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Evaluation of the Influence of Common Viticultural Practices on the Chemical and Sensory Characteristics of Wines

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Summary

The goal of this project is to find critical viticultural parameters that affect the chemical and sensory characteristics of the final wine. Once these parameters are identified, winemakers and vineyard managers can use computational methods developed in our lab

in order to suggest the best vineyard practices to use to achieve specific target characteristics in their final wine. We are taking two complementary approaches to this problem. First, we are developing tools for searching through large existing databases of viticultural information to find the most critical factors. A Decision Tree Analysis algorithm has been developed in our lab for this purpose, and several decision metrics have been evaluated. Second, we are producing Cabernet Sauvignon wines from existing viticultural trials at the Oakville Experimental Station. For the past two harvests, we have produced 37 wines from grapes harvested from vines differing in parameters such as rootstock, irrigation, trellis, pruning, row orientation, and vine density. Chemical analysis of the wines from the first harvest has been completed, and the data has been analyzed. Especially interesting results have been found on the effects of trellis system and crop load on the phenolic profile of the completed wines. Sensory analysis of these wines has also been initiated.

Objectives and Experiments Conducted to Meet Stated Objectives

Objectives

The overall goal of the work proposed here is to evaluate the influence of common viticultural practices on the chemical and sensory characteristics of final wines. While numerous viticultural studies in the past have evaluated the effects of these practices on juice characteristics, very few have carried the analysis through to the wine and a detailed chemical and sensory characterization. This is the type of information that will be necessary in order to efficiently control viticultural practices to achieve a desired final product. Therefore, this work has the following objectives:

(1) To use existing databases of viticultural data to evaluate the effects of these practices on final wine characteristics
(2) To make new wines from existing viticultural field trials in order to examine the resulting wine attributes in a systematic and rigorous manner.
(3) To develop methods for using the information gathered to build a relationship between what is done in the vineyard and the final wine in the bottle.

In addition to these three objectives, a fourth objective was added in the last grant, as per an industry request. That objective is:

(4) To evaluate the ability of enological practices to modify or attenuate the influence of viticultural treatments on chemical or sensory attributes of the wine.

Experiments Conducted to Meet Stated Objectives

Objective 1. Use of existing databases of viticultural data to evaluate the effects of these practices on final wine characteristics. Previously, a Decision Tree Analysis (DTA) algorithm was developed in our lab to extract important inputs from large datasets. This algorithm was tested on an existing enological database from our lab for which a parallel statistical analysis was available. We have also investigated the use of slightly modified algorithms that use "decision metrics" other than the Shannon entropy calculations that we had used previously. These metrics include a normalized gain and an exact probability metric, both of which exhibit less bias toward classification with inputs having multiple categorical values (e.g. vineyard A, vineyard B, vineyard C, etc.), as opposed to simply "high" and "low."

We have evaluated several databases of potential industrial collaborators in order to assess the relevance of their use for this project. We have identified and obtained one such database, and are planning to evaluate one other potential model database

Objective 2. Production of new wines from existing viticultural field trials in order to examine the resulting wine attributes in a systematic and rigorous manner. In the first two years of this grant, wines were produced from viticultural trials at the UC Davis Oakville Experimental Station. Thirty-seven lots were produced (as shown in Table 1) that examined the effects of parameters such as vine spacing, row spacing, row orientation, pruning severity, irrigation, vineyard, and trellis. All grapes were harvested at 24°Brix. Approximately 100 lbs of fruit were harvested for each 8 gal lot (to give 5 gal of finished wine each). The fruit was destemmed and crushed, and sulfur dioxide was added to the must at 50 ppm. The must was inoculated with Premier Cuvee yeast at 1 g of dry yeast per gallon of must. Fermentations were maintained at 70°F and temperature monitored on a regular basis to assure uniformity. Punchdowns were performed manually twice per day. Batches were pressed at 0°Brix and then inoculated with actively growing malolactic (ML) culture. The 2001 wines are currently finishing ML (all, but two, have finished). After cold stabilization, all 2000 wines were analyzed for sugars, acids, and ethanol using HPLC, tannins using the Adams assay, a phenolics profile using HPLC, and color (including copigmentation) using a modified Somers method. Sensory difference testing (duo/trio tests) was also completed using selected pairs of the 2000 wines that differed in one or a small number of viticultural parameters. Since many of these comparisons demonstrated significant sensory differences in the wines, a descriptive analysis of all of the 2000 wines was initiated. For this descriptive analysis, a panel of 15 judges has been trained and will now be given samples for aroma analysis in a blind and replicated manner.

Objective 3. Development of methods for using the information gathered to build a relationship between what is done in the vineyard and the final wine in the bottle. We have previously developed neural network and numerical optimization methods for this purpose and applied them to enological data (Vlassides et al., 2001). Therefore, further progress on this objective will follow completion of the 2000 and 2001 wines and the corresponding database of chemical and sensory attributes of these wines.

Objective 4. Evaluate the ability of enological practices to modify or attenuated the influence of viticultural treatments on chemical or sensory attributes of the wine. This objective is being conducted in conjunction with a separate AVF/CCGPRVE grant entitled, "Vegetative aroma: Sensory definition, chemical interpretation (and ultimately) causal explanation." The initial step in this project, which is underway, is to establish a sensory definition of "vegetative." As part of this effort, the descriptive analysis of our 2000 wines and some of the wines themselves will be used, as some of the descriptors found during panel training are of a vegetative nature. As described in the 2002-2003 proposal, experimental work on enological parameters will begin in the next grant year, if funded.

Summary of Major Research Accomplishments by Objective

Objective 1. In past work, a Decision Tree Analysis program was completed for identifying critical viticulture inputs in a database. However, using this algorithm with Shannon entropy as a decision metric did not give an indication of the significance of the classification at each step. That is, the algorithm identified several inputs as important, but the statistical significance of these choices was not obvious. Therefore, we investigated alternative decision metrics that have been reported to be more effective than Shannon entropy in identifying truly important inputs, and one, an exact probability metric, also gives a measure of statistical significance (similar to a chi squared test). These methods were initially examined in our lab using a different system [Buck, K.S. et al., submitted], and then applied to our viticultural data as discussed below in Objective 2.

As part of this objective, we are planning to examine existing commercial viticultural databases. While we have screened several databases, we have so far found one that is complete enough to use for our analysis and methods development. This is a database from Hogue Cellars in Prosser, WA where we are collaborating with Jordan Ferrier. We have just received this database and are beginning to analyze it now. We are also pursuing one other database that may prove useful for this work.

Objective 2. As part of this objective, we have produced 37 Cabernet Sauvignon wines in 2000 and 37 more wines in 2001 (as shown in Table 1). These lots examined the effects of parameters such as vine spacing, row spacing, row orientation, pruning severity, irrigation, vineyard, and trellis. For the 2000 wines, we completed a detailed chemical analysis of each wine and are currently performing sensory analysis. After completing the chemical analysis for each of the wines, the resulting database was analyzed using decision tree analysis (see Objective 1). Several interesting results were found. First, the decision tree for total tannin by the Adams assay indicated that trellis system was the most important factor in determining total wine tannins in our experiment. Fruit grown on Geneva Double Curtain (GDC) trellising resulted in wines with twice the tannin level of fruit grown on lyre or vertical shoot positioning (VSP) trellis systems (see Figure 1). To attempt to understand this phenomenon, we took light intensity measurements at the fruiting zone on all treatments during the 2001 harvest, and this analysis is ongoing. In addition, we found, again using decision tree analysis, that large polymeric pigment in the final wine is influenced by crop yield and trellis. This is particularly interesting as most large polymeric pigment is formed during winemaking. As can be seen in Figure 2, large polymeric pigment increases with decreasing crop load, and is also higher in wines whose fruit came from GDC trellis systems (data not shown).

For both of these results, it was not clear at first whether all phenolics were increasing as a function of the important inputs, or just tannins and large polymeric pigment. Figure 3 demonstrates monomeric and total phenolics are not affected by crop yield as are the larger molecules. It is not clear whether this effect is due to inherent differences in precursor molecule concentration in the berries or whether the extractability of these molecules differs as function of the treatment. This is a question that we will pursue in the coming year. Analysis of the decision trees for other chemical characteristics of the wines is ongoing.

We have also initiated sensory analysis of the 2000 wines. Initial duo/trio difference testing indicated that significant differences existed in these wines. Therefore, a panel was established for descriptive analysis of all of the wines. Panel training has been completed and aroma descriptors have been chosen for rating. These include cherry, blackberry, dried fruit, olive, cooked vegetable, bell pepper, black/white pepper, and cocoa. Once the data has been collected for these wines, decision tree analysis will again be used to find how viticultural parameters affect each of the descriptors.

Objective 3. This objective will commence after data is collected for the 2000 and 2001 wines. This work will begin sooner with the commercial databases that we gain access to if these databases prove complete enough to build relationships between critical viticultural inputs and quality measures.

Objective 4. As stated above, this work will begin in the coming year, if funded. The sensory analysis of the 2000 wines will be useful in this regard as at least three "vegetative" terms have been identified (i.e. cooked vegetable, olive, and bell pepper). This initial analysis will be used to identify viticultural treatments at Oakville that consistently produce vegetal wines, so that these treatments can be used in the future for further experimentation.

Outside Presentations of Research

Portions of this work have been presented at the Grape Expectations UNEX course (April, 2001), American Society for Enology and Viticulture meeting (San Diego, 2001), and at an invited talk at the Pontificia Universidad Catolica de Chile in Santiago, Chile in November. In addition, one thesis has been nearly completed in this area, two papers have been published, and one related paper has been submitted for publication on the use of alternative decision metrics.

Graham Wehmeier, M.S., (in draft form).

Subramanian, V., K. K. S. Buck, and D. E. Block (2001). "The Use of Decision Tree Analysis for Determination of Critical Enological and Viticultural Processing Parameters in Historical Databases." American Journal of Enology and Viticulture. 52: 175-184.

Vlassides, S., Ferrier, J. G., and D. E. Block (2001). "Using historical data for bioprocess optimization: Modeling wine characteristics using artificial neural networks and archived process information." Biotechnology and Bioengineering. 73:55-68.

Research Success Statements

Carrying through viticultural trials to winemaking is a natural extension that should maximize the useful information arising from these studies. Knowing which viticultural practices are important in determining wine characteristics will allow winemakers and vineyard managers to specify how a vineyard might be managed in order to achieve certain sensory or chemical goals for the finished product. In addition, a winemaker could use information on the viticultural practices used to produce a lot of grapes to modify enological practices in order to limit or enhance these effects.

Funds Status

The following personnel have been and/or will be working on this project for the 2001-02 academic year. Researchers receiving full or partial support from this grant are indicated in bold. We are currently advertising to hire some laboratory help to complete chemical analysis of the 2001 wines produced. Because of internship scheduling, complete expenditure of the current funds may be offset by approximately three months. However, it is anticipated that all funds from this grant cycle will be spent or encumbered (salary) by the end June.

Kristan Buck (Postdoctoral Fellow)
Seth Turbow (M.S.)
Graham Weihmeier (M.S.)
Charles Reisman (M.S.)

TABLE 1. Viticultural treatments for 2000 and 2001 harvests.

Lot	Block	Rootstock	Row Spacing (ft)	Vine Spacing (ft)	Pruning Formula	Trellis	Vineyard	Irrigation	Orientation	Pruning Method
1	Eutypa	110R	8	6		VSP	North	some	N-S	Cordon
2	Eutypa	110R	8	6		VSP	North		N-S	Cordon
3	Eutypa	110R	8	6		VSP	North		N-S	Cordon
4	Eutypa	110R	8	6		VSP	North		N-S	Cordon
5	Eutypa	110R	8	6		VSP	North		N-S	Cordon
6	Eutypa	110R	8	6		VSP	North		N-S	Cane
7	CS Rootstock	110R	11	8	8 bud/lb	GDC	South		N-S	Cordon
8	CS Rootstock	110R	11	8	12 bud/lb	GDC	South		N-S	Cordon
9	CS Rootstock	110R	11	8	16 bud/lb	GDC	South		N-S	Cordon
10	CS Rootstock	101-14	11	8	8 bud/lb	GDC	South		N-S	Cordon
11	CS Rootstock	101-14	11	8	12 bud/lb	GDC	South		N-S	Cordon
12	CS Rootstock	101-14	11	8	16 bud/lb	GDC	South		N-S	Cordon
13	CS Rootstock	1103P	11	8	8 bud/lb	GDC	South		N-S	Cordon
14	CS Rootstock	1103P	11	8	12 bud/lb	GDC	South		N-S	Cordon
15	CS Rootstock	1103P	11	8	16 bud/lb	GDC	South		N-S	Cordon
16	CS Rootstock	5C	11	8	8 bud/lb	GDC	South		N-S	Cordon
17	Dry Farm	110R	8	3.3	12 bud/m	VSP	South	none	N-S	Cordon
18	Dry Farm	110R	8	5.2	12 bud/m	VSP	South		N-S	Cordon
19	Dry Farm	110R	8	7.2	12 bud/m	VSP	South		N-S	Cordon
20	Dry Farm	1103P	8	3.3	12 bud/m	VSP	South		N-S	Cordon
21	Dry Farm	1103P	8	5.2	12 bud/m	VSP	South		N-S	Cordon
22	Dry Farm	1103P	8	7.2	12 bud/m	VSP	South		N-S	Cordon
23	Dry Farm	5C	8	3.3	12 bud/m	VSP	South		N-S	Cordon
24	Dry Farm	5C	8	3.3	24 bud/m	VSP	South		N-S	Cordon
25	Dry Farm	5C	8	5.2	12 bud/m	VSP	South		N-S	Cordon
26	Dry Farm	5C	8	7.2	12 bud/m	VSP	South		N-S	Cordon
27	Dry Farm	5C	8	7.2	24 bud/m	VSP	South		N-S	Cordon
28	Trellis	110R	11	3.3		VSP	South	low	N-S	Cordon

Lot	Block	Rootstock	Row Spacing (ft)	Vine Spacing (ft)	Pruning Formula	Trellis	Vineyard	Irrigation	Orientation	Pruning Method
29	Trellis	110R	11	6.6		VSP	South		N-S	Cordon
30	Trellis	110R	11	9.8		VSP	South		N-S	Cordon
31	Trellis	110R	11	3.3		Lyre	South		N-S	Cordon
32	Trellis	110R	11	6.6		Lyre	South		N-S	Cordon
33	Trellis	110R	11	9.8		Lyre	South		N-S	Cordon
34	Trellis	110R	11	3.3		GDC	South		N-S	Cordon
35	Trellis	110R	11	6.6		GDC	South		N-S	Cordon
36	Trellis	110R	11	9.8		GDC	South		N-S	Cordon
37	Cover Crop	101-14	8	6		VSP	North		E-W	Cordon
38	Cover Crop	110R	8	6		VSP	North	some	E-W	Cordon

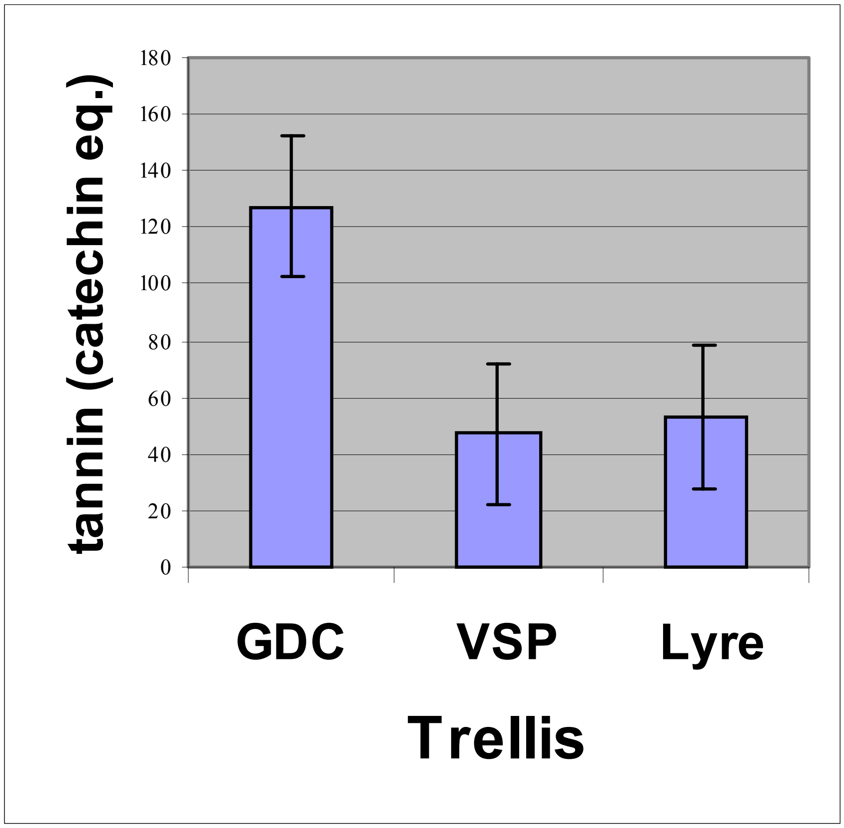

Figure 1. The effect of trellis system on total tannin levels in Cabernet Sauvignon wines.

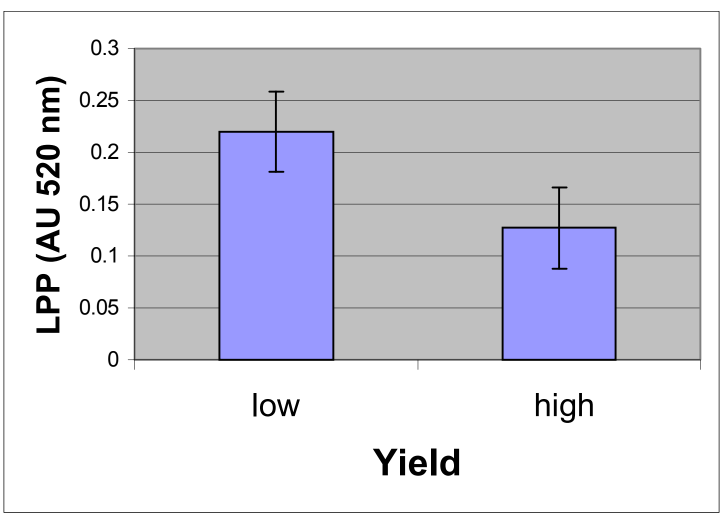

Figure 2. The effect of crop yield on large polymeric pigment concentration in Cabernet Sauvignon wines.

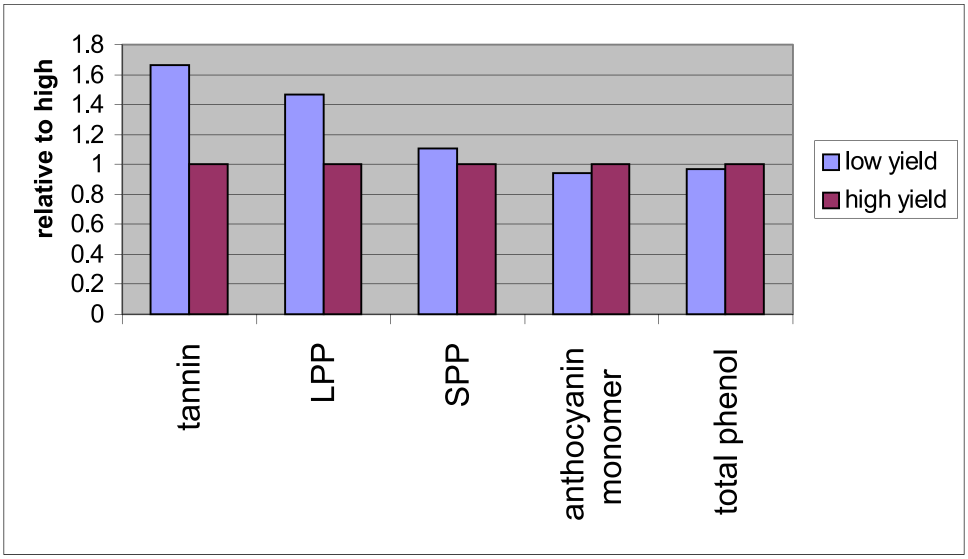

Figure 3. Differential expression of tannins and large polymeric pigment in final wines are exhibited at low crop yields.