigeration during the day, because the supply in the bunker can be replenished as meltage dictates. However, uncertainty of supply and high labor costs have materially reduced the economic feasibility of delivered ice as a refrigerant. Fortunately, there are methods whereby a mechanical system with its inherent fixed-limit capacity can be adapted to meet this fluctuating demand. Figure 26 shows two features of a mechanical system that helps meet this need. First, water as the secondary refrigerant is cooled by the primary refrigerant in the expansion coils, then absorbs from the air (tertiary refrigerant) heat that had been absorbed from the grapes. If the expansion coils containing the primary refrigerant are allowed to accumulate ice during periods of low refrigeration demand, they can release this ice as meltage during peak periods when the demand exceeds the capacity of the mechanical unit. These coils can be placed either under a packed column to receive the water (as shown) or submerged in a tank of the cooling water (Mitchell, Guillou, and Parsons 1972).

The Relative-humidity Factor in Cooling Grapes

Maintaining a low temperature is the primary consideration in securing fast cooling of grapes, but maintaining a high relative humidity during the process is important and often neglected. Considerable water loss can be caused by a low relative humidity during cooling, even though the period may be relatively short. Such water loss frequently happens when the coil temperature is lowered in order to increase the cooling capacity of the unit. Unfortunately, when this is done, the colder coil condenses more moisture from the air, lowering its relative humidity. Further, the source of this moisture is largely from the fruit itself. Coils for coolers in California are usually designed to operate at about −11°C (12°F) below the temperature of the return air (Mitchell, Guillou, and Parsons 1972). The temperature difference will result in a relative humidity of about 70 percent—low enough to cause heavy condensation on the coil surfaces. The temperature difference can be reduced by increasing the coil surface. However, to raise the relative humidity to 90 percent (which would reduce condensation by half) would require coil surfaces three to six times larger (Mitchell, Guillou, and Parsons 1972). The cost of doing this can be reduced by using a packed column as the heat exchanger with the air. Enormous heat-exchange surfaces can be built up relatively cheaply if plastic filaments or other material for the column is used. This large surface compensates somewhat for the relatively inefficient heat-exchange characteristics of air. At the same time, the amount of the more expensive expansion coil can be kept small by submerging it in a tank as an ice accumulator (fig. 26)—water being a more efficient heat-exchange medium than air.

The relative humidity of the cooler can also be raised by a system of fog-spray nozzles. Their design and application are discussed by Guillou (1960) and by Mitchell, Guillou, and Parsons (1972). The fog spray increases condensation on the coils, which adds to the refrigeration load; however, improvement in fruit quality usually will more than offset this disadvantage. Certainly most grape containers (excluding polystyrene and treated corrugated) and the packaging materials within, absorb considerable moisture during cooling and storage. In fact, the gain in weight of each container may be as much as 0.5 pound after a month in storage (Gentry, Mitchell, and Nelson 1963). The most rapid rate of absorption is during cooling when the containers are driest. During this period, the fog spray supplies at least part of this moisture, which would otherwise transpire from the fruit.

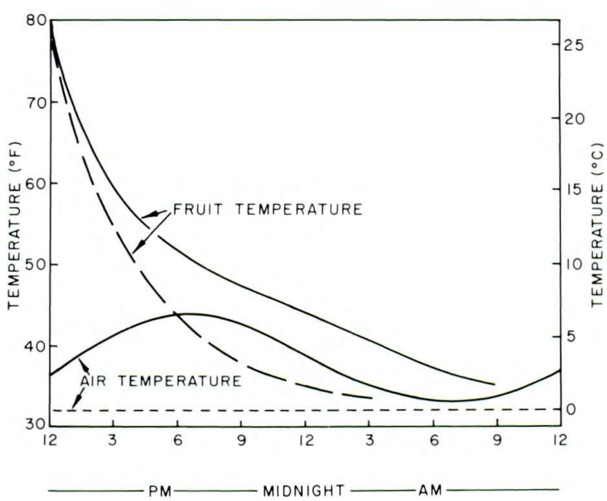


FIGURE 25. Effect of overloading a cooler with hot grapes on the cooling rate of the fruit.
The solid lines show the temperatures in an overloaded cooler, as contrasted with those in a properly loaded facility (broken lines).

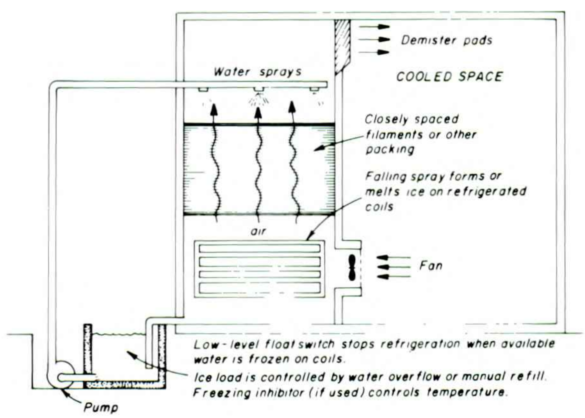


FIGURE 26. Effective use of heat exchangeer to meet peak refrigeration loads with a mechanical system and to maintain satisfactory relative-humidity levels during cooling.
Large cooling surface of the packed tower is effective in maintaining a high relative humidity. Ice accumulated on the coils during periods of low demand can melt off later during periods of high demand supplementing the capacity of the mechanical unit (Mitchell, Guillou, and Parsons 1972).

Fumigation with Sulfur Dioxide to Control Decay of Table Grapes

Sulfur dioxide was first used in California to prevent decay and fermentation of wine grapes (Winkler and Jacob 1925). However, it was several years later before a satisfactory fumigation program was developed for table grapes (Asbury and Pentzer 1931; Pentzer, Asbury, and Hamner 1932). The reason for this delay was, in part, that the high concentrations of sulfur dioxide used for wine grapes caused unacceptable levels of injury in table grapes, and adversely affected flavor and appearance. An initial gas treatment applied before cooling, was developed, which effectively controlled decay during the 8 to 10 days required to transport the refrigerated fruit to eastern markets. Later, the treatment schedule was expanded to include periodic retreatments for grapes held in storage for as long as 6 months (Harvey, 1956; Allen and Pentzer 1959; Ryall and Harvey 1959).

Currently, it is standard practice in California to apply the initial fumigation the same day that the grapes are packed. This treatment sterilizes the surface of the berries, especially wounds made during handling (plate 2-G). The treatment may be applied in a special gassing room before cooling is started (fig. 27). A fan system must include a purge system so the residual gas can be exhausted to the roof or otherwise disposed of. It should be possible to activate this purge system by remote control, and then open the door slightly to allow fresh air to enter the room as the gas-laden air is exhausted. It is more usual to accumulate the packed fruit in the cooler during the daily packing and fumigate it at the end of the day (fig. 18). In this way, cooling is not delayed, and the treatment is applied when most of the working crew has left and will not be exposed to the irritating vapor of the gas. However, when grapes are accumulated in the cooler during the day, fumigation of the fruit should not be delayed longer than *12 hours* after harvest. Periods longer than this before application of the gas increase the danger that fungus spores on the surface of the berries will have time to germinate and infect the fruit, especially if cooling is slow and, as a result, the air remains warm and humid around the berries (Nelson 1951).

Other commodities should not be treated with the grapes, or even be where the fumigant can reach them, because most of them are easily injured by the gas. Since grapes also can be injured, they should be exposed to only the minimum quantity of the gas necessary. This amount will depend upon (1) the decay potential and condition of the fruit, (2) the amount of fruit to be treated, (3) the type of containers and packaging materials, (4) the air velocity and uniformity of air distribution, (5) the size of the room, and (6) the losses through leakage or sorption on room surfaces. Under favorable conditions, a basic sulfur-dioxide concentration of 0.5 percent by volume applied for 20 minutes is adequate. For cluster-wrapped packs, this time should be extended to 30 minutes. To keep the concentration at this level, the absorptive capacity of the lugs and fruit, as well as their volume, must be taken into consideration. The dose can be calculated from the following formula:

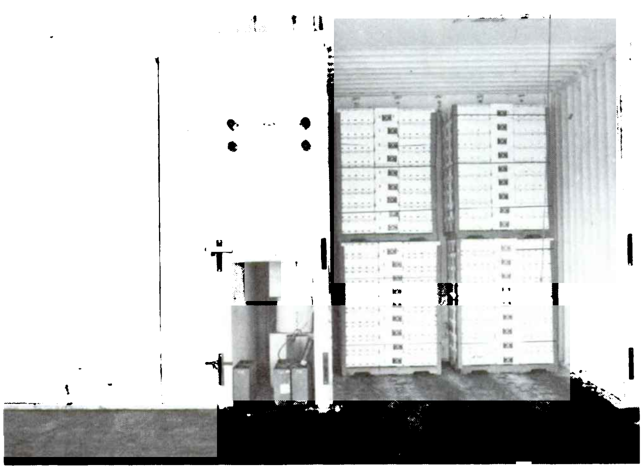


FIGURE 27. Sulfur-dioxide fumigation room with four pallets of packed grapes in position for treatment.
Note liquid sulfur-dioxide cylinders and circulating fan in center compartment. At the end of the treatment period, the circulating air can be diverted and purged from the room. An identical room on the left has the door closed because the gas treatment is being applied.

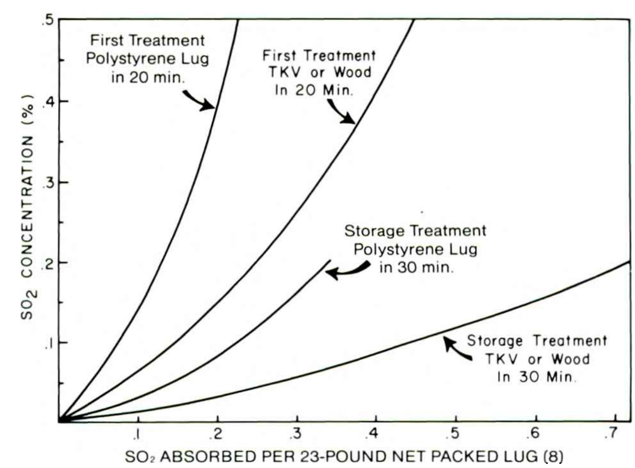


FIGURE 28. The amount of sulfur dioxide absorbed by packed grapes and containers during treatment.
The amount for storage grapes is based on a storage relative humidity of 90 percent.

$$\text{weight } SO_2 = \frac{A \times B}{C} + (D \times E)$$

where A = the concentration of sulfur dioxide to maintain (%),

B = the unoccupied space in the room; this value would be the total volume of the room minus that occupied by the lugs (ft^3 or m^3),

C = volume occupied by one lb or kg of sulfur-dioxide gas; at 0°C (32°F) this would be 5.5 ft^3 or 0.156 m^3 and at 20°C (68°F) this would be 6.0 ft^3 or 0.17 m^3,

D = number of lugs in the room to be treated, and

E = weight of sulfur dioxide absorbed by each lug at the concentration desired (lb or g).

Adequate for factor E for TKV or all-wood lugs is 0.0011 pound (0.5 g) when (1) the fruit is sound, (2) air velocities assure good penetration, (3) the room is relatively gas tight, and (4) the gas has little opportunity to be absorbed on walls and refrigeration surfaces (fig. 28). Allow 0.0006 pound (0.25 g) of sulfur dioxide per lug for polystyrene and waterproof corrugated containers. If chimney wraps or a top pad are used in these last two types of containers, the absorption factor should be increased to 0.0007 pound (0.33 g) per lug. The absorption factor for juice grapes in good condition packed to 36 pounds (16 kg) net weight in TKV or wood lugs should be 0.0022 pound (1 g) per lug.

The gas must be distributed quickly and evenly to all parts of the room. This can be done by spacing special nozzles 6 feet apart along the ceiling in the room. If the outlet is placed in front of a fan, there should be one for each fan, or the air from the single fan should be distributed evenly across the room through a plenum system so that the gas is well diluted by the air before it reaches the fruit.

The *hot-gas* method of delivery may be used if the room requires 10 pounds or less of gas. The steel cylinder containing the liquid sulfur dioxide is first connected to the gas inlet, and the valve is then opened. The cylinder should then be placed in a pot of boiling water to vaporize the fumigant as rapidly as possible. Only about 1 pound a minute can be delivered this way. With some precautions, the *cold-gas* method may be used by inverting the cylinder when the valve is opened. It is faster and requires no supplementary heating equipment. A *riser* extends to the bottom of the larger steel cylinders so that, when the valve is opened, liquid sulfur dioxide flows into the plumbing line and does not change into a gas until it escapes from the nozzles in the room. Every precaution should be taken that air volume and velocity are adequate to vaporize and mix the gas thoroughly with the air before it reaches the fruit. Up to 100 pounds of gas can be released in 2 to 3 minutes with this method.

Storage of Table Grapes

History of Table-grape Storage

Before the 1930s, table grapes could generally be stored for extended periods only if embedded in some dry medium. Since ancient times, grapes in the Middle East have been embedded in packing materials such as barley to preserve their fresh state (Jacob and Herman 1925). In California during the 19th century, Mission grapes were occasionally packed in sawdust and transported within the state for use after the vintage season had ended. Toward the end of that century, Almeria grapes from Spain began to arrive in eastern seaports each fall. These grapes were packed in barrels with ground cork, each holding nearly 50 pounds of fruit. The volume of this imported fruit increased to 20,000 tons annually before 1913 (Stubenrauch 1913). At the same time, the volume of California grapes being shipped to eastern markets was increasing. However, although the Ohanez grapes, packed in cork, could be marketed during the fall and even into the winter, the California fruit, packed in plain packs (no embedding material), had to be disposed of within 6 weeks of harvest.

The California industry attempted to compete for the late-season market by storing grapes in modified versions of the Spanish barrel. About 1912, California grapes were first packed in ground cork imported from Spain (Haight 1924). This attempt and others to store grapes in cork dust were frustrated by the high cost of the material; hence extensive studies were made to develop a cheaper packing material. Redwood sawdust, properly screened and dried, was found to be superior, keeping grapes longer and in better condition than the more expensive cork product (Stubenrauch 1913).

The sawdust keg was for many years the principal storage and export container. It held 32 to 34 pounds (14.5 to 15.5 kg) of grapes and about 14 pounds (6.4 kg) of sawdust. A straight-sided drum of the same capacity was used to some extent, as well as a 22-pound (10-kg) sawdust chest (actually a paper-lined lug). During the 1920s, the so-called *export chest* came into use. It held the same amount of fruit as the keg and, since it occupied less shipping space, it gained favor, particularly as an export container. Also, with the *stem-up* pack, the chest was easier to inspect (Spurlock 1931). The keg, however, remained the main domestic storage container because it held the grapes in the best condition (Hensley and Read 1929; Read 1932). Redwood sawdust was gradually replaced by a lighter-colored material made from spruce, because of better color contrast with red Emperor grapes and because it was less dusty and provided a better cushion than the redwood (Haight 1924; Hensley and Read 1929).

The volume of sawdust-packed grapes reached a peak in 1928 at about 2,000 carloads, and then declined to 500 to 600 carloads by 1932 (Read 1932). This was the beginning of the trend eliminating the sawdust pack as a domestic storage container. Grapes could be stored for several weeks in the cheaper plain pack as cooling and handling methods were improved, especially when sodium bisulfite was placed in the cushion pad to control the spread of decay (Pentzer and Asbury 1935). Finally, when a program was developed for re-treating the grapes with sulfur dioxide in storage, plain packs could be stored longer or as long as those that had been stored in sawdust. The fruit was fresher without the drying effect of the sawdust and had a less woody flavor. Further, the cost of the plain pack was less than that of the sawdust chest.

Current Volume and Marketing Season of Storage Grapes

The movement of grapes into storage usually builds up in the latter part of August as the production of Thompson Seedless peaks, supplemented by such mid-season varieties as Ribier, Flame Tokay, Italia, and several minor ones. By this time, harvest in the early districts (Coachella and upper or lower San Joaquin valleys) is largely complete. Little or no attempt is made to store the early varieties from these districts such as Perlette, Thompson Seedless, Cardinal, and even Ribier. The storages are fairly well filled by the middle of September. During the following 8 to 10 weeks, this stored fruit is moved to market and replaced by the late-season varieties of Emperor, Calmeria, Almeria, and even late-harvested Ribier. Toward the end of October, storages normally reach their capacity and may contain as many as 8 million lugs. These storages are concentrated largely in a belt extending from Fresno to Bakersfield along the eastern side of the San Joaquin Valley.

The harvest season closes during the first half of November, and from then on the market is supplied entirely from these storages. The volume is heavy until after the Christmas–New Year holiday season, then tapers off gradually during January and February. Some storages continue to supply grapes into March and even

April. The length of the storage life of the major varieties varies and falls into the following ranges, depending upon the initial quality of the fruit and degree of excellence of postharvest handling:

Cardinal	1 to 2 months
Thompson Seedless, Italia, Tokay	1½ to 2½ months
Ribier, Almeria, Calmeria	2 to 4 months
Emperor	3 to 5 months

Storage Environment for Table Grapes

The best temperature to attain the full storage potential of table grapes is −1°C (30°F). The fruit can tolerate temperatures slightly lower than this, but the margin of safety above freezing the grapes becomes so narrow that, for practical purposes, this temperature should be considered the minimum (Carrick 1930). Even so, careful monitoring of the temperature of the air coming from the refrigeration surfaces is essential, because freezing of the commodity can be disastrous (plate 3-Q, 3-R, 3-S, 3-T). At −1°C, the vapor-pressure deficit (VPD) of the air is very low, yet significant, considering the long duration of the storage period.

The relative humidity of the air should be as high as practicable—95 percent if possible. Limiting factors are drips from walls and ceiling, and wet slippery floors. A combination of this high relative humidity and the lowest practicable temperature reduces the VPD to the smallest value possible and thereby the lowest possible rate of water loss from the fruit. At the same time, the rate of growth of mold organisms and the rate of respiration are slowed as much as possible—all to reduce the rate of deterioration.

Methods of maintaining high relative-humidity levels, discussed in the last chapter, apply especially here for storage. Refrigeration surfaces (dry-coil, packed-column, or brine-spray) should be as large as possible to minimize the temperature difference between the surfaces and the storage air. Supplementary moisture in the form of fog spray is helpful in maintaining a high relative humidity, especially during the first month of storage when the dry wood and paper of the packages are absorbing moisture to reach equilibrium with the storage air (Guillou 1960). Each TKV or wooden lug will absorb 0.33 to 0.67 pound of water during the first month of storage (Gentry, Mitchell, and Nelson 1963). Every pound of water supplied from a supplementary source saves an equal amount that would otherwise come from the fruit (Nelson and Guillou 1960).

Air velocity, which must be high during cooling to bring the grapes to a low VPD as quickly as possible, becomes a liability when the storage temperature is attained. The rate of moisture loss is related directly to air velocity; hence in grape storages, the velocity should be reduced to that needed only to maintain the desired fruit temperature. Careful monitoring of grape temperatures within pallets will dictate how much velocity is needed, which may be as little as 10 to 20 feet per minute (fpm) in the channels between the pallets (fig. 29).

Figure 30 shows the effect of relative humidity and air velocity on the rate of weight loss of grapes in storage. It is apparent that to market good-quality grapes after

FIGURE 29. Partly filled grape-storage room.
Note stripes on the floor to assist forklift operators in maintaining accurate alignment of pallets, thereby having uniform width of air channels between the rows of pallets.

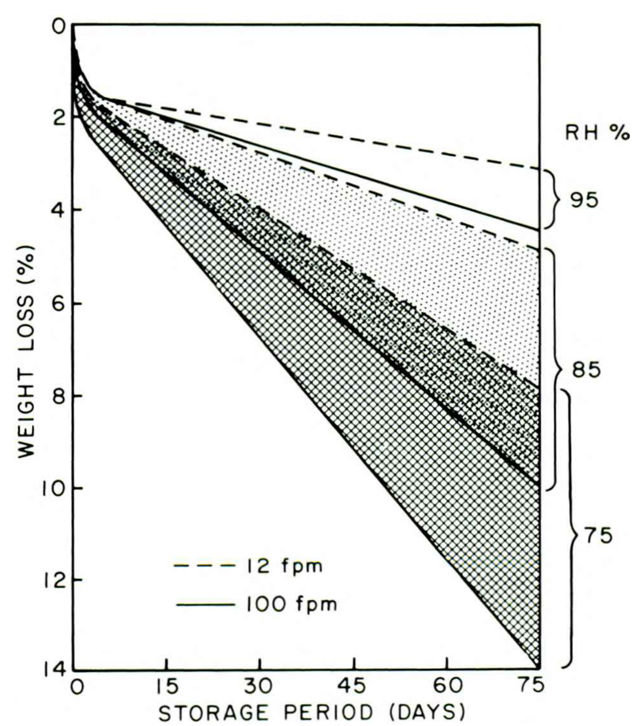


FIGURE 30. The relation of relative humidity and air velocity to the rate of weight loss of table grapes during storage.

several months of storage would require a relative humidity approaching 95 percent and an air velocity approaching 6 fpm, especially if we consider fruit that has lost more than 6 percent of its weight as being unacceptable (Nelson and Guillou 1960).

Uniform container alignment is just as important in the storage room as it is in the cooler. Misalignment will block the slow air movement with the result that hot spots may develop in the room where the air is still. Further, when the velocity should be high for the periodic sulfur-dioxide treatment, poor penetration of the gas may result with blocked channels. Pallets should be spaced so that there are not only channels on each side (2 to 4 inches) but also between the ends (1 to 2 inches). Avoid removing an entire line of pallets across the room because this leaves a wide hole through which the air will move and bypass the channels between the remaining pallets. Also, it is advisable not to have the lines of pallets excessively long, because the concentration of sulfur dioxide drops rapidly from absorption by the containers and fruit as the air traverses the channels between the pallets (Nelson and Richardson 1961). It is better to have the air moving across the narrow dimension of the room with more fans (and gas outlets) than along the larger dimension with fewer fans.

Storage Grape Disorders

Decay is the chief disorder problem of table grapes. Fortunately, sulfur dioxide is effective in retarding the spread of decay fungi. Even so, a heavy mold potential may result in an unmanageable problem, particularly if any facet of the fumigation program is less than perfect. The undetected infection during packing poses the greatest hazard (plate 4-F). Often it takes several weeks at storage temperature for such an infection to develop to the extent that it can be seen easily. By then, it may have spread to the extent that the fruit is ruined. Under these circumstances, it is important to be able to predict early in the storage period the level of decay potential present in the grapes. This knowledge makes it possible to market those lots soonest that have the highest potential. Harvey (1955b) established the feasibility of a method to achieve this. Samples of berries taken during packing were subjected to the same conditions as the packed fruit, except that they were held at room temperature. As a result, infections could be detected in a week at this elevated temperature that would otherwise take several weeks at storage temperature to become evident. Marketing schedules could then be arranged based on the results. Details of applying this method with techniques and materials needed were subsequently published (Harvey 1960).

Supplementing the use of this method for predicting decay should be thorough and there should be frequent inspections of the stored fruit, particularly grapes in packs deep within the pallets—those least likely to receive adequate sulfur dioxide for decay control. Such inspections will not only help in forestalling decay, but also will show whether the sulfur dioxide used weekly is being evenly distributed—whether it is too much in some areas, causing unnecessary bleaching, or too little in others, allowing decay to spread (plates 3-I, 3-K and 4-I, 4-J). If both problems exist, they are probably caused by two factors, or a combination of them: (1) inadequate volume of air being moved during fumigation, and (2) excessive barrier effects of packaging materials (cluster wraps, curtains, or inadequate venting of the container). Further, a consistent pattern of bleaching indicates an excessive dosage of sulfur dioxide and, conversely, a consistent pattern of spread of decay indicates an inadequate dosage consistent with the decay potential of the fruit. Calculation of the correct storage dosage to use will be discussed later.

Physiological aging of grapes is a normal phenomenon. Eventually the pulp tissue turns brown, which gives white berries a dull grayish appearance and red or black grapes a brownish tint. However, in some years this browning may appear sooner than usual in storage and show no consistent pattern of occurrence. It can be particularly troublesome in Thompson Seedless, sometimes after only a month of storage. On close inspection, berries have a dull gray color and, when cut open, show a brown color largely restricted to the rudimentary seed area (plate 3-X, 3-Y). There is no clear explanation for the sporadic occurrence of this disorder, even though the onset of browning can be accelerated by physiological stress such as bruising and elevated temperatures (Nelson, unpublished data). Browning was correlated directly with storage temperature in the range of 0° to 4°C (32° to 39°F). Further, berries flattened by lid pressure, and those areas subjected to abrasion between berries during transit vibration showed a greater tendency to brown than those not subjected to these stresses.

Frequent and close inspection of the grapes during storage is the best assurance of detecting the disorder early enough to dispose of the fruit before the market quality is impaired appreciably. At the onset of browning, it is often difficult to detect; the berries should therefore be examined under strong light—light transmitted through the berry as well as that reflected from it (plate 3-Y). *Early* detection is essential because several days are required to market affected fruit. During this period, stress conditions of handling and higher transit temperatures favor more rapid development of the disorder.

Berry Cracking

Infrequently, Thompson Seedless berries have cracked during storage for no apparent reason, and the incidence can be severe. This type of cracking is not to be confused with that caused by excessive pressure on the fruit during lidding. Typically, the cracks appear as hairline fractures of the skin with no consistent pattern of distribution, either on the berry surface or among berries in the cluster. They do appear most frequently on fruit that is less mature—berries that are thin-skinned and greenest in color. This is the type of fruit typically from heavily overcropped vines. The condition does not appear to be related either to rate of cooling or to high relative humidity during storage. This condition has been observed occasionally in Chilean Thompson Seedless grapes during and shortly after cooling (Nelson, unpublished data). A possible cause could have been unusually heavy irrigation to within a day of harvest. An abundant water supply for the roots, coupled with a high relative humidity under the overhead trellis (which would retard evaporation from the leaves), may have resulted in sufficient turgor pressure of the berries to have caused the cracking. This theory is supported by the observation that cracking was severest in fruit picked and packed in the morning (when turgor pressure would be highest), less in that picked and packed in the afternoon, and least in that carried over on the packing shed floor at room temperature and packed the following day.

As for browning, the most effective treatment is frequent and thorough inspection of the fruit. These inspections should be started immediately after cooling and continue during storage. If cracks appear, they should be checked closely for signs of bleaching along the edges. Absence of bleaching indicates that insufficient sulfur dioxide has reached these injuries to sterilize them and prevent decay. Prompt action should be taken to treat the fruit thoroughly with the gas and dispose of the fruit as soon as possible.

Sulfur-dioxide Treatment of Grapes during Storage

In extended storage of table grapes, control of decay is a critical operation. For practical purposes, this operation becomes the limiting factor for maintaining quality when satisfactory temperature, relative humidity, and air-movement conditions are provided. Only sulfur dioxide is currently acceptable as a chemical agent to accomplish this control of decay. Its successful use is confronted with two formidable problems: (1) established mold infections at the time of packing—and they should be assumed to be present—cannot be eradicated by the initial treatment, however well it is applied; and (2) the retreatments during storage to prevent these infections from spreading and to resterilize the surface of the berries cause chemical injury to the fruit that is accumulative. As a result, the margin of safety between controlling decay and keeping injury to the fruit within acceptable limits becomes increasingly narrow as the storage period is extended. Therefore, the correct dosage of sulfur dioxide for these weekly treatments becomes progressively more critical with storage time. Figure 31 illustrates how a long storage period of 140 days compounds the problem. The data are based on Emperor grapes stored at 2°C (35°F) and treated weekly with sulfur dioxide (Nelson and Richardson 1967). A decay potential was established by placing nine *Botrytis*-infected berries in each pack, each infected berry being surrounded by sound fruit. The spread of decay was measured by calculating the average number of infected berries at each innoculated site. Decay increased at an accelerating rate with time in storage because, as the fungus spread out in all directions from the original infected berry, it made contact with more sound berries. As a result, infection proceeded at an exponential rather than linear rate. It is apparent that the 0.2 percent treatment allowed practically no spread of decay, even after 140 days of storage. However, the amount of bleaching at this time was severe. A concentration of 0.1 percent allowed the fungus to infect two sound berries, but bleaching was rated as only moderate. At 0.05 percent, 3½ berries were infected, at an average, at each site in addition to the original infected berry. Bleaching in this case was rated as only slight (hardly detectable). A good decay-forecasting method (Harvey 1960) would have indicated what concentration would have been needed to keep decay within the required limits. For example, if the method showed only two infected berries per packed lug, there would have been only nine infected berries after 140 days if a 0.05 percent concentration was used—a level of decay still within the 0.5 percent by weight limitation for U.S. No. 1 on a condition inspection. At the same time, bleaching would have been only slight. However, if the method showed three or four infected berries, a concentration of 0.1 percent would have been necessary to keep decay within this limit, even if the bleaching level would be increased to moderate.

The most effective dose will vary depending on the specific set of factors prevailing at the time of treatment. These factors, important as they may be during the initial treatment, become more significant during storage. Containers, especially those of untreated wood

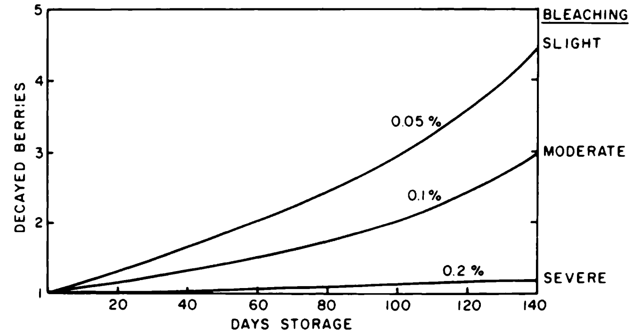


FIGURE 31. Effect of the concentration of sulfur dioxide applied weekly to Emperor grapes stored at 2°C (35°F) on the rate of spread of Botrytis decay and on the extent of bleaching of the berries after 140 days of storage.

or paper packaging materials, absorb moisture rapidly during the first 3 weeks of storage, and this moisture in turn considerably increases their absorptive capacity for sulfur dioxide during fumigation. Consequently, the concentration of the gas during the treatment period is depleted more rapidly with damp containers and, therefore, the fruit is actually exposed to less of the fumigant on a time-concentration basis than would be expected (Nelson and Baker 1963). As a result, the rates and amounts of depletion are related directly to the level of the storage relative humidity (resultant moisture content of the packaging materials) and the number of containers in the storage room (Nelson, Baker, and Gentry 1964).

When sulfur dioxide is used, greatest protection from decay with least injury is obtained over extended storage periods by re-treating the fruit at weekly intervals (Nelson and Baker 1963). Longer intervals between treatments to provide equal protection require substantially higher concentrations of the gas, with the net result that the total exposure to sulfur dioxide is appreciably higher. This interval of 1 week is based on the storage temperature being not more than 0°C (32°F). Higher temperatures would require shorter intervals between treatments or higher concentrations of the gas, because higher temperatures allow decay fungi to grow faster. Figure 32 shows the effect of storage temperature on the rate of spread for decay in Emperor grapes. The data are from the experiment that showed the effect of sulfur-dioxide concentration in treatments of decay during storage (fig. 31). The strong effect of storage temperature on the rate of spread of decay is apparent. A weekly treatment with sulfur dioxide at a concentration of 0.1 percent allowed virtually no spread of decay during 140 days if the storage temperature was maintained at −0.5°C (31°F). However, at 2°C (35°F), decay tripled and, at 4°C

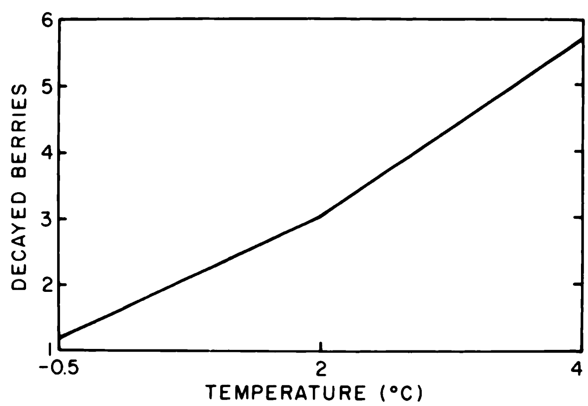


FIGURE 32. Effect of storage temperature on the amount of Botrytis decay of Emperor grapes after 140 days, when treated weekly with 0.1 percent concentration of sulfur dioxide.

(39°F), decay increased nearly six-fold. From these data, it is apparent that a weekly treatment of 0.1 percent at −0.5°C (31°F) controlled decay (fig. 32) as well as a concentration of 0.2 percent at 2°C (35°F) as shown in figure 31. The lower storage temperature, then, not only minimizes problems of decay control but bleaching as well, if an appropriate concentration of sulfur dioxide is used for the weekly treatments.

The formula for calculating the correct dose of sulfur dioxide is the same as that discussed for the initial treatment, except that the values for the concentration and absorption factors are lower. A concentration of 0.1 percent on a volume basis is adequate if the grapes have a low decay potential when packed: for example, if they have not been exposed to rain or other wet conditions that would encourage field infections of *Botrytis cinerea.* Further, a treatment period of 30 minutes is adequate unless excessive packaging materials, such as cluster wraps, delay penetration of the gas; or there is poor circulation of air in the room, which would delay distribution of the fumigant. Under these conditions, a packed TKV or wood lug with 23 pounds (10 kg) of fruit would absorb about 0.001 pound (0.45 g) of sulfur dioxide (fig. 28). Under the same conditions, a packed polystyrene lug would absorb 0.0006 pound (0.225 g) because the plastic absorbs essentially no sulfur dioxide. No adjustments need be made in dosage whether or not cluster wraps are used because, when they are used, the containers are usually packed to a 21-pound (9-kg), instead of 23-pound (10-kg), net weight. The amount of the gas absorbed by the wraps offsets that which would otherwise have been absorbed by the 3 additional pounds of fruit.

Dosages may be adjusted above or below the 0.1 percent concentration depending on decay potential of fruit. It may be reduced to as little as 0.05 percent if the fruit has essentially no decay potential. The absorption factor should then be reduced accordingly—by about one-third from the 0.1 percent factor (fig. 28). This program should cause no discernable bleaching of the fruit even after 5 months of storage. However, frequent and close inspection of the fruit is advisable because some spread of infection can be expected at these low concentrations if any decay is present. If the grapes have been exposed to persistent and heavy fog or dew before harvest, and especially if they have been exposed to considerable rain, the dosage should be increased. If the decay-prediction data indicate a high potential, the concentration should be raised to 0.15 percent or even 0.2 percent with a corresponding increase in the absorption factor (fig. 28). At 0.2 percent concentration, field infections should be completely contained (no spread of decay to unaffected berries). However, significant bleaching of the berries can be expected, especially after 2 months of storage.

A small correction factor should also be considered in calculating the dosage, to allow for the effect of storage relative humidity on the absorptive capacity of the containers. The values shown in figure 28 are based on a relative humidity of 90 percent. If the relative humidity has been 95 percent, the absorptive factor should be increased by about 10 percent; if it has been 85 percent, the factor should be reduced by about 10 percent.

Removal of Residual Sulfur Dioxide after Fumigation

Usually, there is a significant concentration of SO_2 left in a fumigation room at the end of the treatment period. This gas is usually purged through the roof to quickly reduce the concentration to levels that will not injure the fruit or the personnel who must reenter the room. Sulfur dioxide, even at very low concentrations, is very irritating to the mucous membrane of the nasal passages and lungs, as well as the eyes. Effluent gas wafting to where the personnel are located can be a hazard. Further, drawing large volumes of warm air into a storage room to replace the gas-laden air usually causes a rise in temperature of the fruit, and may create an undesirable condensation of water on the berries.

Varying amounts of SO_2 are removed from the air by absorption on the fruit and lugs during fumigation. These amounts reduce the leftover quantity that must be removed by purging on coil sprays after the treatment is completed. An example of this is a typical commercial storage room that was treated on two different occasions with SO_2 to give a concentration of about 900 ppm. In one instance, the room was filled with almost 21,000 lugs of grapes; in the other instance, the room was nearly empty with only 1,000 lugs. With the room nearly full, the fruit and lugs had absorbed enough gas so that 200 ppm still remained in the room at the end of the 30-minute treatment period. However, in the nearly empty room, the concentration was still close to 600 ppm. In both instances, considerable SO_2 still needed to be removed in order to reduce the concentration to a safe level. The maximum concentration permitted by OSHA is 10 ppm for a maximum 15-minute exposure a day or 5 ppm for an 8-hour exposure a day for personnel without protective equipment. Even if personnel need not reenter the room, exposure of the fruit repeatedly to 100 ppm SO_2 for several hours will cause bleaching of berries, which is the reason for an internal scrubbing system that will rapidly remove the residual gas to required levels.

One method of removing SO_2 from the room without purging is by circulating the gas-laden air through the refrigeration coils of a wall bunker with defrosting sprays turned on. Although SO_2 is very soluble in cold water, this method often is not practical because a large spray surface is needed to reduce the concentration to tolerable levels at an acceptable rate, and most fumigation facilities are not equipped to use such a scrubbing system without drastic modifications. Further, this system exposes the defrosted (unprotected) coils to large amounts of the gas, which with water forms sulfurous acid, which can be very corrosive to many metals.

Considerable attention has been directed recently towards the feasibility of a self-contained, portable scrubbing facility—one that can be moved from room to room and needs only an electrical power source. Two systems have evolved, both using cold water as the primary absorber of the fumigant. The *Filocel system* involves pumping water from a self-contained reservoir over a packed column through which the gas-laden air of the room is forced by a fan (Meredith, personal communication). The other system involves forcing the water from the reservoir through venturi nozzles at sufficient pressures to draw the room air through the unit and the spray (Harmon, personal communication). *Demister pads* are usually needed for both systems to prevent excessive amounts of suspended water from being blown into the room. The efficiency of gas removal of both systems can be increased considerably by adding NaOH to the water. Neutralization of the sulfurous acid appears to increase the capacity and efficiency of the water to remove the gas. Unfortunately, the salt Na_2SO_3 that results from the reaction between the H_2SO_3 and the NaOH tends to clog the demister pads, probably because of its low solubility in water at storage temperatures.

Often, very slow removal of the gas has been experienced with these units, especially in very large storage rooms. This may be due to one factor or a combination of several: (1) a high ratio of volume of the room air to the volume of air handled by the scrubber; (2) an inadequate mixing action of the air handler of the room; or (3) inadequate capacity of the water reservoir of the scrubber. Grape storage rooms commonly have volumes of several hundred thousand cubic feet, while these scrubbing units have a capacity of 10,000 to 20,000 cfm. If it is assumed that all SO_2 is removed from the air as it passes through the scrubber each time and that the air is always mixed thoroughly by the room's fan system, the concentration of the gas would be reduced by half for each complete air change of the room. On this basis, the "half-scrubbing time" for a 10,000-cfm unit in a 100,000-ft^3 room should be 10 minutes. It would require six half-scrubbing times or 1 hour to reduce a concentration of 600 ppm to below 10 ppm (600 to 300, 300 to 150, 150 to 75, 75 to 38, 38 to 19, 19 to 10 ppm).

Several factors must be considered in choosing a scrubbing unit for removal of SO_2 from the fumigation atmosphere. The air capacity needed for the unit will be determined primarily by three factors: (1) the volume of the room to be scrubbed, (2) the difference in concentration of SO_2 from the initial level to that required, and (3) the length of the period in which scrubbing must be completed. For this calculation, two assumptions should be made first: that the unit operates at 100 percent efficiency (complete removal of SO_2 from the air as it passes through the scrubber each time), and that the air-handling system keeps the SO_2 concentration uniform throughout the room during scrubbing.

Many grape storage rooms are very large—200,000 ft³ or even more. For practical purposes, the scrubbing period should not be longer than 1 hour. Under these conditions, a 200,000-ft³ room would require a scrubber with a capacity of 20,000 cfm to effect one air change in 10 minutes or six air changes within the hour. This combination would reduce the concentration of SO_2 from 600 ppm to 10 ppm—a level permissible for personnel to work in without protective equipment for not longer than 15 minutes a day. Precooling rooms are often used to give the grapes the initial treatment of SO_2, which may reach concentrations of 5,000 ppm or more. A 1-hour scrubbing period would require 9 to 10 half-scrubbing times of about 6 minutes each. The same scrubbing unit of 20,000 cfm could accomplish this if the room was less than 130,000 ft³.

The efficiency of the scrubbing unit will be determined by (1) the amount of water surface to which the gas-laden air is exposed as it passes through the scrubber; (2) the volume of water in the reservoir, if a closed system; (3) volume of flow-through water, if an open system; (4) temperature of the water; and (5) whether the pH of the water is kept high as with NaOH.

To provide near 100 percent efficiency of the scrubber requires about 20,000 gallons of water for a 200,000-ft³ room—a highly impractical volume for a portable scrubber (Nelson 1982).

NaOH is extremely effective in reducing the amount of water needed for near 100 percent efficient scrubbing. Twenty gallons of water with NaOH was just as efficient as 100 gallons without it. The lowest practical volume of water that could be used would be determined by the solubility of NaOH or Na_2SO_3 in water. At some volume when NaOH is used as a neutralizing agent instead of water as an absorbing agent, the saturation point of the base (about 3.7 pounds per gallon at 32°F) will limit the amount of NaOH feasible to use. At this point, no more NaOH can be introduced effectively into the system. Further, the low solubility of the Na_2SO_3 end product (about 1.1 pounds per gallon at 32°F) may impose a more severe restriction on the minimum amount of water that can be used. The precipitated salt will form crystals that can block air flow through the demister pads or spray nozzles and pumps.

A 200,000-ft³ room with 1,000 ppm of residual SO_2, will require about 35 pounds of NaOH to neutralize the gas. An NaOH-saturated solution of about 10 gallons at 32°F will be required for this condition. On the other hand, Na_2SO_3 at saturation will require about 53 gallons of water to keep the salt in solution, thereby avoiding problems of crystallization on the scrubbing components.

A feasible solution to the problem would be to connect the scrubber to an outside source of water so that a flow-through system would provide fresh water during scrubbing. A flow of about 80 gallons a minute through a 20,000-cfm air handler would be adequate to degas a 200,000-ft³ room from 1,000 ppm SO_2 to less than 10 ppm SO_2 in an hour. This volume of water could be handled by hoses and pumps of modest size. In fact, a pump may not be necessary if the pressure of the water supply is adequate for the drip or spray nozzles. The flow may have to be increased if the water is not cold, since water at room temperature is about half as efficient in absorbing SO_2 as it is near 32°F.

Preparation of Stored Grapes for Domestic Shipment

Movement of palletized grapes directly into the carrier (as discussed under palletization) has largely eliminated the need for sulfur-dioxide fumigation in the carriers. The rigorous treatment of hand-loading and bracing the lugs in the carriers formerly made it advisable to then fumigate the fruit to sterilize fresh injuries. Current handling of the fruit as palletized units has largely eliminated this need. The value of the treatment is especially questionable, if there is no circulation of air during fumigation. This can happen in nonrefrigerated containers and even in those with refrigeration if the fan and the refrigeration unit are activated by a thermostat set at some transit temperature above normal storage temperatures. When storage fruit at 0°C (32°F) is loaded into such a van, there is little opportunity for air movement. Hence, if sulfur dioxide is injected over the load of fruit in the van, the fruit nearer the surface is overexposed to the gas, and the fruit deep in the load is underexposed or may receive none at all. To overcome this problem, the grapes should be given their final sulfur-dioxide treatment not longer than 2 days before loading, and the carrier treatment should then be eliminated. If the treatment must be applied in the van, temporary fans should be installed to assure circulation of the air during the treatment period. Methods for doing this have been reported in detail (Uota, Harvey, and Cook 1960; Gentry and Nelson 1963). Unfortunately, the technique requires some time to install the fan system. Further, the carrier must remain at the loading dock for the entire treatment period so that the fan equipment can be recovered from the load. Largely as a result of these inconveniences, the system has not gained acceptance.

Good temperature management is the most important factor in preserving the market quality of the fruit during transit. It is in the best interest of the shipper as well as the carrier that the pulp temperature of the fruit, when loaded, be at least as low as the lowest practical transit temperature that can be maintained in the carrier. Failure to accomplish this has been the cause of many expensive lawsuits to assess the blame when poor market quality at destination resulted in a financial loss. A further precaution is to have a temperature record of the van or reefer during the transit period. The air temperature over the load can be ascertained by installing a recording thermometer at time of loading. This record is especially valuable to assess the operational efficiency of the refrigeration system—whether there were interruptions in transit or whether temperatures fell below the minimum limit or exceeded the maximum limit. As a further precaution, the shipper can install recording thermometers in the fruit packs. One monitored pack should be placed in the part of the load that is subject to the widest fluctuations in temperature. This most likely would be in the top layer exposed to the air blast from the refrigeration coils. Here, two dangers can threaten: that of freezing, if the refrigeration system should operate at too low a temperature, and that of overheating, if the refrigeration should cease. The other pack should be buried deep in the load where the least air circulation would be, and where there would be greatest danger of a rise in fruit temperature from the heat generated by respiration (fig. 16). Suitable recording instruments to provide this information can usually be rented from service agencies.

It is important that the grape containers be well braced in the carrier so that there will be no shifting of the load. Three directions of movement must be considered: (1) *lateral shifts* that are caused by the sway or "whip" of the carrier as it changes direction; (2) *longitudinal shifts* brought about by sudden acceleration or deceleration forces on the load; and (3) *vertical shifts* caused by an uneven roadbed, coupled with the action of the suspension system of the carrier that moves the load up and down. Lateral shifts are usually most severe in the top layer of containers—those farthest from the roadbed where the amplitude of the swaying is greatest. Longitudinal shifts can be severe with sudden braking; or, as the slack is taken up in a long train starting to move, the jolt in a rail reefer can cause severe shifting of an unrestrained load; or, in switching operations, recoupling of rail cars can sometimes cause very sudden changes in velocity of the reefer. If these movements are in the natural frequency range of the load, the danger of shifting of containers is increased considerably because shifting movements may gain momentum with each impulse.

Proper strapping of pallets is the first precaution to be taken to prevent shifting of loads in transit. With well-tightened vertical as well as horizontal straps in position, the containers should be well protected from shifting *within the pallet* (fig. 11B). However, this strapping will not prevent the *entire pallet* from shifting as a unit in the carrier. It is necessary then that these units, which may weigh a ton, be securely braced against each other and against the walls of the carrier during loading. Dunnage strips should be nailed firmly across the top of the pallets so that the outer ends press firmly against the walls of the carrier to prevent lateral shifting (fig. 11B, 12B). Alternatively, the pallets may be wedged tightly with fold-out expandable filler materials that can be cut to desired widths. These materials are available from suppliers. Longitudinal shifting can be prevented by placing the pallets tightly together, starting at the forward end of a van and from each end of a reefer. Figure 11D shows the final stage of loading a van. Heavy bracing must be cut to take up all the space between the back of the load and the doors when closed. In a rail reefer, there is a heavy steel-bulkhead door on each side of the middle doorway. When loading is complete, these doors can be swung into place and locked—one jammed firmly against the containers of one end of the car and the other securing those in the other end. Care must be exercised that all slackness is eliminated before the bulkheads are finally locked.

Preparation of Stored Grapes for Export

All California export table grapes are now packed in the same kinds of shipping packages as those used for domestic shipments. Use of the sawdust chest was discontinued about 1980. A complete changeover from the standard sawdust export chest of 30 years ago has come about largely because palletization and containerization systems can handle the more fragile domestic packages across the docks without excessive damage to both packages and fruit (Nelson 1970). At the same time, extended protection of the fruit from decay during long export transit periods has been integrated into the handling system (Nelson and Ahmedullah 1976).

The wooden lug, TKV lug, and the polystyrene package do not require special modifications for export. They can protect the fruit during the rigorous dock-handling procedures as long as they are within the protection of the strapped pallet, which must be handled by a forklift, or pallets that are in sea containers, which can be transferred directly from a highway truck to a berth on a container ship. This latter system of handling not only eliminates the physical handling of individual pallets across the docks, but also isolates the fruit from unfavorable temperatures and pilferage. These are significant considerations when traffic in the dock area is commonly congested, with excessive delays in transfer of pallets and little or no security to protect the fruit from injury or loss.

Preparation of grapes for export is essentially the same as that discussed for domestic markets. However, in view of the longer transit period required (sometimes as long as a month), some aspects of the quality of the fruit intended for export and precautions in handling need special emphasis. In the first place, the quality of the grapes should be especially good. It costs no more to ship a lug of top-quality grapes to a distant market, for example, than to ship one which on arrival contains inferior fruit. Yet, the profit-or-loss factor will be vastly different in each case. It is especially important, then, that the fruit be thoroughly inspected before loading to ascertain whether it will withstand the rigors of the extended export-transit period and still be of acceptable quality upon arrival at destination. Usually this is done with the standard Federal-State Inspection Service inspection to determine the quality grade (Calif. Dept. Food and Agr. Regulations 1972). Special attention should be given to the decay potential of the fruit, because this is usually the main quality factor that will change adversely during transit and marketing. If the grapes are to be exported from storage, a *condition* inspection should be made, even though an initial inspection at time of packing may have shown the quality of the fruit to be excellent. As during the transit period, the decay factor is the one that usually changes most during storage.

An additional precaution to reduce the danger of decay is effective timing of the final sulfur-dioxide treatment before loading. First, the treatment should be done in the shipping facility to be sure that *all* of the fruit is exposed uniformly to the gas. This cannot be done with assurance in the carrier! Second, the treatment should be applied not more than one day before loading to be assured of the longest possible protection period during transit.

Controlling Decay during Export Handling

Effective in-transit protection from decay can be obtained with an in-package slow-release sulfur-dioxide generator. The application of the two-stage in-package method was discussed in the previous chapter in the section on conduction cooling, and installation of the packaging materials is illustrated in figure 24. As attractive as this method might appear for providing the decay protection for several weeks, there may be disadvantages in using this method directly for export. The limit of 2 months of protection with this method

FIGURE 33. Steps in installation of a slow-release sulfur-dioxide generator in an export grape pack for decay protection.
A. The tab of the curtain is being raised on one side of the pack to expose the fruit. Depending on the type of liner material, it may be necessary to raise one end of the lid to insert the generator.
B. The generator is being inserted over the grapes, but under the lid and curtain.
C. Insertion of the generator is now almost complete.
D. The curtain tab is now being reinserted. Note that one end of the lid has been raised and will now be renailed in place.

means that the grapes could be stored for only 1 month if 1 month's transit time must be added to that for an export shipment. Often, shippers do not know at packing time when or how many lugs they will eventually export. The shipper may be locked into a packaging system at packing time that might prove unworkable later. However, the system can be modified to overcome this disadvantage, yet retain much of the decay-control capability. No modification of packages or packaging materials is necessary. The grapes can be packed in the usual way, fumigated initially, and then at weekly intervals in storage. At export time, a slow- or second-stage generator can be inserted into the pack over the fruit and under the curtain (fig. 33A-33D). The final storage gas treatment is then applied, after which a polyethylene shroud is installed, completely enclosing the pallet to retain the sulfur dioxide produced by the generators (fig. 34A, 34B). All these operations must be done at storage temperature because it is almost impossible to cool a shrouded pallet of grapes back down to the desired transit temperature.

FIGURE 34. Installation of a polyethylene-film cover around a pallet of stored export grapes now equipped with slow-release sulfur-dioxide generators.
A. Partly assembled pallet of grape lugs equipped with slow-release sulfur-dioxide generators. Note the polyethylene film under the lugs forming a bottom seal.
B. Pallet completely enclosed with the film securely taped so that there are no openings through which sulfur-dioxide gas might escape. Shrink-wrap or stretch film could be used and would have the added advantage of binding the lugs together—perhaps even in lieu of strapping or use of nets.

The in-package method provides effective protection for even the longer transit periods. Also, it has the advantages of keeping the stems and berries fresher because the relative humidity within the shroud is near saturation, and because there is no air movement to accelerate water loss from the fruit. Further, the sulfur dioxide released by the generators is retained within the shroud to the extent that little, if any, of the gas can escape. It is advisable that as soon as the pallets reach destination, and especially when they are removed from the carrier to warmer temperatures, that the shroud be removed. Otherwise, residual sodium bisulfite in the generators will break down, rapidly releasing concentrations of sulfur dioxide that may cause appreciable bleaching of the fruit. This precaution becomes particularly significant with transit periods shorter than 3 weeks when considerable quantities of the generating material are still in the inserts (Nelson and Ahmedullah 1973).

An alternative method is to install a two-stage generator instead of the slow-stage-only generator. In this case, the pallet should be shrouded *immediately* so that none of the fast-stage gas is lost. Also, no conventional storage application is needed because the fast- or first-stage generator supplies this need. The feasibility of this method has been demonstrated for a transit period of 4 weeks (Nelson 1970).

Instruments for Measuring the Postharvest Environment of Table Grapes

Temperature

Essential to any good table-grape postharvest operation is good temperature management. A wide variety of instruments is available to measure this environmental factor. The most suitable one will depend upon the degree of precision that is needed, whether a record must be kept, whether a number of locations must be measured at the same time, how large the sensing probe should be, how resistant it must be to shock and unfavorable atmospheres such as sulfur dioxide, and degree of technical skill required for operation and maintenance of the instrument.

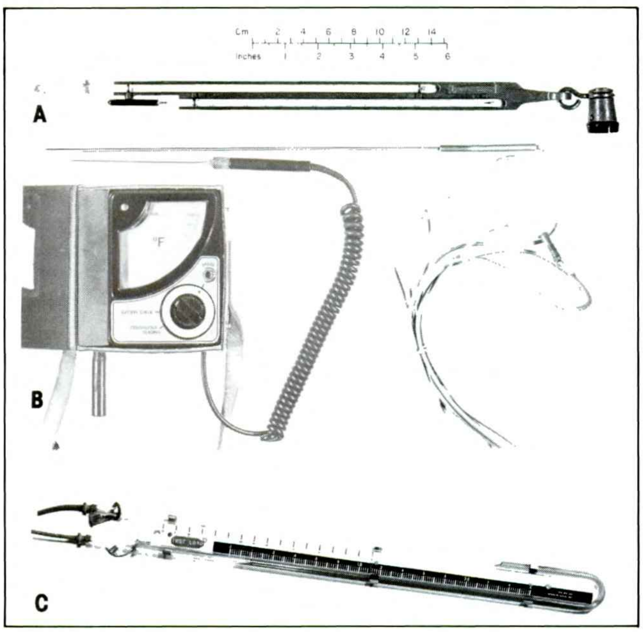


FIGURE 35. Useful instruments for measuring the temperature and air-pressure gradients during cooling and storage of table grapes.
A. Wet-dry bulb thermometer (psychrometer) for determining relative humidity. Note 0.1°F divisions for measuring storage relative humidity within 1 percent.
B. Portable and battery-powered resistance thermometer equipped with a stainless-steel 5-inch (13-cm) probe for determining air and grape-pulp temperatures. Also shown is a longer probe to obtain temperatures deep in the pallet without disturbing the containers.
C. Manometer for determining air-pressure gradients across the fruit to $^1/_{100}$ inch in a forced-air cooling system.

All cooling facilities should be temperature-monitored, preferably with recording capability. Two locations for measurement are important—the air blast as it enters the cooler from the refrigeration surface; and the return air as it leaves the cooler. Close monitoring of the incoming air temperature not only can greatly reduce the danger of temperatures low enough to freeze the fruit, but also can be an early warning if temperatures become high enough to reduce the efficiency of the cooler. The temperature of the return air can be helpful in determining whether there is sufficient volume of air being circulated through the cooling area. A wide difference between this temperature and that of the incoming air indicates a heavy refrigeration load (heat pickup from the fruit). However, if this difference remains large for an excessively long time, it indicates an insufficient volume of air being circulated to cool the fruit at an adequate rate. Sensing probes are needed that can be placed at some distance from the indicator dial or recorder. These may be liquid- or gas-filled bulbs, which require no electrical circuit (unless a recorder is used). Electrical probes—either resistance thermometers or thermocouples—are also suitable. Each requires an electrical circuit. Whatever system is used, the indicated temperature should be accurate to ±0.5°C (±1°F).

It is equally important that temperatures be monitored in storage rooms. What has been recommended for coolers applies for storage rooms except that, because of the larger size of the typical storage room, more sensing probes should be used, especially if there are two or more fan outlets. Also, more accuracy is needed in temperature measurement. The system should be reliable to ±0.25°C (±0.5°F). With this level of accuracy, temperatures can be maintained near freezing without undue risk. Continuous and proper monitoring of the temperature-measuring system must be maintained so that the indicated temperatures are indeed within the level of accuracy needed.

In addition to the temperature-monitoring equipment installed in the facility, portable measuring instruments should be available for cooling and storage personnel. A convenient and effective means of measuring the pulp temperature of grapes during cooling and storage is a resistance thermometer, as shown in figure 35B. Its response is quick, and the probes in different sizes and lengths are suitable to reach the air or fruit, even in the middle of a pallet without disturbing the containers. With more sophisticated indicators, several probes may be installed in the packs, or the air of the facility itself, and each connected to the instrument when a measurement is desired.

Relative Humidity

The relative humidity should be given close attention in a grape-handling facility, especially in the storage rooms. Many instruments measure this factor; however, few, except very expensive ones, are sufficiently accurate and dependable to have much practical value. Figure 35A shows one that is accurate, relatively inexpensive, and simple to operate: a wet-bulb thermometer with temperature divisions of 0.1°F—sufficiently accurate to measure relative humidity to 1 percent in a grape-storage atmosphere. Precautions should be taken that the indicated readings are reliable. There should be no fluid in the safety cavity at the top of the thermometer, and the column in the stem should be continuous with the reserve in the bulb at the base. The *sock* on the wet bulb should be soaked thoroughly with clean (preferably distilled) water. It is difficult to obtain accurate determinations in a grape-storage room by swinging the instrument in the traditional manner. Heat from the operator's body can be a significant factor, and the time needed for a precise reading can be quite long—it can seem especially long in the cold discomfort of the room! Both problems may be eliminated by use of an aspirating psychrometer with the bulbs of the two thermometers in a tube so that a motor can draw the air past the bulbs at a velocity of at least 300 fpm (100 mpm). The motor of the fan should be at least a foot from the bulbs and downstream relative to the air movement of the room, so that heat from the motor does not cause a false reading. The fan (preferably a squirrel-cage type) may be powered by either a battery or house circuit. Such a unit can be left to operate indefinitely. A reading should be taken every 5 minutes or so until a maximum difference between wet- and dry-bulb temperatures is obtained. This may take as long as 15 minutes if ice forms on the wet bulb. During ice formation, misleading readings are possible because heat is released during crystallization of the water into ice. However, after freezing is complete, the ice bulb behaves just as a wet bulb does above freezing. Once the temperatures are obtained, the relative humidity can be determined from tables (Marvin 1941).

Air Pressure in Forced-air Cooling

An important air-handling factor discussed earlier under forced-air cooling is the pressure differential of the air across the pallet of fruit. The manometer shown in figure 35C is relatively inexpensive, adequately sensitive, unbreakable (plastic), and simple to operate. It is indispensable in evaluating all parameters that affect the half-cooling time of a forced-air cooling facility.

Air Velocity

Air velocity has been mentioned often as an important factor affecting rates of cooling and water loss from grapes. A rather inexpensive instrument for measuring this parameter is the pin-wheel anemometer as shown in figure 36A. However, it cannot measure air velocities

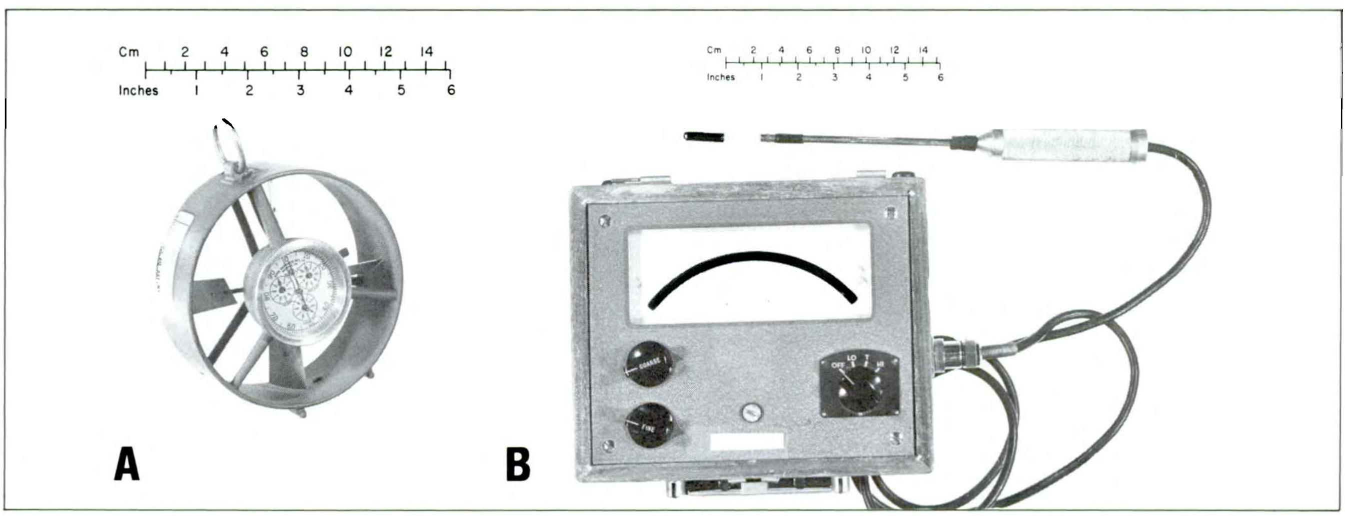


FIGURE 36. Useful instruments for measuring air velocities during cooling and storage of grapes.
A. Pinwheel anemometer capable of measuring velocities as low as 50 fpm (16 mpm).
B. Thermoelectric or hot-wire electric anemometer capable of measuring velocities as low as 10 fpm (3 mpm). This small probe can be inserted into channels less than ½ inch (1 cm) wide.

dependably below about 50 fpm (16 mpm). Unfortunately, air velocities as low as 10 fpm (3 mpm) can be quite meaningful. The hot-wire anemometer shown in figure 36B may be used effectively in this situation because it can indicate air velocities as low as 10 fpm. In addition, the probe is very small, so it can be inserted into very narrow channels for measurements. The instrument is fairly expensive and the probe quite fragile; however, it is simple to operate.

Sulfur-dioxide Concentration

Sulfur dioxide is indispensable to control decay in the long-term storage of grapes. Its harmful effect on the fruit as well as beneficial properties have been discussed in the sections on initial and storage gassing. The amount of exposure to the gas is related to injury and to effectiveness of decay control. This exposure depends on two factors: time of exposure and concentration of the gas. Further, this concentration can be highly variable depending on several factors.

Monitoring any fumigation facility requires some type of instrument that will determine the concentration of the fumigant during treatment. Many instruments are available to do this; but, here again, most are expensive and require considerable expertise to operate and maintain. One instrument that solves most of these problems, yet is relatively simple and effective to use, is shown in figure 37. It is a steel syringe so well sealed that when the handle is pulled back and locked, 100 ml of evacuated space is created. On the opposite end, a glass ampoule can be inserted into the rubber inlet. If open at both ends, air can pass slowly through the ampoule and into the chamber of the syringe. Any sulfur dioxide present in the air will bleach the packed column; the extent of bleaching will be in direct proportion to the concentration of the gas. When the vacuum is completely released (a 100-ml sample of the air), the ampoule can be laid on the indicated scale and the concentration determined by the length of the bleached column. Ampoules are available that cover a wide range of concentrations—high enough for those needed for the initial and storage treatments, and low enough for those in unvented packages with in-package sulfur-dioxide generators. Samples can be taken from as far away as 50 feet (16 m) by using very small Teflon tubing to conduct the air sample to the outer end of the ampoule. This instrument is useful to verify whether suspected areas (including the air spaces in the center of the packed lug) are receiving concentrations of the gas adequate for protection of the fruit from decay. Often changes in packages, packaging materials, container orientation, amount of fruit in the room, or air-handling methods can significantly change the amount of exposure of the grapes to the gas.

The syringe instrument takes about 3 minutes to complete an analysis so the number of determinations that can be completed during a fumigation treatment is very limited. Also, a continuous record is not possible. There are instruments, though, that can overcome these limitations. Most are infrared analyzers that measure the concentration of the gas electronically. As many as 10 sampling areas can be monitored during one fumigation treatment as the response time of these instruments is only a few seconds. The cost of one of these instruments may be as much as $3,000.

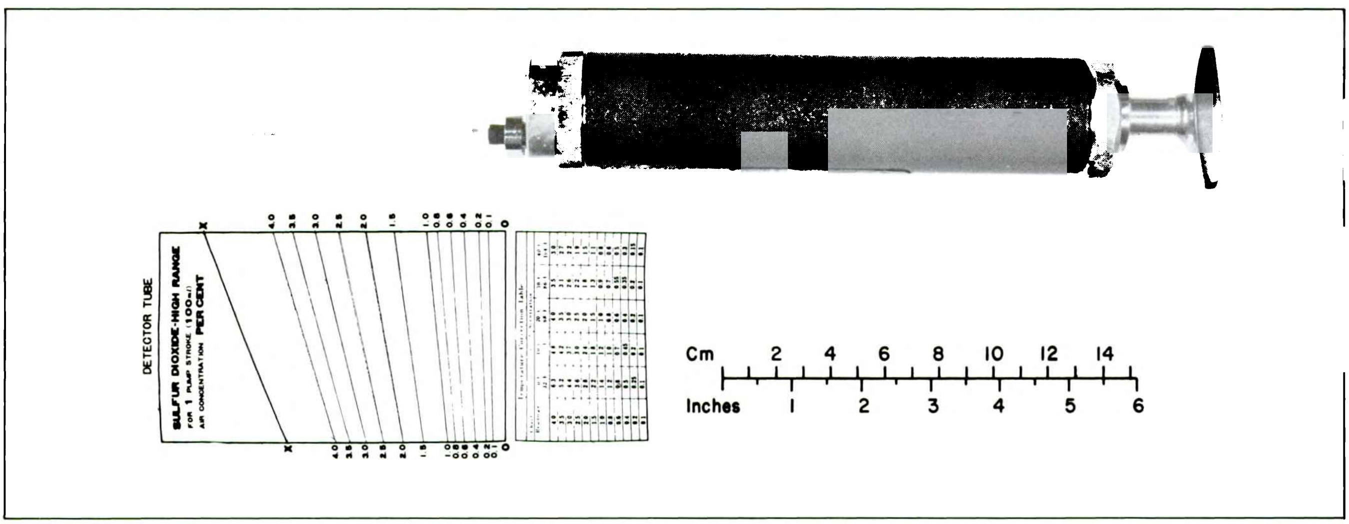


FIGURE 37. Useful instrument for measuring the concentration of sulfur-dioxide within containers equipped with in-package sulfur-dioxide generators as well as in gassing and storage rooms during treatment. Glass ampoules are obtainable to cover ranges of sulfur-dioxide concentrations as high as 4 percent and as low as 0.0001 percent. A used ampoule on the instrument shows a discolored segment on the outer end about an inch long. If this ampoule were laid on the chart below, the discolored segment would indicate a sulfur-dioxide concentration of 0.0015 percent.

Distribution Handling

Complex Nature of Problems

Many problems of maintaining the market quality of table grapes arise during handling from major distribution centers to the consumer. Up to this point, when the grapes are removed from the refrigerated carrier, they have been handled by personnel who, for the most part, can concentrate on grapes only, and in facilities designed to cater to the specific needs of this fruit. However, during distribution, personnel are faced with an enormous array of fresh fruits and vegetables, each with its own specific requirements for temperature, humidity, and degree of care needed in handling; and the personnel have to decide whether isolation from other commodities is needed because of odors or other factors. Further, many commodities differ widely in the length of their potential shelf life—hence, there is the problem of knowing how rapidly each must be moved to the consumer before unacceptable deterioration takes place.

Temperature and Relative-humidity Management

Suitable temperatures during the distribution phase of marketing can be maintained only if the arrival temperature of the grapes in the carrier is within acceptable limits. It should not be more than 4°C (39°F). The temperature-record chart of the carrier, if available, may be useful for this purpose. However, it may not necessarily indicate the actual temperature of the fruit, especially the fruit deep in the load, because the recorder is usually placed in the air space above the load. Improperly cooled fruit may have temperatures still considerably above that shown on the chart if air circulation down through the load has been been insufficient to cool the fruit to the set temperature (not an uncommon occurrence). The actual temperature of the fruit can be easily determined with the thermometer shown in figure 35B. With a sensing probe 18 inches to 36 inches (45 cm to 90 cm) long, fruit temperatures can be determined in the middle of a pallet without unstrapping the unit and removing lugs. This center fruit is most likely to be the warmest, and therefore its temperature is the most important to ascertain.

In order for good arrival temperatures to be maintained, unloading facilities should not expose the fruit to warm air during transfer from the carrier to temperature-controlled rooms in the facility. Figure 13 shows that less-than-ideal temperature conditions frequently exist during this marketing phase. The results, then, are often berries soft from drying, or decayed fruit, in amounts directly related to the elevation and duration of the unfavorable temperatures. Unavoidable exposures should be as short as possible to prevent a rise of fruit temperature and moisture condensation on the cold fruit. Once in the holding rooms, the grapes should be kept at temperatures as near 0°C (32°F) as possible. The longer the fruit must be held until moved to retail markets, the more critical it is that this low temperature be maintained. The danger of decay spreading in the fruit increases rapidly if temperatures are not kept low, and especially if the grapes are held for more than 2 days before being moved to retail stores. The reason for this is that grapes are normally treated with sulfur dioxide just before being shipped from California. This treatment will prevent decay from spreading significantly for as long as 10 days if transit temperatures have been well below 4°C (39°F). For longer periods, the fruit must be re-treated with the fungicide, which is usually not feasible to do in receiving centers for several reasons—danger of gas injury to other commodities, lack of corrosion-resistant facilities, and discomfort of employees exposed to the gas.

Since grapes are very susceptible to shrinkage, the factor of water loss is important. It can be kept low if the fruit is held in a room at low temperature and high relative humidity. In addition, the fruit should be kept away from the air blast of the cooling unit because moving air has a drying effect on the fruit, and the rate of drying is directly related to the velocity of the air. Since the temperature of the fruit should already be at the desired level, rapidly moving air is really more of a liability than an asset—just enough movement is needed to keep the temperature of the fruit and air uniform throughout the room. Figure 30 illustrates how significant relative humidity and air velocity are in relation to the rate of water loss from grapes, even at storage temperature. The shrinkage that takes place now during the distribution phase—if good environmental conditions are not provided—added to the shrinkage that took place since harvest may be the difference between high- or low-quality fruit on the produce counter.

When the grapes are transferred from the main distribution center to retail outlets, the environment of the holding room should be maintained around the fruit. Refrigerated vans carrying only produce are most desirable. If nonrefrigerated vans must be used, they should be insulated and kept tightly closed to prevent circulation of air during transit, especially for hauls of any great distance and in warm weather. Avoid, if possible, open trucks; the moving air will very soon cause heavy condensation on the fruit if the air is warm and humid, and it will also raise the temperature of the grapes—both are conditions that seriously affect the market quality of the fruit.

Physical Handling of Grapes during Distribution

Since practically all table grapes are now shipped palletized, these units should be kept intact as long as possible—even, if feasible, into the holding room of the retail store. Once the pallet is dismantled and each lug handled individually, the danger of rough handling is increased. Frequently packages are dropped, turned over, misaligned in restacking, or even walked on! Such handling causes damage to the grapes that may not be apparent at the time but certainly will be when the fruit reaches the produce counter.

Handling techniques become even more significant as a market-quality factor after the grapes reach the retail store. Not only must packages be handled individually, but the fruit must be removed from the containers for sale. How the packages are handled into and out of the holding room, how they are moved to the produce counter, how the clusters are removed and handled by store personnel, and how much the clusters are handled by customers can have a drastic impact on the sales appeal of table grapes. In the first place, the produce manager should demand that the grapes be moved *promptly* and *carefully* into the holding room as soon as the carrier arrives with the daily delivery. Rehandling should be avoided if possible, and the containers should be stacked squarely so that ends do not break through the thin lids and crush the fruit. Secondly, the temperature of the holding room should be maintained as low as possible above freezing and the fruit be kept in this favorable environment as long as possible before it is moved to the "hostile" environment of the produce counter.

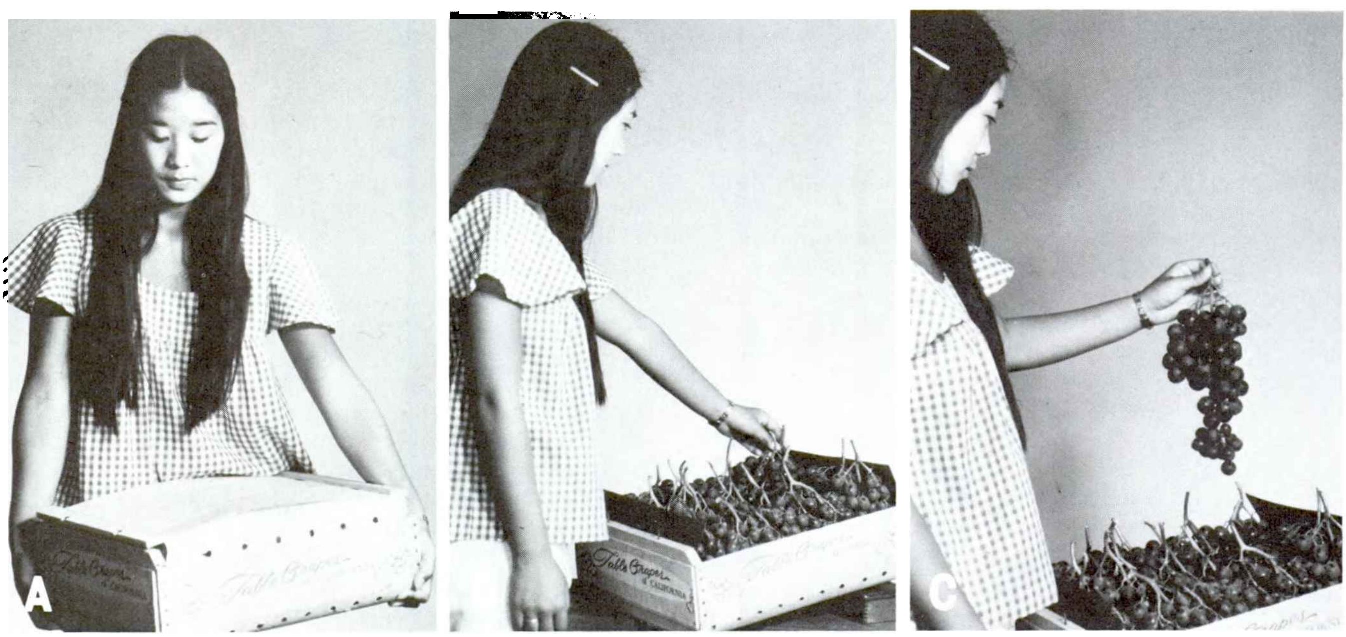


FIGURE 38. Correct method of handling grape-shipping containers and removing the clusters of fruit in the retail store.
A. The container should be handled gently at all times—no dropping or turning over. If the containers need to be restacked before being emptied, care should be exercised that they are set squarely on the one below so that the ends bear the weight of those above; otherwise the ends may crunch into the thin lid of the lug below or the bottom of the one above, crushing the fruit—or worse yet, the stack of containers may tip over!
B. When the container is to be unpacked, place it at convenient height with the labeled end toward the unpacker and the other end raised slightly.
C. The clusters must always be handled by the stems—avoid pulling, bending, or even touching the berries as much as possible. Withdraw the first cluster from the pack at the far end. The cluster in either of the corners is likely to be the last one packed and can be lifted out with the least stress on the berries. Continue removing clusters, always proceeding from the far end toward the label end.

Displaying the Grapes in the Retail Store

When the grapes reach the produce counter, the manager now has the opportunity to demonstrate skill in displaying the fruit to the best advantage for sales appeal. Several problems as well as opportunities face the manager in this phase of marketing. The environment of the produce counter usually is unfavorable for maintaining grapes in an attractive condition. Temperatures can be moderate or even high and air movement significant, all of which promotes drying of the fruit. Unfortunately, spray mists cannot be used on grapes to offset the drying and to keep their fresh appearance, as they can be used on many other fruits and most vegetables. In fact, even the moisture of condensation on cold grapes is very undesirable as it smears when berries rub against each other during handling, causing an undesirable appearance. However, even though many of these deteriorative factors are unavoidable, their impact on quality can be lessened by shortening the length of time the fruit is on the counter and by using methods of display that reduce handling of the clusters by store personnel and customers.

Grapes should be displayed in space that is kept cold. The temperature of this space should be held low enough to prevent condensation on the cold fruit after it is brought from the holding room. This display technique is especially effective on warm humid days when condensation would be heavy otherwise.

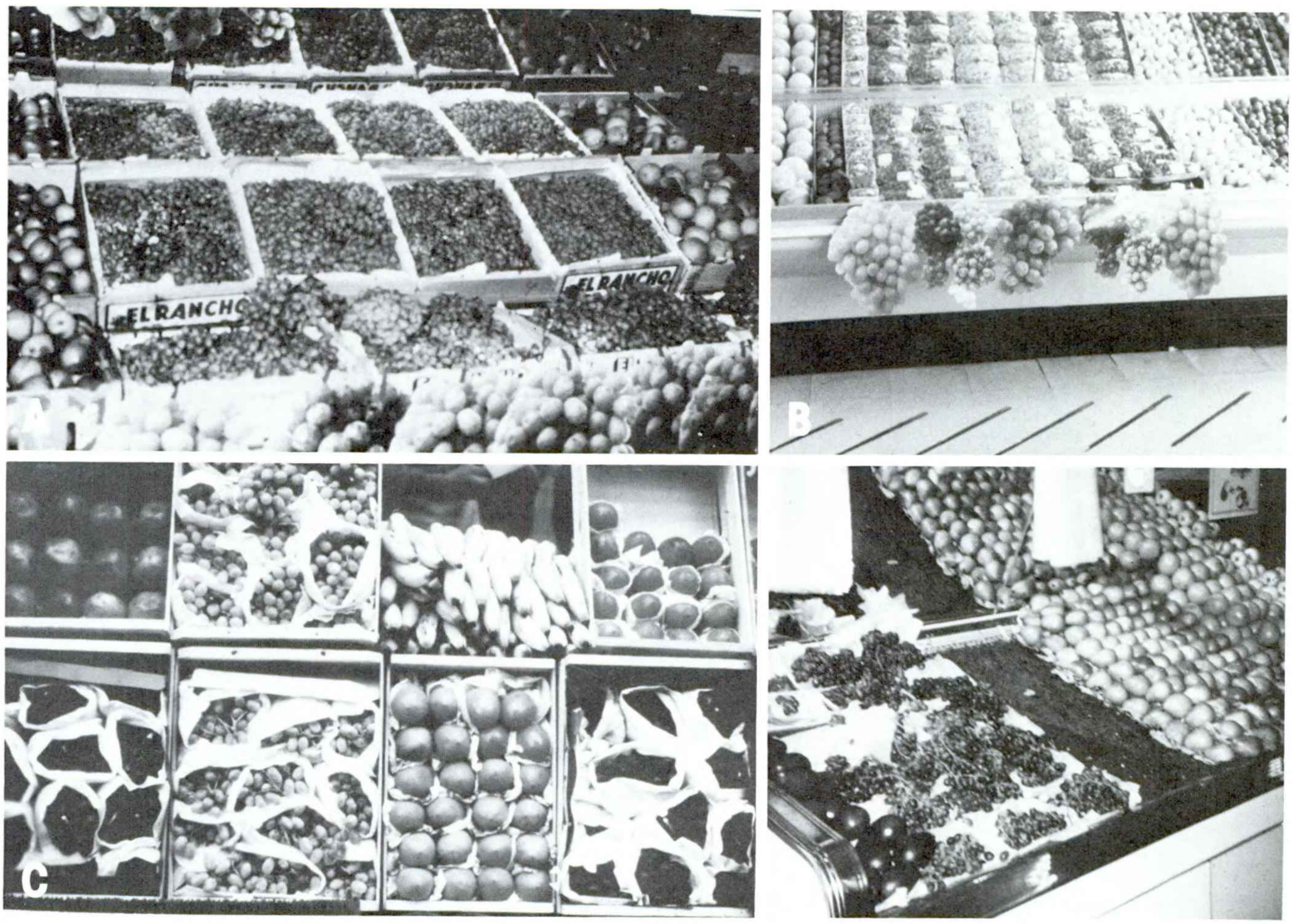


FIGURE 39. Attractive methods of displaying table grapes on produce counters in retail stores.
A. Naked packs of grapes displayed in the shipping containers with some clusters piled loosely near the forward edge of the counter for easy access by the customer. Keep bulk displays small and replenish often. Large piles of grapes result in excessive mauling of the fruit before it is sold. Also, monitor often to keep the display neat and attractive.
B. Transparent film wrapped over consumer units to be sold as individual packages. Featured is a row of sample clusters suspended over the front edge of the counter.
C. Display of chimney-wrapped clusters still in the shipping containers. Note mixing of containers of other produce for interesting color and shape effects.
D. Clusters with chimney wraps opened so the customer can examine the fruit and have easy access for handling.

The length of time between the holding room and the customer's market basket can be controlled somewhat by the amount of fruit on the produce counter. This amount should be minimal depending on the type of display so that turnover is as rapid as possible. In a counter display, avoid duplicating packages that contain the same variety of grapes. Also, large deep piles of grapes in a bulk display may look impressive, but turnover will be slow and the handling given the fruit by the customers as they browse through the display can be disastrous to quality. Customers are not noted for being especially gentle in handling a fragile commodity such as grapes, so the more the fruit can be isolated from this handling, the better for sales appeal. It should be recognized, though, that many customers expect to handle the produce before buying. In this situation, the manager has the problem of how much fruit to isolate without discouraging the sale. Consumer packaging has reduced this demand to some extent, which is a partial solution to the problem.

When setting up a display of grapes, the manager should consider carefully the method of removal of clusters from the containers. Grape lugs may be opened in one of at least three ways depending upon the type of closure. The lug should first be placed on a firm level surface. If it is a TKV or wood lug with a nailed-on lid, a special claw hammer or wedge is needed to lift the lid by prying between the end of the lug and the cleat of the lid. If the lid is the snap-on type, the edges of the lid should be grasped firmly and the lid bowed so that the notches in the cleat at one end disengage from the nails in the lug. If the container is a polystyrene lug, the lid can be removed by first pressing firmly inward on one end of the lug with one hand to disengage the locking device and, at the same time, raising the lid with the other hand. Before removal of the fruit, the lug should be oriented with the label end toward the unpacker, then the opposite end raised about 15 degrees (fig. 38B, 38C). The last cluster packed in the container is normally in one or the other corner at the upper end. This cluster is the easiest to remove without excessive pulling, after which the rest can be easily removed. The clusters should always be held by the main stem, and touching the berries be avoided as much as possible. Defective berries should be removed with shears, not pulled loose because this leaves an unsightly wet brush on the end of the stem. For a container display, the first two or three clusters should be removed so that the customer can more conveniently remove additional clusters after the container has been put on display. For a bulk display, each cluster should be carefully laid on the counter in whatever arrangement is desired. If the grapes are packed in wraps, each wrap should be opened as the exposed cluster is placed in position on the counter (fig. 39D).

Table grapes can be arranged into many attractive displays, according to the imagination and training of the manager (fig. 39). The wide variety of colors of grapes, sizes and shapes of berries, provide interesting material to work with. Since grapes sell on appearance to a significant extent, this factor should be stressed. Many commodity groups and sales organizations have dealer-service personnel available to assist a produce manager with display techniques.

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