Nutrient Status in Texas Wine Grapes and Potential Impacts to Wine Stability

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Introduction

Because of the rapid growth of the Texas wine industry across a large land area with diverse viticultural conditions, a better understanding of the relationships among Texas vineyard soils and vine and must nutrient status is being investigated. It is surmised, based on Texas extension enologist observation and wine producer comments, that large volumes of Texas wines have mineral imbalances. Mineral nutrient imbalance can often lead to instabilities such as calcium tartrate instability or premature aging through iron catalyzed oxidation. Affected wines may require costly treatment procedures in those wines in which the instability is identified, and unsightly precipitation and sometimes recall, disgorging, treatment and rebottling in those where the problem was not identified and the product made it to bottle or worse, into the marketplace.

Mineral nutrition directly and indirectly affects crop production quantity and quality. Nutrient uptake is affected by many vineyard conditions, in particular by the soil pH. Iron availability in particular is limited in high pH soils above 7, or in heavily limed soils. In order to achieve optimum growth and fruit quality, adequate levels of all nutrients must be present in the petioles and the relative amounts must be balanced. Even with optimum levels of nitrogen and potassium, poor growth can be attributed to low levels of magnesium, boron, zinc or other micronutrients. For example, Zn and B affect fruit set, and K and Mg affect bunch stem necrosis and thereby the number of clusters per vine and number of berries per cluster (Robinson 1992). Nitrogen availability affects vine vigor, and the quality of the berries, must and wine including the levels of amino acids and volatile esters. Potassium buffers must and wine pH and P is reported to affect free and bound monoterpene content of must and wine (Bravdo 2000). There are symptoms of vine impairment associated with low levels of calcium (stem and bunch breakdown), and iron (lime-induced chlorosis), however, vine impairment due to excess levels of iron and calcium have not been reported. It is suspected that some vineyard regions of Texas have conditions that favor the excess uptake of nutrients such as calcium is causing excessively high pH and instability in wines produced from these regions.

It is known that nutrient imbalance can negatively affect wine quality. Polyvalent metal cations such as iron and calcium when present in high concentration in wine and other beverages can adversely affect the chemical and sensory profile of wines. They may cause objectionable organoleptic properties including metallic taste, discoloration and oxidative flavor changes, as well as forming hazes and cloudiness. This work seeks to investigate nutrient status in some Texas vineyards and the effects on stability and quality of the resulting wines through the following:

1. Determine the general soil fertility and vine, must and wine nutrient status of samples from two principle vineyard regions of Texas: the High Plains and far West Texas.
2. Investigate the nutrient and mineral status in wines with known stability issues, and those produced in areas of abnormal soil fertility and vine nutrient status.
3. Investigate the relationship of vineyard nutrient status to instabilities in Texas wines with known stability issues, in particular the influence of abnormal must mineral nutrient status on wine oxidation and chemical stability
4. Determine the efficacy of phytic acid to treat and prevent iron catalyzed oxidation and calcium tartrate instability in unstable wines.

5. Suggest soil fertility and vine nutrient status remedial actions, and wine treatments for known and potential problematic areas.

Materials and Methods

During 2008, vineyard soil, petioles at bloom, and grape samples were collected within one week of harvest from the High Plains and far West Texas. This regimen is being repeated during 2009 for petioles and grape samples. During 2009, microvinification of grape samples will be included. All soil, petiole, grape and must samples were analyzed for standard mineral nutrient status. Mineral content was determined by inductively coupled plasma (ICP) analysis. Must and wine samples and phytic acid treated samples will undergo additional analyses including pH, titratable acidity, alcohol, reducing sugar, primary amino acids by NOPA, ammonia, and color and phenolic content profiling.

Phytic acid (PA) treatments will be evaluated for efficacy in treating and preventing iron catalyzed oxidation and calcium tartrate instability in unstable wines. Wine treatments will be performed with various amounts of phytic acid ($C_6H_{18}O_{24}P_6$, CAS 83-86-3) ranging between Fe:PA and Ca:PA molar ratios of 1:1 to 10:1 and 6:1 to 100:1 respectively, coprecipitated after metals reaction with calcium carbonate. Phytic acid concentrations before and after sample treatments will be measured.

Results and Discussion

Preliminary results from 2008 samples from West Texas are summarized in Table 1, Vineyard Soil Analysis and Table 2, Petiole Analysis. While it is premature to draw conclusions based on incomplete data collection and analysis, it does appear that West Texas has widely varying soil conditions, with high average calcium levels. Magnesium levels are on average about 4 times greater than recommended. Calcium and iron concentrations among petioles are on average about twice the recommended levels. What impact these results may mean to fruit and wine quality or stability is still uncertain. Grape must and subsequent wine samples were intended to be collected from products produced from the same vineyard sample locations collected in 2009, however, sample collection from wineries has been challenging and to date only a few must and wine samples have been collected for analysis. For 2009 microvinifications of samples will be conducted in an attempt to avoid challenges in collecting winery samples.

PA is a strong chelating agent and antioxidant present in all seeds (Trela 2008). PA contains six orthophosphate moieties with 12 dissociable protons and therefore it has a high chelation potential for polyvalent cations over a wide range of pH values. The binding affinity increases exponentially with the valency of the cation, which means that PA chelates low levels of iron even in the presence of high calcium concentrations. PA occupies all redox coordination sites on iron and thereby completely inactivates its catalytic activity, which accounts for its excellent antioxidant potential. This chelating capacity can remove or inactivate reactive metals, for example iron(III) and its ability to generate hydroxyl radicals that often adversely affects biological systems and the production or storage of foods and beverages. It also interacts with a variety of other compounds including proteins (Trela 2008).

The proposed method of treating iron and calcium using PA may provide a novel means for selective removal or stabilization of metals, especially iron and calcium, from wines. The advantages of this novel method over other methods include its low cost, the safety of its industrial use, the absence of hazardous wastes during processing compared to traditional ferrocyanide treatments, the toxicological safety of the treated wine for human consumption, even in the case of over clarification, the efficacy to remove or stabilize iron and calcium in wine, and selectivity of its reaction to improve wine quality and stability.

Table 1. 2008 West Texas Vineyard Soil Analysis Summary by ICP[1].

Element	Average	Min	Max	Std.	Recommended Range[2]
Boron	0.8	0.2	1.4	0.4	0.75-1.0
Calcium	6833.7	489.0	22975.0	8521.9	
Conductivity	471.1	42.0	3350.0	712.7	
Copper	0.5	0.1	6.5	1.1	

Iron	3.6	2.8	5.1	0.6	
Magnesium	389.0	101.0	715.0	179.6	100-125
Manganese	3.0	1.1	9.3	1.6	
Nitrate-N	9.5	1.0	75.0	14.3	
pH	7.8	7.0	8.6	0.5	5.5-6.5
Phosphorus	30.9	4.0	110.0	26.7	20-50
Potassium	313.9	117.0	835.0	145.7	125-150
Sodium	258.2	58.0	879.0	211.6	
Sulfur	102.3	8.0	826.0	187.6	
Zinc	1.0	0.2	12.1	2.1	4-5

[1]All units in mg/g dry weight except pH and conductivity.
[2]Midwest Small Fruit Pest Management Handbook, Bulletin 861.

Table 2. 2008 West Texas Grapevine Petiole Analysis Summary by ICP[1].

Element	**Average**	**Min**	**Max**	**Std.**	Recommended Range[2]
Boron	50.5	40.0	66.0	5.9	25.5
Calcium	2.4	1.2	3.4	0.5	1.2-1.8
Copper	15.2	3.0	35.0	6.6	5-15
Iron	109.9	38.0	450.0	108.0	31-50
Magnesium	0.8	0.5	1.3	0.2	0.26-0.45
Manganese	82.3	34.0	247.0	55.3	
Nitrogen	2.0	1.2	3.1	0.4	0.9-1.3
Phosphorus	0.5	0.2	0.9	0.2	0.16-0.29
Potassium	3.4	1.9	4.8	0.6	1.5-2.5
Sodium	2480.4	1230.0	12630.0	2729.9	
Sulfur	2973.1	1613.0	4291.0	537.1	
Zinc	86.6	35.0	194.0	39.2	30-50

[1]All units in mg/g dry weight.
[2]Midwest Grape Production Guide, Bulletin 919-05.

Potential Application of Research

This work is currently attempting to characterize mineral imbalances, their relationships to vineyard nutrient status, and offer potential solutions to iron catalyzed oxidation and calcium stability issues in wines, and nutrient imbalance in the vineyard. The use of PA to treat and prevent iron catalyzed oxidation and calcium tartrate instability in wines is being evaluated for commercial use in winemaking. This combined knowledge may help vineyard managers and winemakers adjust management practices to produce higher quality products at reduced cost to increase the economic impact of the Texas wine industry.

References

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