tional initial treatment. After three to five days, the second-stage sheet, with thin polyethylene film shielding the bisulfite from the humidity, starts to evolve SO_2 in very low concentrations and continues to do so for as long as two months at storage temperatures, substituting for the weekly storage treatments.

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

Controlling water loss

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

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

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

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

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

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

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

Klayton E. Nelson is Professor, Department of Viticulture and Enology, University of California, Davis.

Trellising and spacing adjust to modern needs

W. Mark Kliewer

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

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

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

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

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

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

The cordon-style trellis system, shown here before and after pruning, is widely used for growing wine grapes in California. U. C. research in recent years has demonstrated substantially greater yields from modifications of the basic system.

not differ significantly between trellis treatments. (Low fruit maturity or pruning weight, or both, generally indicates that grapevines are overcropped.)

The trend in the grape industry in California as well as many other places in the world is towards mechanical harvesting and pruning. An innovative system developed by U.C. researchers for training cordon-trained vines on coiled wire reduces the cost of vine training and results in the development of cordons of uniform height desirable for mechanical pruning and harvesting.

There is still considerable interest in continuing trellis research. A five-year trellising study with Chenin blanc vines at Davis showed that vines trained to a 4-foot-wide double-curtain trellis (quadrilateral cordon) consistently yielded about 40 percent more than vines on a standard two-wire vertical trellis with no sacrifice of fruit maturity. Ongoing experiments at Davis, and in several California wine-grape-growing areas are studying the effects of interactions between trellis system, row spacing, rootstock, irrigation, and nitrogen fertilization on productivity and fruit and wine quality.

Vine spacing trials in California date back to the early work done by F. T. Bioletti and A. J. Winkler from 1925 to 1928 at Davis. They compared the square and avenue systems of arranging vines with vine densities ranging from 4 by 4 to 12 by 12 feet in the former system and from 3 by 12 feet to 4 by 18 feet with the latter. Crop yield the third year after planting was almost inversely proportional to the planting distance; however, by the sixth and seventh years yield of widely spaced vines approached that of narrowly spaced vines. At the same number of vines per acre there was little difference in crop yields between the square and avenue vine arrangements. Other researchers have advocated wide spacing between rows, indicating that economics more than anything else should dictate row and vine spacing; costs of cultivation, dusting, harvesting, and the like are determined more by the number and length of rows than by the actual acreage of the vineyards.

The only other well-documented spacing trial in California was by Winkler at Oakville, from 1949 to 1969 using White Riesling and Cabernet Sauvignon vines on a nonirrigated site. Yield per unit area did not vary significantly among the planting densities except at the closest (6 by 8 feet) and widest (12 by 12 feet) spacings, in which yields averaged somewhat less than row spacings between these two. However, yield and growth of individual vines were markedly less the shorter the distance between vines.

Vine spacing between 6 by 8 and 12 by 12 feet did not affect berry size, chemical composition of the fruit, quality of wines, or storage of reserves in dormant canes. However, spacing had a direct effect on individual vine growth; the wider the spacing the greater the growth and thus the capacity to mature a correspondingly larger amount of fruit. Winkler's data also indicated that operating cost should be the main criterion in determining vine spacing, and that a 12-foot distance between rows was best for most areas of California. The recommended distances between vines within rows were 6 feet for moderately vigorous varieties and 8 feet for vigorous varieties.

In other research, when close-spaced vines (7 by 7 feet) in North Coast vineyards were respaced to 10 by 10 feet by removal of alternate diagonal rows, they yielded as much as nonrespaced control vines (7 by 7 feet) within four years. The reduction in vine density resulted in lower production costs.

With the increasing scarcity and cost of suitable vineyard lands in central California and the North Coast, along with greater use of irrigation water, vineyard rows for wine production have tended to be more closely spaced in recent years than the traditional 12 feet between rows commonly used in the past. Ongoing field experiments in both the San Joaquin Valley and North Coast have been established to look at the interaction of row spacing with trellising as a means of increasing productivity without sacrificing wine quality.

W. Mark Kliewer is Professor, Department of Viticulture and Enology, University of California, Davis.