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Development and Incorporation of Mechanization into Intensely Managed Grape Vineyards

Justin R. Morris

An invitation from the Sixth International Symposium for Cool Climate Viticulture and Enology held in Auckland, New Zealand provided an opportunity to moderate a Focus Session discussing vineyard mechanization and deliver a Keynote Address on the subject. Following is a brief overview of the Keynote Address.

Scarcity and increased cost of hand labor, larger yields per acre, and competition from markets with inexpensive labor led growers to explore the mechanization of vineyard operations. For over 35 years, research in the Enology and Viticulture Program at the University of Arkansas focused on the idea that commercial prosperity of the grape industry would eventually rely heavily on complete systems of vineyard mechanization which include mechanization of shoot and fruit thinning, summer and winter pruning, shoot positioning, cordon and trunk scrubbing, leaf removal, center breaking, and harvesting. Furthermore, it was recognized that these mechanized operations must reduce costs without negatively affecting wine quality.

In April 2002, the University of Arkansas was issued a patent for the Morris-Oldridge (M-O) Vineyard Mechanization System. The M-O System offers a systems approach to mechanization by providing the sequencing of steps and timing of operations for the 12 major trellising systems used in the grape-growing industry. Equipment involved in this total system includes over 40 different machines and attachments. The various machines and attachments are for specific operations, but work together toward the goals of balancing the crop and optimizing yield and quality in a specific vineyard. The machines used for each trellis system differ and only five or six machines are required for each trellis system. Timeline charts for the various operations for each of the 12 major trellis systems are part of the System. The M-O System offers the highly competitive grape and wine industry a functional tool that provides sustainability, predictability, and high quality grapes.

Harvesting of grapes mechanically has been done for a number of years. The successful mechanization of harvest operations increased interest in mechanizing other vineyard operations. However, until the development of the M-O System, no system had been commercially available that detailed the appropriate machine to use at the proper time to accomplish total mechanization and “balanced cropping” by mechanization of dormant pruning, shoot/cluster thinning, fruit thinning, leaf removal, canopy separation, and summer pruning as well as mechanization of harvesting. Dormant pruning by hand is a time-consuming, labor-intensive process used to achieve the desired balance of fruit yield and quality with bud development control the following year. Our research has shown that mechanical pruning is not the only answer to balancing a crop, but rather clears the way to fine tune the crop level with mechanical shoot and, if needed, mechanical fruit thinning. We have called this approach to balancing the vine “balanced cropping by mechanization.”

Commercial trials on the California Central Coast has utilized our balanced cropping concept which incorporated three operations:
1) Mechanized dormant pruning - to retain the number of nodes necessary to achieve an estimated 200% of the final desired yield level (based on past vineyard records of yield and dormant pruning weights);
2) Mechanized shoot thinning - performed when the new shoots were 10 to 20 cm (four to eight inches) to achieve an estimated 130 to 150% of the desired final yield level; and
3) Mechanized fruit thinning – performed during or after the berry growth 'lag phase' to reach the desired crop levels if, after the dormant pruning and shoot thinning operations, the vines still carried too heavy a crop for the target yield.

In unpublished studies over six years, using the M-O System concept, it was found that mechanical shoot thinning or mechanical fruit thinning eliminated the problem of too heavy a crop and allowed crop adjustment to be made after potential frost and fruit-set problems. Balancing the crop with the M-O System and machines annually produced an average of 26% more fruit than the hand-balancing method. **This aspect of the M-O System, the ability to produce consistent annual yields, may have equal or greater economic impact than the labor-saving aspect.**

OXBO International Corporation acquired the license for the M-O System patent, and they are currently manufacturing and marketing the System, and it is being used in Washington State and Missouri in addition to California. Large-scale research studies ongoing for five years in the Central Coast vineyard were established to validate the effectiveness of the mechanization system by comparing yield and quality of fruit and wine produced by either hand or machine farming. Preliminary data indicate that actual yields are close to target yields required by winery representatives, but variable among cultivars. The vineyard manager has observed that mechanized farming is more precise and consistent than hand farming; the machine-farmed vines will more closely reach target production levels than the hand-farmed vines in actual large-scale production. In the first two years of study, quality parameters were comparable between hand- and machine-farmed grapes. Additional years of research on these plots will allow verification of these trends as well as provide an opportunity to study the long-term effects of mechanization on vine vigor and fruit quality.

Research at the Central Coast vineyard has illustrated that a complete systems approach to vineyard mechanization can benefit growers of juice and wine grapes in the following ways:
1) Allows consistent and predictable yield and fruit quality;
2) Provides as much as a 50-60% reduction in pruning cost and a 75-85% reduction in shoot thinning and fruit thinning costs; and
3) Allows the vineyard manager to operate with significantly fewer but better-trained, higher-quality employees.

In fact, the control over vineyard operations offered by vineyard mechanization will help increase the consistency of quality grape production. Although applications of technology to vineyard operations often require significant initial investment of time and energy to standardize a vineyard and maintain uniformity, these inputs are returned by the extent of vineyard mechanization made possible and the total control obtained over

the timing of production operations. Vineyard operations can be customized to the climate, terrain, and seasonal variations of a specific region. Shoot and fruit thinning and pruning operations can be optimized and mechanized to compensate for late frost, over-cropping, or other factors. Fruit can be harvested at peak ripeness during the cooler night hours to maximize quality.

It is anticipated that the future will hold even more applications of technology to improve and enhance the production of high quality grapes and wines. It may be that specific vine needs in a given row relative to a particular cultural operation will be fed into a computerized mechanical unit for individualized treatment (shoot thinning, fruit thinning, leaf removal, pruning, etc.). Someday, a robotic pruner may “read” the vines, adjust itself, and mechanically cut where needed. The combined use of modern data gathering systems and mechanized production systems may some day make the production and harvesting of wine and juice grapes as exact a science as the processing operations. However, such tools will be of economic value only with the production of uniform new vineyards and/or modification of existing vineyards to allow for complete mechanization utilized to produce a higher quality wine.

Economics of Mechanizing Pre-harvest Vineyard Operations

Michael Thomsen and Justin Morris

Labor accounts for over half of the pre-harvesting costs in mature vineyards. Scarcity and increased cost of labor along with increased competition from producing regions overseas (some with much cheaper labor) have caused growers to examine various forms of mechanization in the vineyard in order to remain competitive in the grape and wine market, Harvest mechanization has been available commercially since the late 1960s. However, traditional vineyard operations along with the large number of grape species, trellising systems, and their combinations have impeded the progress of overall vineyard mechanization.

Since 1966, a great deal of research at the University of Arkansas was dedicated to defining factors affecting vineyard uniformity and designing total mechanization systems for grape vineyards that would optimize yield without detrimental effects on grape juice or wine quality. Through a cooperative effort between Justin Morris and Tom Oldridge, the Morris-Oldridge (M-O) System for mechanizing vineyards was developed. The M-O System provides a comprehensive approach to mechan9izing the twelve major trellising and training systems used throughout the world. A patent was issued for the M-O System in 2002 and has been licensed to OXBO Corporation.

The cost savings that can be realized from mechanizing pre-harvest operations are economically important. These **cost savings** are estimated at $273 per acre on a Vertical Shoot Positioned trellising system (VSP), $529 per acre on a Two-foot Lyre, and $612 per acre on a Quadrilateral. These cost savings translate into 44 percent, 49 percent, and 61 percent respectively. The main reason for differences among the different trellising systems is due to the length of cordon per acre. The row spacing

assumptions for the VSP and lyre trellising systems are the same (9 foot row widths); however, vineyards on a lyre would have double the length of cordon. For this reason, mechanical pruning and shoot thinning operations take twice as long on lyre trellising and result in doubling of the costs. Similarly, despite having wider row widths, the quad trellising also involves twice the length of cordon per row as VSP. The net result is that the total feet of cordon, and hence pruning and shoot positioning costs, on quad trellising are between those estimated for the other two systems.

The use of mechanized production systems has the potential to stabilize grape yield and supply for wineries through the concept of "balanced cropping." Balanced cropping is economically feasible within a mechanized production system and allows growers to make their final crop adjustments late in the growing season thereby providing an opportunity to compensate for poor conditions early on.

The results of this study indicate that vineyard mechanization can greatly lower the cost of pre-harvest cultural practices. Most of the cost savings that result are due to the removal of hand labor. Although the results presented in this study reflect vineyards on the West Coast, the mechanization system was developed under Eastern and Midwestern conditions. Economic advantages reported here should be of similar magnitude for growers of high quality wine grapes suited to Eastern climates.

Rootstock and Training System Affect ‘Sunbelt’ Grape Productivity and Fruit Composition

Justin R. Morris, Gary L. Main, and R. Keith Striegler

‘Sunbelt’ is a ‘Concord’-type juice grape suitable for warm climates. Release announcements for ‘Sunbelt’ reported yields of 5.9 to 10.9 t/ha which is not economical for commercial juice grape production in Arkansas. An experiment was initiated in 1998 to determine if the observed limitations to yield were due to the root system. Treatments included nongrafted ‘Sunbelt’ and ‘Sunbelt’ grafted onto Couderc 3309, Extra, and 1103 Paulsen rootstocks. Data was collected for two years on vines trained to a bilateral cordon (BC) system. These vines had low yields (7.3-13.7 t/ha) and low Ravaz indices (1.8-3.3). The vines were converted to a Geneva Double Curtain (GDC) training system, and an additional two years of data were collected. After conversion to GDC, yields were 200-300% higher with improved Ravaz indices regardless of root system. The GDC training system gave yields of 26.8-41.9 t/ha in the final year. On GDC, yields were 39% greater the second year on vines grafted to Couderc 3309 than own-rooted vines. However, low pruning weights raise questions of vine sustainability. The high yield suggests that Couderc 3309 could increase long-term yields with proper vine management and requires further study. Fruit composition was acceptable for juice production on all root systems. Yields of 27 and 30 t/ha over two years for nongrafted vines on GDC with good fruit composition and dormant pruning weight indicate that the yield-limiting factors were above ground and not below. With GDC training, ‘Sunbelt’ produced commercially acceptable yield and fruit composition when grown on its own roots in Arkansas.

Impact of Pruning Methods on Yield Components and Juice and Wine Composition of Cynthiana Grapes

Gary L. Main and Justin R. Morris

Four pruning methods, hand (balanced to 50+10), machine (box cut to 80 nodes), machine+hand (box cut to 110 nodes with hand prune to 80 nodes), and minimal pruning (no pruning) were applied to Cynthiana (*Vitis aestivalis* Michx.) for four years (2002 to 2005). There were only minor differences in vine nutrition, and fruit and wine composition among the pruning methods. Minimal-pruned vines had high yields and less mature fruit in the first year followed by low yields the second year with yield stabilization by the third year. Wines produced were similar within year among pruning methods with the exception of wine from minimal-pruned vines in the first year. No sensory differences were found between wines from hand-pruned vines vs. other methods in any year (wine from minimal-pruned 2002 excluded). After the first year, all pruning methods produced similar fruit and wine. In the final year of the study, all pruning methods had comparable yields. However, the minimal-pruned vines averaged 50% more clusters over four years with a 7 to 10 day delayed harvest as compared to hand-pruned vines. The use of machine pruning either alone or in conjunction with hand pruning is a viable option for Cynthiana production in regions with a sufficient growing season. Minimal pruning may also be an acceptable method, but additional research is needed.

Product Development and Nutraceutical Analysis to Enhance the Value of Dried Fruit

Renee Threlfall, Justin Morris and Jean-François Meullenet

Value-added fruit products suitable for production by small-scale farmers and processors were developed and evaluated. Apples, blueberries, peaches and strawberries from local growers were processed into a dried fruit product. The total phenolics, total anthocyanins and oxygen radical absorbing capacity (ORAC) were determined. Drying the fruit concentrated total phenolics, total anthocyanins and ORAC levels as compared to fresh fruit. The nutraceutical components of the blueberries, peaches and strawberries of the local dried fruit were higher than those of commercial dried fruit purchased at a natural food store. The dried fruit from both the local and commercial fruits was used to create a fruit pie filling for consumer evaluation. Consumer acceptance of fruit pie filling from dried fruit grown locally and dried commercial fruits was evaluated using a 9-point verbal hedonic scale and a 5-point Just About Right scale. In terms of consumer evaluation, the pie fillings made from local dried fruits were either better or at parity with those from commercial products. In addition to the nutraceutical benefits, the pie fillings were consumer acceptable products that could represent an avenue for small-scale farmers to add value to surplus fruit.

The Muscadine Experience: Adding Value to Enhance Profit

Justin R. Morris and Pamela L. Brady

The Institute of Food Science and Engineering, Justin Morris, P.I., received a grant from the National Research Initiative (NRI), CSREES, USDA. The purpose of this grant was to help small and medium-sized farms and entrepreneurs enhance the viability of their operations through the establishment of vineyards, on-farm wineries, and production of value-added products from grapes and grape by-products. This project will involve the preparation of a number of publications specifically for this target audience. The first of these to be published is an update of *The Muscadine Experience: Adding Value to Enhance Profit*. New material added to this booklet includes data comparing the cost of establishing a muscadine vineyard with the costs for other types of grapes and operating costs for vineyards of different grape species. Some of the data tables were revised to improve clarity and the references were updated.

Sensory Characteristics, Composition, and Nutraceutical Content of Juice from *Vitis rotundifolia* (Muscadine) Cultivars

Renee T. Threlfall, Justin R. Morris, Jean-François Meullenet, and R. Keith Striegler

Eight *Vitis rotundifolia* (muscadine) cultivars, including five black cultivars (Black Beauty, Ison, Nesbitt, Southern Home, and Supreme) and three bronze cultivars (Carlos, Granny Val, and Summit), yielded 58 to 74 kg/vine. Juice yields were 473 to 551 L/t with soluble solids (12.6 to 14.6%), pH (3.09 to 3.42), total phenolics (179 to 373 mg/L), and total anthocyanins (2.0 to 104 mg/L). Consumers and a trained descriptive panel evaluated the juices plus two commercial juices. Consumers rated Black Beauty, Granny Val, Ison, Southern Home, and Summit juices highest for overall liking. The descriptive panel created a sensory lexicon with major attributes identified as sweet, sour, cooked muscadine, cooked grape, and astringent. Correlation between consumer and descriptive data indicated overall liking correlated positively to sweetness and caramelized and correlated negatively to sour and green unripe. Consumers showed a preference for juice sweetness with soluble solids 14% and soluble solids/acid ratios of 26 to 31. The muscadine cultivars produced quality juices with potential nutraceutical impact to expand marketing of muscadine products.

Reduction of Malic Acid in Wine Using Natural and Genetically Enhanced Microorganisms

Gary L. Main, Renee T. Threlfall, and Justin R. Morris

Naturally selected yeast, ICV-GRE and 71B, the malolactic bacteria, Lalvin 31, and the genetically enhanced yeast, ML01, were compared for biodeacidification of malic acid in production of Vignoles wines. The ICV-GRE yeast consumed 18% of malic acid with no

lactic acid production. Lalvin 31 added to the wine fermented with ICV-GRE converted the remainder of the malic acid to lactic acid and consumed some citric acid. The ICV-GRE + Lalvin 31 treatment produced less lactic acid as compared to the ML01 treatment due to malic acid consumption by the ICV-GRE yeast and had the lowest titratable acidity. ML01 was effective at converting 5.7 g/L (100%) malic to lactic acid during the first 60 hr of fermentation. The 71B yeast consumed 1.9 g/L (33%) of the malic acid with no lactic acid production. Wine produced with ML01 had higher levels of total sulfur dioxide (SO_2) than the other treatments. A secondary experiment found that the ML01 yeast produced 34.6 mg/L sulfur dioxide, which was three times as much as ICV-GRE and six times as much as 71B. The amount of lactic acid and SO_2 produced by ML01 yeast could be of concern to enologists depending on style of wine desired.

Evaluation of Wines Made From New Cultivars

Justin Morris, Gary Main and Keith Striegler

The introduction of new grape cultivars is essential to the continued development and growth of a regional wine industry with distinctive wines. Over the past four decades, the University of Arkansas has evaluated hundreds of grape cultivars with only Cayuga White, Vidal, Seyval, Chardonel, Chambourcin, and Vignoles being widely planted. Many of the cultivars tested were not suitable viticulturally, or had poor juice chemistry, or poor wine quality. In 2006, wines were produced from thirteen white grapes and from three red grapes. Grapes were hand harvested from plots located at the Missouri State Fruit Experiment Station, Mountain Grove, MO, and transported to the University of Arkansas Agricultural Research and Extension Center (AAREC), Fayetteville, AR, or grown at the AAREC.

Wines were made from the following lines and cultivars: 34-4-49 (W); Chambourcin (R); Corot Noir (R); GM 318 (W); GM 322 (W); La Crescent (W); M 36-12/110 (W); M 36-13/38 (W); M 36-13/9 (W); NY 81.315.17 (W); NY 84.101.04 (W); Rubin Tairovski (R); Traminette (W); Valvin Muscat (W); Vignoles (W); Vignoles (W); and XIV-186 (W).

Soluble solids levels of 21% or higher are generally desired in order to obtain 11.5 to 12.0% alcohol. Although the cultivars 34-4-49, M 36-12/10, M 36-13/9, and XIV-186 had low soluble solids, the low titratable acidity indicated that an additional increase in soluble solids was unlikely. The cultivar Corot Noir needed additional ripening and had poor color. Rubin Tairovski also had poor red color although it had high (23%) soluble solids. Corot Noir was also noted for persistent foam that was difficult to remove from air locks. All wines except La Crescent (1.1 g/L residual sugar) fermented to dryness and the fructose levels exceeding 1 g/L in the finished wines are the result of fructose addition. La Crescent wine may be best when finished in a sweet style due to its malic acid content. The finished wine had a high citric acid level (0.7 g/L) and a high malic acid level (5 g/L). The malic acid level is notable because soluble solids were high (23.6%) and because the ICV-GRE yeast used in this study consumes up to 25% of the malic acid. Other wines with elevated malic acid levels were NY 84.101.04, Valvin Muscat, and Vignoles. Most of the cultivars produced wines with commercial merit. All

wines were presented for sensory evaluation at the Midwest Grape and Wine Conference. Results of the evaluations can be obtained by contacting jumorris@uark.edu .

Use of a Thin-film Vacuum Evaporator to Produce White Table and Dessert Style Wine

Gary Main, Justin Morris, and Renee Threlfall

Vintners attempt to maximize all viticulture operations to produce high quality fruit with optimum varietal character and sugars. However, increasing soluble solids in must from mature grapes is sometimes necessary to achieve desired alcohol content. Soluble solids can be increased by chaptalization or with several juice concentration methods. The thin-film vacuum evaporator (Evapor) is a type of entropy evaporator that uses centrifugal force to create a uniformly thin juice film that flows over a heat-transfer surface. Juice passes across a rotating heat-transfer surface in a thin layer (0.1 mm) under vacuum; and in less than a second, enough water is removed to decrease the juice volume by up to 30%. As water was removed from the juice, there was a general decrease in pH and an increase in titratable acidity. Aromas and yellow-brown (golden) color in the wine also increased with degree of juice concentration. When Riesling juice was concentrated, the wines had more complex fruity/floral aromas. Wine produced from chaptalized Riesling juice appeared water-like compared to the Evapor-treated wines, with ethanol as the major aroma component. Seyval blanc wines behaved similarly and aromas progressed from apple-like in the wine from unadjusted juice to vanilla/honey in the wine made from 35°B juice. Flavor components also increased in complexity with increasing juice concentration. Amounts of titratable acidity, citric and malic acids and calcium increased in the wine from juice that had been Evapor concentrated as compared to chaptalization. In a additional experiment, a triangle test was used to determine if a sensory difference existed between the sugar- and Evapor-adjusted Cayuga White wines. The panel could not differentiate the two wines. Concentration of juice translates to a reduction in final wine volume. Therefore, an economic loss could be realized unless the wine from concentrated juice demands a premium price as compared to chaptalized wine. The use of concentration versus chaptalization depends on many factors, but the juice and wine must benefit from concentration of aroma, flavor and acids. Economics, grape cultivar, final quality, and style of wine all play roles in the determination of sugar adjustment methods.

Effect of Macerating Enzymes and Postfermentation Grape-seed Tannin on the Color of Cynthiana Wines

Gary L. Main and Justin R. Morris

Macerating enzymes and postfermentation enological tannin were used on Cynthiana (*Vitis aestivalis)* to examine effects on color extraction and retention. Color measurements of must treated with five enzyme preparations (Trenolin color DF,

Lallzyme EX-V, Crystalzyme Tinto, Rohapect VR-C, and Vinozyme G) and a control with no added enzyme were compared during fermentation on the skins. For all treatments, maximum red color occurred by day three of fermentation and then declined. At the end of alcoholic fermentation, Trenolin Color DF, Lallzyme EX-V, and Vinozyme G had greater percentages of red and less blue and yellow than the control. A postfermentation grape seed tannin treatment (with or without Grap'TanPC) was established after combining replicates of each enzyme preparation. In newly bottled wine and wines stored for 11 or 22 months, there were small but significant differences due to macerating enzymes and tannin addition. Lallzyme EX-V and Vinozyme G promoted more polymeric pigment formation and had more ionized anthocyanin than the control. The addition of Grap'TanPC mimicked the effect of the enzyme preparations and increased anthocyanins, polymerization, ionized anthocyanin and yellow color. Time in the bottle had a greater impact on color than enzyme or tannin. Although statistical differences existed for color in both enzyme preparation- and tannin-treated wines, the magnitude of the color differences was small and may not be commercially important. The effect of macerating enzymes should be examined on other grapes with diglucoside anthocyanins to see if similar results are obtained.

An ideal point density plot method for determining an optimal sensory profile for Muscadine grape juice

Jean-Francois Meullenet, Caroline Lovely, Renee Threlfall,
Justin Morris, and Keith Striegler

The objective of this study was to compare the use of the Euclidian distance ideal point mapping (EDIPM), a newly developed method, to the external response surface approach to optimize the formulation of muscadine grape juices. EDIPM is a method which allows the identification of individual consumer's ideal point in product maps and yields group maps identifying product placement opportunities. It is based on identifying for individuals the point in the map (i.e., the ideal point) minimizing the correlation between distances to the test products and hedonic scores given by the individual. This method was compared to the external preference mapping extension proposed by Danzart, 1998.

Manuscripts in progress

Long-term Effects of Mechanical Pruning, Pruning Severity, Node Adjustment, Fruit Thinning and Shoot Positioning on Yield and Quality of 'Concord' grapes

Effect of Training System, Pruning Severity, Spur Length, and Shoot Positioning on Yield and Composition of Cynthiana Grapes

Long-Term Effects of Training System, Flower Thinning and Shoot Tipping on Cayuga White, Seyval blanc and Vidal blanc Grapes

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