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Current Developments in Harvest Mechanization and DOV

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The total mechanization of raisin harvest and drying is a long-term goal of the California raisin industry. Research and innovation toward this end began in the 1950s with mechanical raisin roll pickup. The most significant progress has involved the continuous-tray mechanized systems and the adoption of dry-on-the-vine (DOV) systems. Grower innovation and industry development are continuing; equipment suppliers and manufacturers as well as researchers at the universities and the USDA are also committed to this goal.

Current work on raisin harvest mechanization can be divided into two main areas: tray drying (single or continuous) and DOV.

TRAY DRYING

Single-Tray Handling after Hand Harvest

Boxing is the only practice that has been mechanized for raisins harvested onto single trays. Attempts to mechanize the turning operation have not yielded commercially acceptable results. Mechanized raisin roll pickup was first used in 1954 by a Fowler-area grower (Figure 33.1). His farm-built raisin roll pickup machine was pulled by a tractor and operated off its own power unit. The rolls were picked up by a row of teeth that extended just below the soil surface; they were then transferred onto an inclined conveyor belt with paddle-like cleats. The trays were opened manually onto a small sand shaker. The raisins were then conveyed up an elevator into a funnel spout and directed into sweat boxes. The discarded paper was picked up by a wide rake with a propane burner that was dragged behind. Today, most of the same basic methods are still used in pickup machines, but with the additional benefits of hydraulic power and bulk bins (Figure 33.2). Several models of grower-built and commercial raisin roll pickup units are now in use in the industry, and some

Figure 33.1 An early raisin roll pickup machine invented by Mr. Forbes, a raisin grower near Fowler, California (photo taken in 1968). *Photo: L. Peter Christensen.*

Figure 33.2 A modern raisin roll pickup machine with bin trailer. *Photo: L. Peter Christensen.*

include sand shaking. In the 1970s, one manufacturer produced equipment that also mechanically separated the raisins from the rolls, but most units still require hand labor for this task. The raisins are conveyed into bulk raisin bins, tipster bins, or conveyor bulk trailers. Conveyor bulk trailers have a bottom conveyor system (something like a manure spreader) that moves the raisins onto a shaker in the yard. Most growers, however, box directly into bulk raisin bins that are handled with a forklift in the yard. If shaking is required, growers use a raisin shaker that includes a bin dumper.

Various pickup units have been designed for different roll preferences. Cigarette rolls are most common for single tray pickup; they are easily lined up end to end in the row middle and can be dumped quickly by hand during pickup (Figure 33.3).

Machine pickup typically reduces boxing labor by about 40 or 50 percent. This reduces the normal labor hours for picking up from between 2 and 2.5 per ton to between 1 and 1.5 hours per ton. Shaking in the yard requires about 1 labor hour per ton. Pickup machines with sand shakers can eliminate this cost. There is seldom much opportunity to hand sort raisins on pickup machines.

Continuous-Tray with Hand Harvest

Continuous-tray drying and handling was pioneered in the 1950s by John Stanley of Del Rey. His system, the Stanley Raisin Maker, utilized continuous paper and incorporated mechanical turning and pickup. While his system was mostly used for hand-harvested fruit, experimental and commercial-scale mechanical harvesting with the University of California cutterbar was successfully evaluated with this system. Various other grower-built and commercial continuous-tray units have since been developed, improved, and successfully used. This approach eliminates all manual handling of trays after picking.

The system uses a continuous tray 30 to 34 inches (76 to 86 cm) wide. Several tray materials have been evaluated over the years, including porous plastic and a variety of paper products. The porous plastic product was initially more expensive, but was reusable for as many as 3 years with some repair. Today, however, only extensible paper is being used, because of its availability, lower initial cost, and ease of handling and disposal. Grapes are picked in the traditional manner into pans and spread onto the continuous tray, which is rolled ahead down the row. Picking frames as long and wide as conventional trays are often used to gauge piece-rate payment. Continuous-tray hand harvest has been reported to be as much as 20 percent faster than harvest into individual trays.

The soil area for the tray must be kept flat if mechanical turning is to be practiced. Terracing is possible only if the grower elects not to turn the raisins. Also, the continuous tray should be at least 20 inches (51 cm) from either berm so that tractor wheels and equipment will be able to pass on both sides. Mechanical turning consists of flipping or turning the raisins over as the continuous paper travels over and under two rollers (Figure 33.4). The turning machine is drawn by a tractor and may require a second worker whose job is to thread the paper into the machine at

Figure 33.3 Mechanical pickup of cigarette rolls lined up in a row middle. *Photo: L. Peter Christensen.*

Figure 33.4 Mechanical turning of raisins on a continuous paper tray. *Photo: L. Peter Christensen.*

the row ends and where breaks occur. Optimum turning speeds range between 2 and 2.25 miles (3.2 and 3.6 km) per hour. From 2 to 2½ acres (0.8 to 1 ha) per hour can be turned in this way.

Pickup machines are either self-propelled or tractor pulled. Some convey the raisins back to bins behind the pickup unit (Figure 33.5) while others convey the fruit across the row to a separate tractor-pulled bin trailer (Figure 33.6). All involve some kind of sand screening; some incorporate a vacuum fan to clean the raisins. Disposal of continuous paper is accomplished by burning it or covering it with soil using a pair of border disk blades. The number of workers in the operating crew can range from two to six. A self-propelled unit may require only two workers; besides running the pickup unit, they must also retrieve the full bins and complete tray material disposal at the end of each day. Larger crews are needed if two tractor-bin-trailer rigs are being used in rotation for filling. A forklift operator stacks full bins and provides empties while one or two workers direct the filling of bins and feed the tray into the unit at the row ends. Travel speed typically ranges between 1.7 and 3 miles per hour (2.7 and 4.8 km/h). Most operators report pickup rates that range between 15 and 30 acres (6 and 12 ha) per 10-hour day.

Figure 33.5 Self-propelled two-person continuous-tray pickup machine. *Photo: L. Peter Christensen.*

Figure 33.6 Tractor-pulled four-person continuous-tray pickup machine. *Photo: L. Peter Christensen.*

Continuous-tray mechanization is most economical with high yields and a large acreage; the per-ton cost of trays and the per-acre cost of machinery are proportionally reduced. However, vineyards planted in short rows reduce equipment efficiency. For example, a 1991 study at California State University, Fresno showed that two different continuous-tray mechanized pickup systems were less economical overall than hand pickup at 1.36 tons per acre (3 t/ha). Costs for mechanized pickup ranged from 8 to 15 percent higher than those for a single-tray hand operation. In a vineyard with a yield projection of 2.5 tons per acre (5.6 t/ha), however, mechanized pickup was shown to cost 16 to 21 percent less than hand pickup.

Continuous trays cannot be rolled like individual trays for protection against overdrying, caramelization, and rain, and this has been a disadvantage. In emergencies, however, growers have been able to cut continuous trays into 7- to 20-foot (2 to 6 m) lengths and rolling them as cigarette rolls.

Continuous-Tray with Machine Harvest

Some vineyards incorporate mechanized fruit harvest and spreading onto the continuous tray with mechanized pickup and handling after drying. This approach requires more sophistication in vine management: a special trellising system that facilitates vine maintenance and machine harvest as well as cane cutting 1 week before harvest to aid fruit removal and minimize juicing and mechanical damage.

The concept was originated and developed by Harold P. Olmo and Henry Studer of UC Davis, and is described in chapter 32, Raisin Harvest Mechanization: A Bit of History. Growers Phil and Norman Engelman and Earl Rocca in the Biola area were among the early cooperators who built production-scale fruit spreading equipment to pull behind their Chisholm-Ryder over-the-row mechanical harvesters. Studer's original pickup machine design has been modified by Rocca Ranches into a commercial unit that includes an automated bin-filling trailer. Rocca Ranches uses its production scheme and specialized equipment on about 180 acres (73 ha) of 'Fiesta,' 'Zante Currant,' and 'Thompson Seedless' vines.

The Rocca trellis consists of a foliar support two-wire T crossarm at 62 inches (157 cm) and two lower, vertically attached fruiting cane wires at heights of 41 and 53 inches (104 and 135 cm). The vines are standard head-trained. Fruiting canes are manually severed with pruning shears about 7 days before harvest. The cluster stem structures dry out, facilitating pedicel

(capstem) and berry abscission. This allows the grapes to fall off as single berries, with pedicels attached in most cases and very little juicing.

The vineyards are harvested with self-propelled, over-the-row horizontal-rod–type harvesters (Figure 33.7). The harvested fruit is conveyed automatically into a rear-attached spreading machine where it is metered onto the continuous tray as single berries (Figure 33.8). The paper trays are 34 to 40 inches (86 to 102 cm) wide, depending on crop load and terrace shading. The paper is laid on a smooth, flat surface for harvests before September 10; a moderately sloped terrace is used for later harvests. Harvest proceeds at about 1 acre (0.4 ha) per hour. Taking into account all equipment hours associated with the harvest (including setup, cleaning, and repairs), the seasonal average is 0.7 acres (0.3 ha) per hour. Midmorning to late afternoon harvest ensures drier stems that will break more easily for the harvester. A light application of drying emulsion (ethyl oleate + potassium carbonate) can be applied to the berries while they are moving on a conveyor belt to the spreading machine.

The uniformity of drying for the single berries makes turning unnecessary. With favorable weather conditions, the fruit is dry and ready for pickup in 7 to 10 days (Figure 33.9). The raisins are retrieved with a self-propelled pickup machine that pulls a bin trailer equipped with an adjustable conveyor system (Figure 33.10). Pickup works best in the early morning hours (4 to 10 AM) when the fruit is not warm or pliable. The normal pickup rate is 1.65 acres (0.67 ha) per hour. Screen shaking usually is unnecessary due to the moisture uniformity and cleanliness of the product.

Rocca Ranches also finish-dries DOV 'Zante Currant' ('Black Corinth') raisins with its system. The

Figure 33.7 Continuous-tray harvest with commercial over-row harvester and spreading machine. *Photo: L. Peter Christensen.*

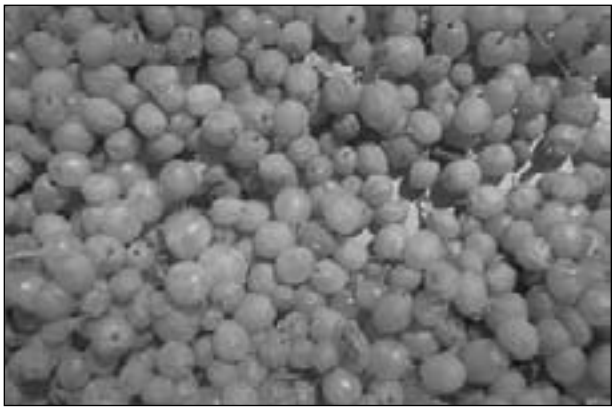

Figure 33.8 Single berries with and without attached cap stems (pedicels) after machine harvesting onto a continuous tray 1 week after cane cutting. *Photo: L. Peter Christensen.*

Figure 33.9 Pickup of machine-harvested raisins from a continuous tray 8 days after harvest. *Photo: L. Peter Christensen.*

Figure 33.10 Rocca Ranches pickup machine and bin trailer assembly. *Photo: L. Peter Christensen.*

canes are cut in August and fruit is allowed to dry for 4 to 5 weeks on the vine. All of the fruit (DOV and fresh fruit behind the cut canes) is then machine harvested onto the continuous tray where it finish-dries in 7 to 10 days for mechanical pickup.

DOV WITH MACHINE HARVEST

'Zante Currant' Naturals

The 'Zante Currant' variety was the earliest California success for experimental and commercial DOV in natural raisins (raisins dried without drying emulsion). The first trials in the late 1960s demonstrated successful DOV to 12 percent raisin moisture in 4 to 6 weeks after cane cutting on a two-wire Duplex trellis system. Fruit on the south wire tended to dry about 2 weeks before fruit on the north wire. Harvest with the vertical impactor harvester was demonstrated in 1969. The DOV potential of 'Zante Currant' is based on its early ripening, thin skin, and small berry characteristics, which allow early cane cutting and vine drying within a few weeks. The quality of these DOV raisins is exceptional, with fine wrinkles, intact bloom, and a lack of stickiness or caramelization. The variety's main drawback with regard to DOV is the high fruitfulness of latent and basal buds that produce about 30 percent of the crop in the head of the vine. These clusters are not severed from the vine during cane cutting and remain fresh. In the spring, before they set fruit, they must be removed either by hand, flaming, or foliar application of a growth regulator; alternatively, they can be retained and then harvested by hand and tray-dried.

Hiyama System

Hiyama Farms of Fowler have developed a unique DOV system for 'Zante Currant' through innovation beginning in the early 1980s. In the original system, still in production, the vine is trained to a split head or short bilateral cordon and utilizes a wide, welded steel double-T trellis. The fruiting canes are wrapped onto a 56-inch (142 cm) wide crossarm with six wires; a wider (64-inch [163 cm]) upper crossarm with four wires serves as foliar support. Canes are usually cut on or around August 20. A few days later the fresh fruit behind the cut canes is hand harvested onto trays. This fruit accounts for about one-third of the total crop and is dried and handled using standard hand harvest methods. Machine harvest of the DOV fruit occurs 4 to 6 weeks after cane cutting, depending on weather. The harvester is an over-the-row commercial model modified for a wide trellis. For fruit removal, it use fiberglass rods that strike the fruit zone vertically from below.

A newer system developed by Hiyama Farms uses an 8-foot (2.4 m) wide, 5-foot (1.5 m) high all-steel T trellis with a 4-foot (1.2 m) long vertical shoot positioning trellis extension in the center (Figure 33.11). The trellis configuration forms the shape of a cross with an overall height of 9 feet (2.7 m) and a width of 8 feet (2.4 m). The vines are spaced 6 feet (1.8 m) apart within the row and trained to cordons along a central wire. Fruiting canes are tied out perpendicular to the cordon onto four fruiting wires on each side of the crossarm. Thus, the system has a balanced crop load on each side of the trellis. Shoots arising from the cordon are pushed vertically with shoot positioning wires that are hooked onto each side of the vertical trellis extension. This vertical shoot positioning separates the canopy of renewal shoots from the fruiting zone where the fruit will dry on the vine. It also encourages the development of cane renewal wood. A notch at the center of the crossarm provides access for mechanical cane cutting equipment. Advantages of the new system include an expanded and balanced fruiting zone, a separate cane renewal zone, and a well-defined vine structure for cane cutting and pruning. Cane cutting for DOV and hand harvest for tray drying of the fresh fruit in the renewal zone are performed as in the original system. Drying time for the DOV portion is typically 4 to 6 weeks. A grower-built, self-propelled harvester travels down the row middles and harvests two adjoining half-rows at a time (Figure 33.12). The row width is 15 feet (4.6 m) to accommodate the trellis and equipment.

Figure 33.11 The Hiyama cross trellis for 'Zante Currant' employs bilateral cordon vine training, vertical shoot positioning wires, and horizontally spaced fruiting wires. *Photo: L. Peter Christensen.*

Figure 33.12 The Hiyama harvester picks two half-rows when traveling down each row middle. *Photo: L. Peter Christensen.*

'Thompson Seedless' DOV Using Drying Aids

Australian successes. The first experiment confirming that cane cutting and trellis drying were feasible for 'Thompson Seedless' vines was carried out in 1958 by CSIRO (Commonwealth Scientific and Industrial Research Organization) at Merbein, Australia. The practice was used in conjunction with a spray application of the traditional dipping emulsion to accelerate grape drying to produce the lighter colored Australian 'Sultanas.' Early commercial use in Australia was mostly a salvage measure during rain-affected drying seasons. It was found that fruit mold and rot from rain could be arrested if canes were cut and the fruit were sprayed with drying emulsion. The treated fruit would then dry on the vine and could be harvested by hand or machine. This prompted some growers to adopt the DOV concept while research continued.

Australian researchers developed the first system that incorporated complete canopy separation of fruiting and renewal zones with the split cordon training method and the Irymple trellis. One arm of the trellis is horizontal, the other is raised at an angle, and both can be swiveled on a pivot on the post. Alternate sides of the bilateral cordon-trained vines are spur- and cane-pruned. The spur-pruned side grows nonfruiting replacement canes that climb up the angled replacement arm. They then become the fruiting canes for the following season. The arms of the trellis are pivoted each year so that the fruiting side is always horizontal and the renewal side is always angled upward. Canopy separation was found to facilitate mechanical cane cutting, the application of the drying emulsion, and the mechanical harvesting operation. While the concept was sound, it was impractical due to trellis structural problems and the need for a dedicated machine for harvest. However, this trellis and the split cordon and hanging cane concepts became catalysts for further innovation in trellis design.

Grower and innovator Ivan Shaw has developed the most advanced DOV system in Australia. It includes a new trellis and vine management system as well as the design and construction of the necessary equipment. Equipment developed by Shaw includes a leaf-plucking device for leaf removal to facilitate emulsion application and fruit drying, a device for mechanical cane cutting, a custom raisin harvester, and a mechanical raisin bin handling and dehydration system. The original Shaw system uses quadrilateral cordon training on a high (5- to 6-foot [1.5 to 1.8 m]), narrow (1-foot [0.3 m]) T trellis. Each side of the cordon system takes its turn at being used either for fruiting (hanging fruit canes) or renewal (one- to two-node spurs) in alternate years. The hanging canes are supported below with wires attached to an inverted V trellis (Figure 33.13). This widens the canopy toward the bottom and positions the fruit out from the vine row. The fruiting canes are severed by machine, and drying emulsion is applied to accelerate the drying of the fruit.

Further evolution of Shaw's system has led to the use of a single bilateral cordon and, more recently, the replacement of the inverted V trellis with a sloping, swing-arm trellis (Figure 33.14). The swing-arm is used to alternate the cropping side between seasons by rotating the trellis. The modified sloping system facilitates the upward growth of replacement shoots to maximize fruitfulness and provides a separate fruit canopy for spray application and fruit drying. It must be remembered, however, that complete adoption of this system, even in California, would have to include the use of the drying emulsion and the production of oleate-category raisins. This is because the portion of the crop produced on the more shaded north or east side of the canopy would be unlikely to dry well without the drying aid.

Experience in Australia has shown that DOV is best suited to vigorous, high-yielding vines. This not only maximizes the savings achieved through mechan-

Figure 33.13 Ivan Shaw of Merbein, Victoria, Australia, with his original inverted V trellis with bilateral cordon training and alternate fruiting and renewal sides. *Photo: L. Peter Christensen.*

Figure 33.14 Ivan Shaw's swing-arm trellis is an alternative to the inverted V trellis. *Photo: L. Peter Christensen.*

ical harvesting, but also ensures retention of the vines' photosynthetic capacity (i.e., 50 percent or more of the leaf area) when the canes are cut. Many of their new vineyards are planted with improved clones of 'Thompson Seedless' ('Sultana') grafted onto 'Ramsey' ('Salt Creek') rootstock.

California experience with the Australian method. In 1968, workers at CSU Fresno began to experiment with the Australian DOV method. Various trellises, formulations and concentrations of drying aid emulsion sprays, and equipment designs were evaluated. Commercial vineyard adaptation, economic studies, and consumer preferences were ultimately included in the experimental process. Some growers achieved successful commercial production, the product was acceptable to consumer panels, and harvest labor requirements were reduced. The process has not been adopted by the California industry, however, as of the date of this writing. Reasons include concerns about foreign competition in marketing a lighter colored 'Sultana' type raisin, higher costs than traditional methods during the study period, and substantial yield reductions over time. Long-term yield studies have shown reductions of 30 percent by the sixth year. This has been attributed to the reported defoliation levels of 80 to 91 percent that resulted from cane cutting, drying emulsion sprays onto the foliage, and harvester contact.

The potential value of future use of the drying emulsion with DOV should not be discounted. Newer trellis and vine management systems that achieve canopy separation allow better spray coverage of the fruit zone without spraying the renewal leaves and canes. This should minimize the damaging effects of the spray on the functioning canopy and reduce the recommended per-acre spray rates. Also, the 2 percent concentration rates of ethyl oleate (by volume) and potassium carbonate (by weight) used in the 1970s have since been shown to be unnecessarily excessive. Rates as low as 0.5 percent (by volume) for ethyl oleate and 0.6 percent (by weight) for potassium carbonate have proven satisfactory in tests in Australia. Market acceptance of the lighter and variable-colored and green-tinged fruit may be the most limiting constraint.

DOV of Natural 'Thompson Seedless' Types

Simpson overhead system ('Fiesta'). Lee Simpson of Madera grows 'Fiesta' vines with an overhead trellis for an alternating-middle DOV and renewal system. The 6½-foot (2 m) high, flat trellis uses a 2-inch (5 cm) stake at individual vines planted at 8- and 6-foot (2.4 and 1.8 m) row and vine spacings, respectively. The vines are head-trained with fruit canes tied to alternate middles. The opposite side of the vine is spur-pruned

for shoot and cane renewal the following year (Figure 33.15). Flower clusters in the head of the vine are pinched off in the spring along with some shoots and leaves that might otherwise interfere with cane cutting for DOV. Strong-growing shoots on the renewal side are positioned over into the renewal middle. Most of these serve as fruit canes the following year.

Fruit canes are hand cut by the second week in August for DOV harvest about 6 weeks later (Figure 33.16). The mechanical harvester consists of a hydraulically powered square roller bar mounted on the front of a tractor with a wide catching chute underneath (Figure 33.17). The bar rotates forward just underneath the trellis wires where the dried clusters are hanging. The dislodged raisins drop into the catching chute and are conveyed back into a bin on a three-point-mounted forklift. Leaves are removed by a blower fan and a vacuum fan on the conveyor system. Empty bins are dropped off as needed, and low-profile forklifts retrieve the full ones.

The initial investment is high due to the need for close vine spacing, overhead trellising, subsurface drip irrigation, and the purchase of new, low-profile equipment. However, projected yields (as high as 5.5 tons per acre [12.3 t/ha]) would more than offset capital investment costs, as compared to those of conventional raisin production. The labor requirement for all operations is about 31 hours per ton of raisins, a figure similar to that for traditional hand harvest and tray drying. However, these hours are more evenly distributed over the year as opposed to the peaked labor requirements of hand harvest.

Sun Maid south-side system. A patented DOV system has been developed by the Sun Maid Growers cooperative, working through its DOV Committee. The original concept was devised by grower Dave Walker of Caruthers using a trellis that positioned the fruit canes on the south side of the canopy while renewal shoots were supported vertically and away from the fruit bearing zone. Since most raisin vineyards are planted east-west, this exposes the fruit zone directly into the sunlight on the south side of the row. Complete DOV can be accomplished in about 6 weeks of normal drying weather after cane cutting in mid- to late August. It provides a way for growers of conventional, head-trained 'Thompson Seedless' raisin vineyards to convert over to a DOV system for the production of "naturals."

Figure 33.15 The Simpson system uses an overhead, alternating middle (fruiting and renewal middles) trellis with the 'Fiesta' variety. *Photo: L. Peter Christensen.*

Figure 33.16 'Fiesta' DOV fruit drying in alternate middles after canes are cut. *Photo: Jack Kelly Clark.*

Figure 33.17 A square roller bar rotates to dislodge 'Fiesta' DOV raisins, which drop into a front-end hopper. Simplicity of design and operation are features of the Simpson harvester. *Photo: Jack Kelly Clark.*

Various trellis designs have been developed using different trellis materials and dimensions. Basically, the fruit canes are wrapped onto two wires supported about 15 to 26 inches (38 to 66 cm) away from the row center and 50 to 55 inches (127 to 140 cm) from the ground. Reinforced end posts and custom-bent, studded T-posts or other specialized in-line post or stake assemblies are used to accommodate the crop's off-center weight load (Figure 33.18). The renewal shoots from the vine head are directed vertically through two to three sets of narrowly spaced wires (usually 12 or fewer inches [30 or fewer cm] apart) on a trellis extension. Another design uses a foliar trellis angled upward on the north side to support the renewal shoots. This arrangement tends to invigorate the renewal shoots and provides good sun-

Figure 33.18 A Sun Maid south-side trellis design supports all of the fruiting canes on a well-anchored south-side support system. *Photo: L. Peter Christensen.*

Figure 33.19 The Sun Maid system's south-side fruit is fully exposed to the sun for DOV; renewal shoots are trained vertically for canopy separation. *Photo: Jack Kelly Clark.*

light exposure for bud fruitfulness and maturity for future cane selection.

Complete canopy separation (of fruit-bearing canes from renewal shoots) provides for south-side fruit exposure to speed drying and enables mechanical cane cutting for DOV (Figure 33.19). Some manual direction of shoots in the spring is necessary to achieve separation. Clusters borne in the head of the vine (behind the cut canes) are either pinched off in the spring, removed by hand and hung on the wires for drying in the fall, or hand harvested for tunnel dehydration or winery use.

Several mechanical cutterbar and rotary blade cane cutters have been developed. Most require some follow-up cutting by hand. You can blow dead leaves from the fruit zone about 3 days after cane cutting to reduce drying time. Several custom self-propelled and pull-type harvesters have been developed for the system. Rotating and vibrating fiberglass rods or fingers shake the raisins from the south side of the canopy (Figures 33.20 and 33.21). Mechanical trimming can be used after harvest to ease the removal of the dry, cut canes. New canes for next year are selected by hand from the vertical shoots that develop in the renewal zone.

Overhead quad-cordon system. The overhead quadrilateral cordon vine training system was designed by Gary Pitts of Fowler, California. It uses a flat, overhead wire system to support canes at about 82 inches (208 cm), with a lower (68-inch [173 cm] high) 32-inch (81 cm) wide T trellis with quadrilateral cordon training (Figure 33.22). Alternate cordons and row middles are used for fruiting and renewal. The fruiting canes are tied toward the fruiting middle, perpendicular to the cordons. The opposite cordon on the same vine is spur-pruned for renewal shoots only. Shoot-positioning wires are used in the spring to push the shoots on each cordon toward their dedicated middles. Cane cutting by machine or by hand is facilitated by the clearly visible and well-defined position of the fruit canes that arise from the cordons.

The system shows promise for natural DOV of early ripening varieties and with drying emulsion sprays. Initial costs for the trellis are high; these may be offset by the advantages of a well-defined vine training and trellis system to accommodate canopy separation, selective spray application, ease of cane cutting and cluster removal from the renewal zone, and potentially high yields.

Balanced DOV Trellis Concepts

New early ripening varieties from the USDA–ARS breeding program at the Horticulture Research Laboratory in Fresno increase the potential for DOV on both sides of the vine canopy. If canes can be cut in early

Figure 33.20 A tractor-pulled force-balanced shaker head harvester picking a south-side DOV system. *Photo: Jack Kelly Clark.*

August at full fruit maturity, raisins may be able to dry under trellises that do not completely separate canopies or expose fruit to the south side. In this way, crop loads could be balanced across the vine row and trellises could be expanded to accommodate larger crops. The two most promising concepts evaluated at the UC Kearney Agricultural Center are *open cross* and *open gable*.

Open cross. A modified version of the Hiyama trellis, the open cross trellis uses a 5-foot (1.5 m) wide horizontal fruit-bearing support with a central 3-foot (0.9 m) long vertical trellis extension for renewal shoots (Figure 33.23). Vines are trained to a bilateral cordon at the center of the trellis. Fruit canes are tied out onto two or three horizontally spaced wires on each side. Shoots arising from the cordon are self- or hand-directed between vertical pairs of wires or moved upward with moveable wires. This achieves canopy separation and encourages renewal cane development. Canes are cut at or near the cordon for DOV.

The dimensions and wire placement of this trellis can be tailored to vine vigor. It is best suited to north-south rows because of the shading effects of the vertical shoots on one fruiting side. The enhanced cane renewal with vertical shoot positioning is an advantage of this trellis, especially with vines of moderate vigor. However, vertical shoot positioning can encourage excessive growth in the shoot renewal zone of a high-vigor vine. Therefore, excessive vine vigor must be controlled with irrigation and fertilizer practices. Mechanical cutting of canes is possible with shoot positioning, canopy separation, and trellis design. Trellis design provides an open area between the cordon and fruiting wires to accommodate a cutting device. One version of this concept is shown in Figure 33.23. It uses bent T-posts on each side of the row to support the fruiting wires. The design provides an open space on each side to allow access for a mechanical cane cutting device. The harvesting equipment used for the Sun Maid south-side system is adapted to this system. The poor accessibility and poor

Figure 33.21 A self-propelled lateral shaking (vertirotor head) harvester working in a south-side system. *Photo: Jack Kelly Clark.*

Figure 33.22 The overhead quad-cordon system uses alternating row middles for fruiting and cane renewal. It offers a well-organized vine management system for canopy separation and for hand and mechanized operations. *Photo: L. Peter Christensen.*

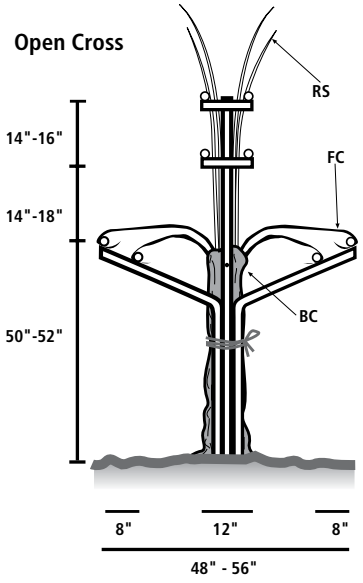

Figure 33.23 The open-cross trellis is a modification of the Hiyama system. It achieves canopy separation with horizontal cane wires on both sides of the canopy and vertical shoot positioning in the center. Open areas in the cane-supporting trellis provide access for mechanical cane cutting.

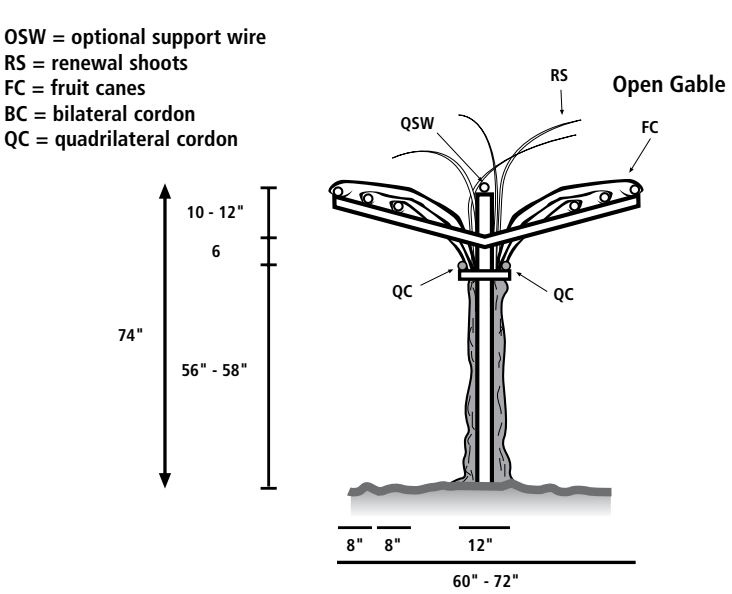

Figure 33.24 The open gable offers workers access for vine management, including hand cutting of canes. The optional foliar support wire helps to confine the renewal shoots to the center, away from the fruiting zones on each side.

visibility for hand cane cutting for DOV and hand fruit removal from the renewal zone along the cordon are disadvantages of this system.

Open gable. The open-gable trellis is configured as a wide V with an overall width of 5 to 6 feet (1.5 to 1.8 m) as shown in Figure 33.24. This provides a 6- to 8-foot (1.8 to 2.4 m) open space between rows to allow passage for standard equipment and sunlight penetration during DOV drying. Vine training is either bilateral or quadrilateral cordon. The cordons are located about 6 inches (15 cm) below the fruiting wires for visibility and worker accessibility for hand pruning and cane cutting. The trellis gable angle is 22° to 28° from horizontal, with an upper height of about 74 inches. Three cane wires on each side support the fruit-bearing canopy and crop load. Manual cane cutting is facilitated by eye-level visibility of the cordons from which the canes originate. Workers can easily walk under the open-gable trellis; the permanent vine structure is easily accessible for all hand operations.

The open gable concept has potential for high production (3.5 to 4.5 tons per acre [7.8 to 10 t/ha]) and a well-organized vine management system. Canopy separation is not necessary with early varieties that can be cane-cut before August 15. This is because heat accumulation in the open row middles during the day enhances raisin drying. Mechanical harvesting can be performed with a force-balanced radial shaker harvester.

Growers need to manage the crop load to match the vine potential to ensure early, uniform fruit ripening. Quadrilateral cordon training offers more renewal leaf area (behind the cut canes) for vine maintenance and cane selection than is allowed by bilateral cordon training. However, it will also produce the most fruit behind the cut canes.

DOV IN THE FUTURE

DOV systems are likely to evolve rapidly. Always remember that DOV is most feasible on uniform, vigorous vineyards with lower costs per ton and longer-term yield expectations. Young vineyards on good soil or nematode-resistant rootstocks are the best candidates. They stand the best chance of withstanding the negative effects of cane cutting on vine growth and yield. Australian research demonstrated a 10 percent yield reduction over time with a 60 percent loss in leaf area as a result of cane cutting. A retention of at least 50 percent of the leaf area is needed to maintain normal yields over time.

Earlier-ripening varieties provide the best opportunity for early cane cutting with good fruit maturation.

Ultimately, plant breeders may come up with a variety that will dry on the vine naturally with no cane cutting required.

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