

## A Total Vineyard Mechanization System and Its Impact on Quality and Yield

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**Abstract** *Grapevines can be modified by various trellising and pruning methods so they may be successfully mechanized. There are six conditions that must be optimized to successfully mechanize a vineyard. A properly trained vine allows efficient operations with out excessive damage to the vines or reduction of fruit yield and/ or quality. Shoot positioning can be accomplished efficiently with machines which can improve fruit quality and make basal nodes more productive. Conditions during harvesting, handling, transporting and processing can affect quality and must be strictly controlled.*



*Figure 1. Mechanical pruning of Bilateral Cordon, shoot-positioned grapes at the U of A Experimental Farm vineyards.*

**Introduction** The global marketplace for wines is becoming increasingly competitive. Chile, Argentina and others will continue to impact the U.S. wine market. We must stay aware of the developing regions of the world that have good soils, climate, water, cheap labor, a managed economy, and a favorable exchange rate. This concern coupled with the ever-increasing cost and shortage. of qualified help will keep us continuously appraising our ability to compete. Improving our efficiency and productivity through mechanization without adverse effects on wine quality is just one of the many areas for research emphasis.

**Vineyard mechanization.** Totally integrated systems, which include proper cultivars, trellis design, pruning techniques, cultural programs and harvesting methods are in use today. Extensive research on handling and product utilization has been required to make mechanical harvesting feasible.

It is impossible to discuss vineyard mechanization without understanding the importance and significance of the trellis and the training and pruning of vines. The following conditions must be optimized in order to successfully mechanize a vineyard:

- 1. Vine height.** Optimum height is dependent on the harvester used and gives the most flexibility to the setting of the harvester shaking mechanism.
- 2. Vine and row alignment.** Any vines or grape stakes out of alignment will be damaged and slow the rate of harvesting. Straight rows and trunks are equally critical for other mechanized operations such as pruning and shoot positioning.
- 3. Vine row obstructions.** If a totally clear vineyard is not possible, preplanning must be implemented to circumvent obstructions.
- 4. Soil conditions.** Wet soil can slow or stop harvesting and pruning operations. Uneven surfaces can cause the machines to damage vines or to do an inefficient job.
- 5. Vine trellis system.** The trellis system must be designed for maximum harvest efficiency for a given cultivar and mechanical harvester.

Traditionally, grapevines have been trained to provide a support system for production. However, these systems are not necessarily suited to mechanization. Trellis systems must be designed and shoots positioned to accommodate precise mechanical movement to use machines successfully for pruning, harvesting, and other grape production operations. The morphological characteristics of different varieties can also influence the system required. Poor trellis design and training of vines can be major contributors to a high percentage of MOG such as bark, cane, leaves and petioles.

- 6. Removal of metallic debris.** It is imperative in mechanically harvested vineyards trellised on wooden stakes that a magnet be installed on the machine's discharge conveyor to collect staples and other iron-containing objects. These objects can cause extensive damage to processing equipment.

**Trellis systems for total vineyard mechanization.** The standard trellis systems for long cane pruning systems are effective for mechanical harvesting but impossible for mechanical pruning. To totally mechanize a vineyard, the trellis system must be designed to allow maximum accessibility of the fruit to the shaking mechanism of the harvester and to allow effective mechanical shoot positioning and mechanical pruning. A properly trained vine allows efficient machine operations without excessive damage to the vines or reduction of fruit yield and/or quality.

The Geneva Double Curtain Training System (GDC) developed by Nelson Shaulis in Geneva, NY, (Shaulis et al. 1966) was one of the first training systems to accomplish these objectives, although the original design and intent of the GDC system was production driven. The GDC trellis system doubles the length of cordon per vine, and when used in conjunction with shoot positioning, increases the number of shoots that have basal nodes exposed to sunlight. Vigorous vines of large-leaved *Vitis labruscana* L. cultivars, which have a drooping-shoot growth habit and annual cane prunings of 1.35 kg or more, give the greatest response to the GDC system (Jordan et al. 1981). This system works equally well on certain French-American hybrid and vinifera cultivars.

The GDC trellising system requires a three-wire trellis with two horizontal cordon-support wires and a single trunk-support wire. The vines are cordon trained and short cane pruned (i.e., 4 to 6 nodes). In contrast to *Vitis vinifera* L., the fruiting canes of *Vitis labruscana* cordon-trained vines are selected from the lower 180° of the horizontal cordon. The cordon must be in continuous contact with the support wire to obtain maximum efficiency from mechanical harvesting and pruning.

Bilateral cordon (BC) trained *Vitis labruscana* vines also can be effectively harvested and pruned by machine (Cawthon and Morris 1977, Morris and Cawthon 1980). The BC trellis system for eastern-grown *Vitis labruscana* consists of establishing bilateral cordons on 8 gauge, high-tensile-strength (HTS) steel wire at about 180 cm above the vineyard floor. The fruiting canes are selected as described for the GDC system. Also, this system is suitable for use on certain French-American hybrids and *vinifera* cultivars. In Arkansas the author compared the three major trellis systems and reported the BC system to be as productive and to produce as comparable a fruit quality as the Umbrella Kniffin system (originally, the predominate trellising system for the region). However, the GDC system was more productive than either of the other two systems with no reduction in fruit quality. The BC and GDC systems can be effectively harvested, shoot positioned, and pruned mechanically.

Bilateral cordon (BC) training with spur pruning is currently a common training system in California vineyards (Christensen et al. 1973). Since *Vitis vinifera* cultivars grow upright, the fruiting spurs are selected from the upper 180° of the cordon. A common BC trellis used for some California wine grapes consists of a two-wire vertical trellis. A foliage support wire (13-gauge HTS) is usually attached 30 cm above the cordon wire. This wire is moved upward for better foliage support as the spur positions move upward with age. For extremely vigorous vines, some growers install a third wire at the top of the stake for additional support, and some growers install a cross arm on top of the stake to spread two top wires 72 cm to 90 cm apart. The width of the cross arm is determined by vine vigor. However, many new trellising and training systems exist in California and throughout the United States.

**Mechanical pruning studies at the University of Arkansas.** Early studies by the author have examined the effects of mechanical pruning on yield, vine size, and juice quality of shoot-positioned 'Concord' grapevines on GDC or BC training systems (Fig. 1). The results showed that continuous mechanical pruning of Concord grapes as an aid is recommended only in shoot-positioned vineyards where pruning can be followed by cane selection and adequate node limitation in order to maintain good yield and fruit quality (Morris and Cawthon 1981). It was concluded that a pruning cycle consisting of one year of completely mechanized pruning followed by a year of balanced pruning be adopted or follow the mechanical operation by hand balancing each year (Table 1).

The color acceptability was rated lower than expected on hand-pruned (30+10) GDC-trained vines because of the blue appearance rather than the expected purple color. The high pH allowed structural transformations of the anthocyanin molecules, resulting in the shift in hue. SC-trained, no touch-up vines had the lowest ratings for both color intensity and color acceptability. Juice flavor was rated unacceptable from the 90 node plots with no touch-up on the GDC training system and with no touch-up treatment on the SC system, following mechanical pruning.

**Table 1. Effect of training system and pruning treatments after six consecutive years on yield, uneven ripening (% green fruit), % soluble solids, acidity and color abs. at 520 nm of Concord grapes.**

Treatment	Yield (MT/ha)	Soluble solids (%)	Green fruit (%)	pH	Acidity as tartaric (%)	Color abs. at 520 nm
<b>GDC</b>						
30+10	15.7a	15.2a	3.0ab <sup>z</sup>	3.79d	0.72d	0.343ab
Mech./adj. best 60 nodes	15.9a	15.1a	2.3a	3.68cd	0.78bcd	0.291bc
Mech./adj. best 90 nodes	8.1b	13.8b	9.1abc	3.61cd	0.82abcd	0.281cd
Mech./no touch-up	8.6b	13.3bc	12.6b	3.46abc	0.86abc	0.199ef
<b>SC</b>						
30+10	10.1ab	15.0a	4.0ab	3.60bcd	0.80abcd	0.320abc
Mech./adj. best 60 nodes	12.4a	15.7a	4.1ab	3.48abc	0.76cd	0.364a
Mech./adj. best 90 nodes	9.9ab	13.6b	8.8abc	3.41ab	0.90a	0.230de
Mech./no touch-up	6.5b	12.0c	11.4bc	3.35a	0.88ab	0.167f

Source: Morris and Cawthon (1981).

<sup>z</sup>Means within columns followed by the same letter or letters are not significantly different at the 5% level, by Duncan's multiple-range test.



*Figure 2. Mechanical shoot positioning machine for Geneva Double Curtain-trained grape vines. Machine developed by Tom Oldridge of Lowell, AR, and mounted under a mechanical harvester.*

**Table 2. Effect of training system and pruning treatments on sensory quality of Concord juice on the sixth and final year of the study.**

	Color		Flavor
	Intensity	Acceptability	
<b>GDC</b>			
30+10	7.8a <sup>z</sup>	6.0ab	5.6cd
Mech./adj. best 60 nodes	7.1ab	7.0a	6.6bc
Mech./adj. best 90 nodes	6.9ab	6.3ab	4.8de
Mech./no touch-up	4.4c	4.9b	4.0e
<b>SC</b>			
30+10	7.7a	7.9a	7.6ab
Mech./adj. best 60 nodes	7.3ab	6.9ab	8.3a
Mech./adj. best 90 nodes	5.7bc	5.9ab	5.8cd
Mech./no touch-up	2.7d	2.8c	4.0e

Source: Morris and Cawthon (1981).

<sup>z</sup>Means within columns followed by the same letter or letters are not significantly different at the 5 % level, by Duncan's multiple-range test.

A pruning system widely used in Australia (Possingham, et. al. 1993) and in some California vineyards is Minimal Pruning of Cordon-Trained Vines (MPCT). In some of these commercial vineyards, the vine has been initially trained to 5 to 6 foot cordons. After developing the basic framework of the vine there is no pruning or trimming of the sides or top of

the vine. Canes hanging closer than about 3 feet to the ground are either trimmed mechanically or tucked back into the canopy. The ideal result for MPCT vines is to develop a self regulating vineyard.

The morphology of vines trained to and maintained in the MPCT system is different than that of pruned vines. The MPCT vines carry more leaves per vine and have an increased leaf area (Downton and Grant 1992, Possingham et. al. 1993). At harvest, MPCT vines, when compared to conventionally pruned vines, have given higher yields and have an increased number of clusters. These clusters are smaller, with a reduced number and size of berries.

Studies at the University of Arkansas have indicated that mechanical thinning of vines that have excessively heavy fruit loads will help prevent alternate bearing of minimal-pruned vines. Additional research and equipment has been designed and tested that will effectively thin shoots and thin fruit from vines that require crop reduction.

**Shoot positioning at the University of Arkansas.** Shoot positioning improves fruit quality and exposes the lower nodes on the bearing units to sunlight, which makes the basal nodes more productive. Shoot positioning is particularly effective with large vigorous vines of *Vitis labruscana* cultivars, which have large leaves and a drooping-shoot growth habit. Shoot positioning can be accomplished either by hand or, more efficiently, with a mechanical shoot positioner. This new shoot positioner, developed by Tom Oldridge of Lowell, AR, is an improvement over other machines for positioning GDC-trained vines (Figs. 2, 3).

As soon as the tendrils touch the wire or another cane they fasten quickly. Vines are usually shoot positioned for the first time just before bloom. Complete shoot positioning usually requires a second and sometimes a third pass with a mechanical shoot positioner (Cawthon and Morris 1977). If the Oldridge GDC brush attachment is used, the vigorous shoots growing between the two cordon wires will be pulled or knocked down to maintain two separate foliage canopies. This totally mechanized system is currently being investigated at the University of Arkansas.

### **Mechanical harvesting**

#### **Harvest mechanization effects on quality.**

Conditions during harvesting, handling, transporting and processing that can affect quality are included in the following: environmental conditions, cultivar, cultural practices, chemical harvesting aids, MOG, and physical transfer of the grapes to the processor. Mechanically harvested grapes can be of higher quality than hand-harvested grapes when these influences are considered and when the grapes are delivered promptly to the processing unit. Although many processing grapes can be mechanically harvested, there are still several problems that lead to quality loss.

**Machine effects.** With all harvesting methods, grapes are recovered as cluster parts or individually torn berries, and for this reason mechanical harvesting is never used for fresh market grapes. Perhaps the major quality problem with mechanically harvested grapes is fruit damage from the beater rods or slappers and the handling required after harvest. The percentage of intact, mechanically harvested berries is as low as 40%.

**Cultivar and production system effects.** Certain cultivars readily suited for mechanical harvesting (e.g. 'Concord', 'Niagara', 'Thompson Seedless', 'Gewurztraminer', and 'Cabernet Sauvignon') will yield the same amount of fruit whether hand harvested or machine harvested.

Cluster morphology, and the adherence of berries to clusters, and clusters to vines are the main factors that determine how easily and in what condition the fruit is removed. Fruit of most cultivars is removed primarily as single berries. This is particularly true of berries with loose attachment.

The ease or difficulty of mechanical harvesting also depends upon training system, type and condition of the trellis system and wire, and vine vigor.



*Figure 3. View of the Oldridge shoot positioner in Figure 2 with cutter bars installed for pruning. Brushes pull canes into position to be cut. Both machines are being evaluated at the U of A as well as in other grape-producing regions of the United States.*

**Handling and processing effects.** Long delays between mechanical harvesting and delivery to the processing plant can result in increased enzymatic activity and browning, oxidation (i.e., loss of color), and development of off-flavors and microbial growth. Temperature from the time of harvest to the time of processing probably influences the quality of machine-harvested grapes more than any other factor. The temperature of the grapes at harvest governs the storage temperature, regardless of the external air temperature. High grape temperature at harvest in combination with a delay in processing leads to rapid deterioration of grape juice quality.

Because of the problems associated with excessive heat and quality deterioration, grapes should be harvested during cool periods of the day or night to minimize quality loss.

It has been established that machine-harvested grapes may contain a rather high percentage of MOG such as bark, cane, leaves, and petioles. All of this material may not be removed and eventually may reach the processed products. Cultivars that are more difficult to harvest usually contain more MOG than do easily harvested cultivars. MOG may be reduced by cultural practices or improved cleaning machinery.

Addition of SO<sub>2</sub> to machine-harvested grapes decreases quality loss during holding. Addition of SO<sub>2</sub> immediately after harvest has been shown to slow post-harvest deterioration of machine-harvested grapes by delaying alcohol accumulation and loss of soluble solids for 24 hr when held at 35°C. SO<sub>2</sub> discourages bacterial spoilage; it also serves as an anti-oxidant to prevent juice browning.

Guidelines have been developed by the author at the University of Arkansas in cooperation with commercial grape processors to maintain or improve the quality of machine-harvested grapes.

- 1) Select the proper rpm for the shaking mechanisms or strikers and the proper ground speed for the harvest for each cultivar and crop load situation. The importance of proper machine adjustments and operation cannot be overemphasized.
- 2) Establish a time limitation from harvesting to processing plant delivery. The time limitation will depend upon the cultivar (2 to 4 hours for grapes used for premium white wines and 8 to 14 hours for grapes used for red wine and grape juice).
- 3) Optimize fruit temperature and SO<sub>2</sub> usage. The SO<sub>2</sub> should be applied, when harvesting under high temperature conditions, at the rate of 50 to 100 ppm as the grapes pass over the final delivery conveyor.
- 4) Eliminate problems of material other than grapes (MOG). This may require the mechanical trimming of low-hanging canes that interfere with harvest, removing bird nests and tall weeds, and preparing a smooth surface on the vineyard floor.
- 5) Cease cultivation sufficiently prior to harvest to minimize dusty conditions during harvesting.
- 6) Inspect the vineyard for foliar-feeding insects and, if necessary, apply sprays sufficiently ahead of harvest.
- 7) Provide a bin or conveyor inspector as part of the harvesting crew. This individual would remove MOG; watch for plugging of cleaning fans, hydraulic leaks, and mechanical failures; and monitor the application of SO<sub>2</sub>.
- 8) Cover harvested grapes at all times. Also, delivery bins or containers must be properly cleaned after the grapes are dumped at the processing plant or winery.
- 9) Clean mechanical harvesters thoroughly with an approved detergent/sanitizer as needed or at least at the end of each 8 to 10 hour operating shift (under some conditions, a complete high-pressure water rinse may be required during the operating shift).

In summary, it is possible to provide total mechanization of grape production with continued research and precision in both vine manipulation and sophisticated machinery. Mechanical shoot positioning, pruning, and harvesting have been perfected for certain cultivars grown on proper trellising systems. These systems have essentially replaced the need for hand labor. Additional research and development must continue with emphasis on development of totally integrated systems that provide high quality grapes that can be harvested with less damage, more selectivity, and less debris.

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