

## **Precision Viticulture- A Mechanized Systems Approach**

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### **Introduction**

*Winegrowers and winemakers have always been a special group of producers not only because of their product that can be manipulated from rootstock all the way to final bottling, but also because of their very special language. Winegrowers speak of phylloxera, Pierce's Disease, Botrytis cinerea, canopy management, veraison, anthocyanins and tannins until the average person looks askance at the speaker. Winemakers likewise talk about TA, pH, Brix, Brix/acid ratios, VA, SO<sub>2</sub> skin contact, oakings, resveratrol, mercaptans, degree Balling, body, balance, nose and other generally inexplicable letters and phrases. And now, the large-scale grower or vintner has new, futuristic terminology and technology to add. As wine production becomes more competitive, these people are becoming conversant with GPS, GIS, PA, mass flow, load sensors, yield mapping and georeference. Global positioning systems (GPS), geographical information systems (GIS) and computers may form the foundation for efficient, profitable precision agriculture (PA) (also known as SSM or site-specific management) in the large-scale vineyard. This new technology is of value to growers when it allows production of more uniform vineyards that will produce high quality, uniform, mature fruit.*

### **Precision Agriculture**

The use of precision agriculture in vineyards is still in its infancy, but some believe it is the agricultural system of the future [12]. GPS, with differential correction, can effectively georeference a variety of data in the field, and GIS can organize this knowledge and data. The computer with a seemingly endless variety of software has the analysis and control capabilities to develop comprehensive systems needed for site-specific management and postharvest processing [11]. An increasing number of progressive consultants offer PA services. The most common PA services offered are soil sampling with GPS, site-specific, agronomic interpretations, field mapping with GIS, yield map analysis and variable rate applications of fertilizers [12].

Continuous weight sampling is combined with GPS data to create a georeferenced map of the harvest. Mass accumulation yield monitoring uses load cells under the receiving bin to monitor the weight of the harvested grapes as they are deposited in the bin. By combining the weight change in the bin per unit of time with GPS time and position data, a yield map of the vineyard is constructed (11). It is possible to obtain vigor and quality measurements on every zone or even every vine in a vineyard. Since the 1980s when the microcomputer became available, it has become possible to acquire, analyze and use spatial field data as well as to outfit vineyard machinery with computerized controllers and sensors. Vineyards can be divided into management zones, often called grids, where each zone is quantified and managed independently. Technology exists to build sensors that record specific information from each vine in order to formulate Brix maps, titratable acidity maps, phenolics maps, etc. "High resolution imagery from digital aerial and satellite sensors has been used in crop production in CA to identify plant stress, direct plant tissue and soil sampling efforts, and provide information for analysis and interpretation of crop growth" (5). Again, these techniques are tools like any other tool of agriculture and will be of value when they allow the winegrower to produce uniform new vineyards and/or modify existing vineyards. Uniform vineyards will not only produce a higher quality wine, but also allow for complete mechanization of vineyard operations.

### **Hand Labor vs. Mechanization**

In addition to these specialized monitoring systems, another change has begun to affect grape production systems: the increasing cost of hand labor. Traditionally, growers of premium wine grape varieties have used hand labor in vineyards. Migrant workers have provided much of the labor for production and harvesting of grapes. However, an increased interest in the condition of migrant workers has resulted in increased wages and costly improvements to housing, education and health benefits for these workers. These developments and the total lack of a labor source in some locations have led to an increased interest in mechanized production systems for grape producers to remain competitive. The increasing cost of quality hand labor can justify the initial expense of mechanized systems (6). Furthermore, a well-qualified operator may be able to earn an annual wage similar to several seasonal migrant hand laborers and support a family in a manner that is more stable and comfortable.

Mechanized production systems must be compatible with the operational requirements of precision agriculture. Production equipment such as sprayers, shoot positioners, pruners, thinners, leaf removal units, harvesters, etc. must possess a high level of control and accuracy. The control and accuracy of this production equipment demands uniformity of the vineyard

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upon which to operate. The objective of the grapegrower should be to use precision agricultural techniques to develop and/or convert a given vineyard to maximum uniformity. Site-specific management can allow for designing vineyards with proper trellis, correct spacing, specific rootstocks, optimal fertilization and designer irrigation systems to create the necessary uniformity needed. Only when this is accomplished, can total vineyard mechanization systems be fully successful upon implementation.

The initial investment of time and energy needed to standardize a vineyard and maintain uniformity is returned in total control over the timing of production operations and degree of vineyard mechanization. Vineyard operations can be personalized to the climate, terrain and seasonal variations of a specific vineyard. Thinning and pruning operations can be optimized and mechanized to compensate for a late frost, over-cropping or other factors. Fruit can be harvested at peak ripeness during the cooler night hours to maximize final quality. With computerized data gathering and dispensing systems available, it could be possible to bar code end posts with specific vine needs relative to the cultural operation being conducted and to scan these instructions into the mechanical unit's computer system for individualized treatment of each row. The combined use of modern data gathering systems and mechanized production systems could possibly be used to make the production and harvesting of wine and juice grapes as exact a science as the processing operations.

### **Mechanized Vineyard Production Systems**

The future of vineyard mechanization revolves around the concept of complete systems of mechanization - the mechanization of each and every cultural operation throughout the seasons, including harvest and postharvest handling operations to improve the efficiency and economics of grape production. Labor-intensive operations that may be mechanized include canopy management, pruning, shoot positioning, thinning and leaf removal.

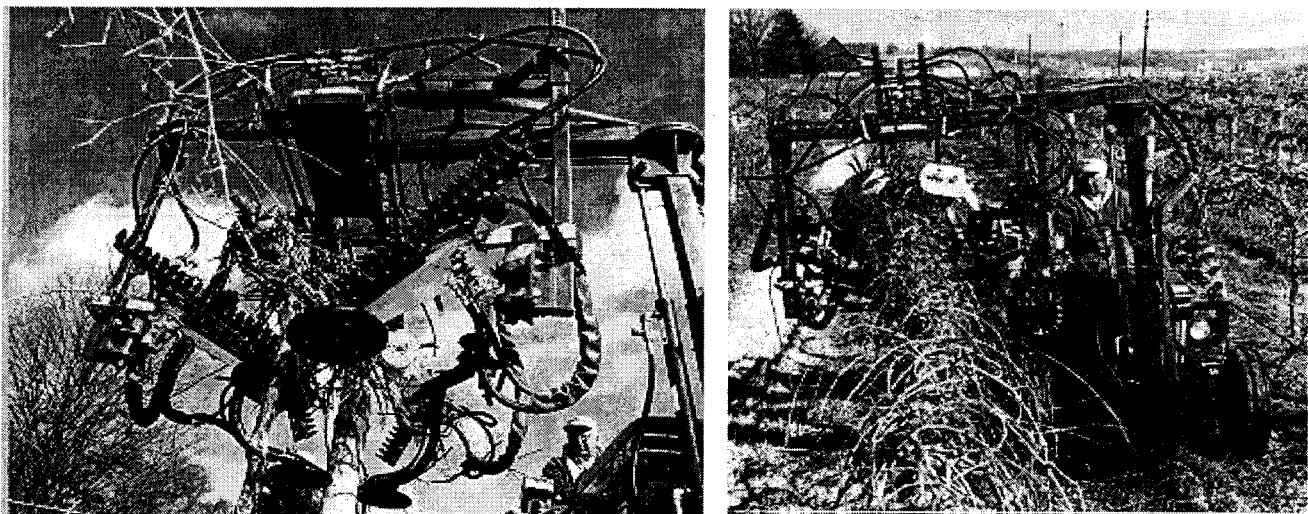


Figure 1. Tractor mounted pruner (left, close-up of attachment; right, machine in action) that will prune both sides of SC trellis. Developed for the Morris-Oldridge complete vineyard mechanization plan.

Major requirements for successful vineyard mechanization are uniformity of training system, row width and row alignment. A great deal of research at the University of Arkansas has been dedicated to optimize vineyard uniformity for numerous grape varieties through various training systems, pruning severities and other management techniques. In studies in Arkansas, Concord grapevines trained to GDC [13], or high wire, bilateral cordon systems were studied for the effects of mechanical pruning on yield, vine size and juice quality [7, 8, 9]. The results showed that continual mechanical pruning on both the GDC and Single Curtain (SC) trellis (Fig. 1) is most effective in shoot-positioned vineyards where adequate node, shoot or fruit limitation follows pruning to prevent poor quality due to over-cropping. Recent unpublished studies at the University of Arkansas have shown that mechanical thinning will compensate for the need to follow-up machine pruning with a hand pruning crew.

Fruit thinning is a major step toward successful mechanization of vineyards. Traditional hand thinning of French-American hybrid and vinifera cultivars is expensive. Almost all hybrids tend to over-produce due primarily to the high number of clusters per node and the extremely fruitful basal nodes. Fruit thinning is almost always required to produce

premium wines from French-American hybrids (Fig. 2). Mechanical thinning is one crop control technique that is both economical and successful on these hybrids. Recent unpublished data from the author shows that mechanical fruit thinning eliminates overcropping without the need for hand thinning.



Figure 2. Fruit thinner from the Morris-Oldridge Plan mounted on a tractor and working in a Cabernet Sauvignon vineyard in Lodi, California.

In a few cooler growing regions, the crop must be limited to ensure maturity due to a shortened growing season. Crop adjustment is used in many grape regions of the world and is even enforced by law in some. In some regions, not only fruit thinning, but also leaf removal is practiced to produce a specific quality (Fig. 3). Fruit thinning and leaf removal are expensive operations when carried out with hand labor.

Mechanical and minimal pruning has been widely adapted in Australian wine grape vineyards to eliminate expensive hand labor. In Australia adoption of mechanical pruning by hedging and minimal pruning systems followed the introduction of

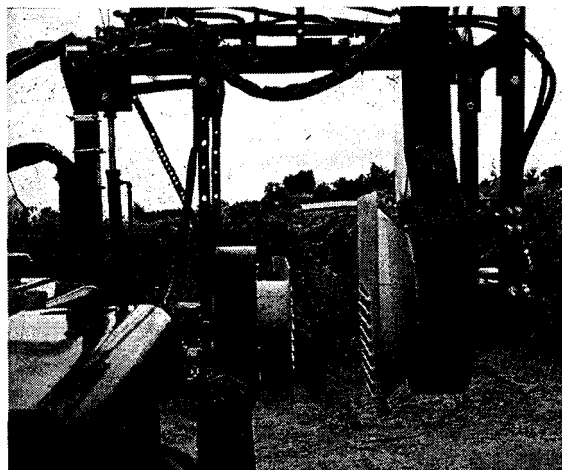


Figure 3. A Morris-Oldridge Plan tractor-mounted leaf remover working in a California vineyard. Can be used on "U", Lyre, or VSP. Joint research with Dr. Keith Striegler, CA State Univ., Fresno.

mechanical harvesters in the early 1970s. It was estimated in 1992 that about 60% of Australian wine grape vineyards in both the warm irrigated districts and cooler regions were pruned mechanically, leading to substantial savings in production costs [3]. By 2000, this had increased to 80% [4].

For minimal pruning, vines trained on a high wire single trellis are left unpruned, but are skirted, to stop fruit and shoots from contacting the ground [ 1 ]. The same results are obtained by zero pruning in which low hanging shoots are manually placed up into the canopy. Trials with minimal pruning over 17 seasons have shown that the vine has the capacity, through balanced growth, to maintain its shape, productivity and fruit quality [3]. In Australia, minimal pruning results indicate that traditional pruning may be unnecessary. Minimal pruning appears to overcome many problems associated with both conventional hand pruning and severe mechanical pruning. Variations of minimal pruning can be observed in commercial vineyards in cooler regions in Australia along with the adoption of crop control techniques for high yielding, vigorous vines to restrict yields in order to ensure adequate maturity and final quality [2].

### **The Morris-Oldridge Plan for Mechanizing Vineyards**

New equipment has been developed, modified and evaluated for the mechanization of each viticulture operation requiring hand labor. Since 1966, research has been conducted at the University of Arkansas that resulted in mechanized

concepts and systems that allow almost complete mechanization of mature grape vineyards. Tom Oldridge has commercially built and tested machinery for the past 25 years that improved much of the existing equipment. Through a cooperative effort between the author and Oldridge, the Morris-Oldridge plan for mechanizing vineyards was developed which includes over 40 different machines and attachments that have been evaluated for the mechanization of the 12 different trellising and production systems shown in Table 1. These systems involve mechanization of viticultural operations such as pruning, canopy management, thinning, leaf removal and harvesting for established vineyards. All equipment, except the harvester, bolts to a tractor-mounted frame with hydraulic controls. Twenty of the forty attachments already exist in industry.

Mechanical harvesters, mechanical shoot positioners and mechanical pruning devices have been used for some time, but until now, there have been no commercial systematic plan that detailed the appropriate machine to use at the proper time for the major grape-growing systems. These detailed procedures are designed to maintain fruit quality and have proven to be cost effective.

One plan deals with *Vitis labruscana* and other grapes with drooping growth habits trained on GDC and GDC-like trellis systems (Fig. 4). A mechanical pruner has been developed and patented by Tommy Oldridge that can be used to prune after leaf fall and through the vine's dormant period. Two of these pruning units can be mounted under an over-the-row harvester to prune both sides of the GDC in one pass. Also, a tractor-mounted model is available that prunes one side of the GDC and requires two passes on each row. Other mechanical units have been developed which will remove excess fruit after berry set and shatter. At the end of June, approximately 25 to 30 days post bloom, final adjustment of fruit load is performed to balance vineyard conditions by fruit removal. Mechanical units for this operation are a part of the Morris-Oldridge (M-O) Plan.

**Figure 4. Seasonal Chart of M-O Plan for Vineyard Mechanization of *Vitis labruscana* (and other grapes with drooping growth habits) on GDC Trellis and GDC-like Canopy Systems**

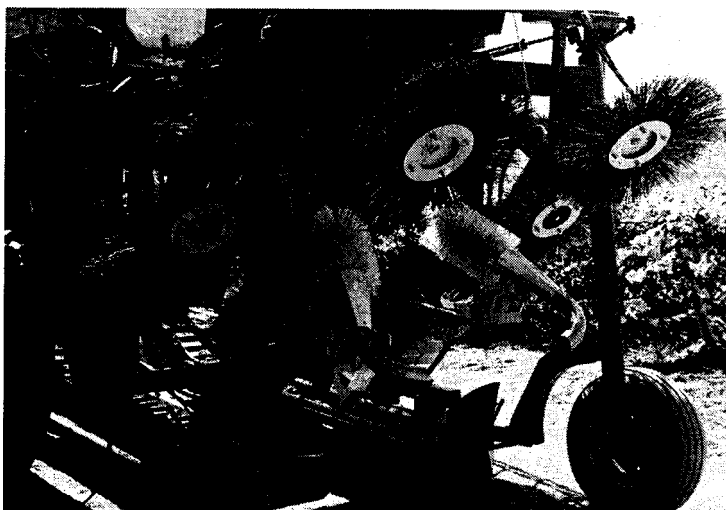
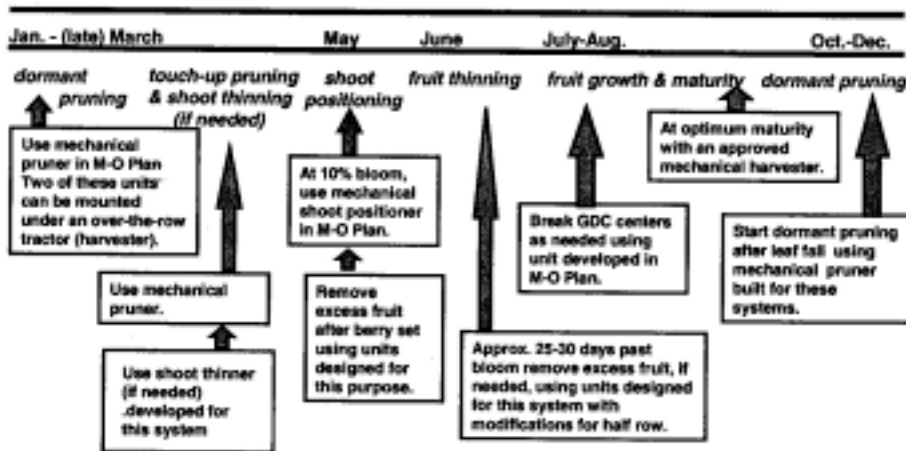


Figure 5. Mechanical shoot positioner mounted under a harvester so that it positions both sides of a GDC trellis. Cutting bars (not visible) can be mounted at base of the brush system, turning the unit into a pruner.

At 10% bloom, the shoots need to be positioned and a mechanical shoot positioner for this system has been patented (Fig. 5). Mechanical shoot positioning and first fruit removal is carried out in May. Shoot positioning, depending on the grape species being grown, can allow for effective mechanical trimming of grapes. Positioning is only effective on the extremely vigorous *Vitis labruscana* varieties. Vines are usually shoot positioned for the first time at first bloom, but complete shoot positioning usually requires a second pass. In July, the centers on these double curtain trellises need to be separated or broken; mechanical units adequately perform this operation. Weighted bars or a breaker bar machine is a part of the Morris-Oldridge Plan for GDC-trained vineyards. In addition to allowing more sunlight exposure in the canopy, two distinct foliage canopies allow the GDC system to be more efficiently harvested than a nonpositioned canopy. It is almost impossible to efficiently mechanically harvest a double curtain trellis that has not had the centers properly divided.

In minimally and mechanically pruned systems, a major step toward successful mechanization is fruit thinning (Figure 2). The amount of fruit that should be removed from Concord vines has been calculated by Robert Pool of the New York State Agricultural Experiment Station in Geneva, New York [10]. Berry development curves show that Concord berries reach about 50% of their final size when about 1100 degree days have accumulated. By harvesting a predetermined number of vines at this time, the grower can estimate the crop and determine the desired crop to be mechanically removed. Careful attention must be given to variation within the vineyard, i.e., weak areas or areas with poor fruit set. If the vineyard has been established so that fruit set and maturity has become uniform (weak areas identified and corrected), this system is nearly perfect.

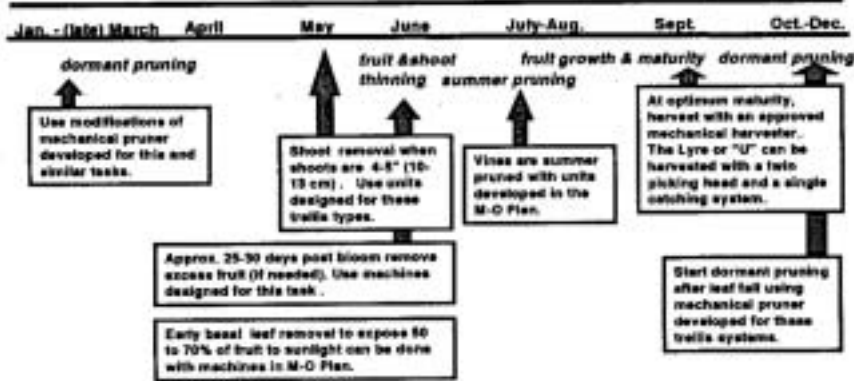


Figure 6. Mechanical harvester to harvest the Lyre or "LT" trellis developed for the Morris-Oldridge mechanization plan.

At full maturity, the grapes are harvested with a harvester that can be equipped with quad rods or s bow rods to assist in removing difficult-to harvest fruit and allow for excellent fruit removal and minimal damage to foliage. This allows for maximum foliage for photosynthesis and storage of carbohydrates in the vines until frost and/or leaf drop.

Similar descriptive instructions have been developed for the 12 systems used for grape production listed in Table 1. These mechanization systems use various machines for each operation and give a description of the proper usage of each attachment and the critical time for carrying out each operation. More recently, a mechanical harvester has been developed by Morris and Oldridge (Fig. 6) that will harvest the Lyre or "U" trellis. Due to the unique configuration of this trellising system, it previously was not possible to mechanically harvest fruit trellised in this manner. The descriptive instructions for mechanization of the Lyre or "U" trellis are shown in Figure 7.

Figure 7. Seasonal Chart of M-O Plan for Vineyard Mechanization of *Vitis vinifera* and French American Hybrid Grapes Produced on Lyre or "U" & Other Divided Canopy Trellises



## Conclusions

Precision agriculture and mechanized operations are the wave of the future. These new technologies maximize the efficiency of production in supplying agricultural products to a growing world population. The traditions of quality in the wine and grape industry do not have to be sacrificed to modernization. In fact, the control over vineyard operations offered by PA and vineyard mechanization will help to increase the consistency of quality grape production.

Examples of two of the 12 system plans for control and timing over operations for the M-O Plan for total vineyard mechanization are presented. Vines must be pruned to achieve the desired balance of fruit yield and quality, and traditional pruning by hand is a lengthy process. Winter injury and spring frost can reduce the fruit load to far below the level intended when vines were pruned. Proper implementation of mechanical pruning and mechanical fruit thinning has been successful in adjusting and controlling the crop level following the frost and freeze period. The speed of mechanized operations gives growers the flexibility to prune later and leave more buds. If, after the danger of killing frosts has passed, the fruit load is too high, the crop can be mechanically thinned approximately 30 days postbloom, a job that likely could not have been accomplished in the time-span with hand labor.

Table 1. Twelve systems that can be mechanized using the Morris-Oldridge Plan

- I. *Vitis labruscana* grapes (and other grapes with drooping growth habits) on Single Curtain Trellis.
- II. *Vitis labruscana* grapes (and other grapes with drooping growth habits) on GDC Trellis and GDC-like canopy systems. (See Fig. 4)
- III. Minimal-pruned *Vitis labruscana* grapes (and other grapes with drooping growth habits) on Single Curtain Trellis.
- IV. Minimal-pruned *Vitis labruscana* grapes (and other grapes with drooping growth habits) on GDC Trellis and GDC-like canopy systems.
- V. *Vitis vinifera* and French American Hybrid grapes produced on High Wire Bilateral Cordon (SC).
- VI. *Vitis vinifera* and French American Hybrid grapes produced on GDC Trellis and GDC-like canopy systems.
- VII. Minimal-pruned *Vitis vinifera* and French American Hybrid grapes produced on a High Wire SC Trellis.
- VIII. Minimal-pruned *Vitis vinifera* and French American Hybrid grapes produced on the GDC Trellis systems.
- IX. *Vitis vinifera* and French American Hybrid grapes produced on standard California T-Trellis.
- X. *Vitis vinifera* and French American Hybrid grapes produced on Standard Vertical Moveable Catch Wires.
- XI. *Vitis vinifera* and French American Hybrid grapes produced on Lyre or "U" and other divided canopy systems. (See Fig. 7)
- XII. *Vitis vinifera* and French American Hybrid grapes produced on Smart-Dyson Ballerina trellis system.

Additional research in the area of total vineyard mechanization and its impact on quality is needed on all species of grapes with emphasis on the development of totally integrated production, harvesting and handling systems. The timely performance of most of the mechanized operations will be critical to the success of a total systems approach. By effectively mechanizing cultural and harvest operations, the production of grapes for premium wine on a global basis will remain competitive in regions where inexpensive, quality hand labor is unavailable.

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