The Effects of Nitrogen, Tillage and Irrigation on the Color of Willamette Valley Pinot noir Wine

By

Kelly L. Helms

A THESIS

Submitted to

Oregon State University

Department of Bioresource Research

And

University Honors College

In partial fulfillment of the requirements for the degree of

Honors Bachelor of Science in Bioresource Research

Food Quality Option

Presented May 11, 2000

Commencement June 2000

AN ABSTRACT OF THE THESIS OF

Kelly L. Helms for the degree of Honors Bachelor of Science in Bioresource Research

presented on May 11, 2000.

Title:

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Abstract Approved: ______________________________

Mina R. McDaniel

Various vineyard practices influence the quality of a wine. In 1999, three levels of nitrogen (N), two levels of tillage and two levels of irrigation were applied to Pinot noir grape cultivars at Benton Lane Vineyards in the Southern Willamette Valley. N treatments were zero, soil and foliar applications. Every other row was tilled by machine. Those vines that were irrigated received 0.5 gal/hr of water for 200 hours during ripening in August. The grapes were harvested and wines were fermented from three replicates of each treatment. Spectrophotometric readings at 420nm and 520nm were used to determine the "Color Intensity" and "Hue." Ten untrained but experienced panelists rated the "Overall Color Intensity," "Purple Hue," and "Garnet Hue" of the wines using a traditional 16-point intensity scale. The panelists' intensity ratings indicated that N and irrigation had a significant effect on the Overall Color Intensity and Purple Hue of the wine. There were no significant differences in Garnet Hue intensity among the wines. The instrumental results were correlated with the panelists' ratings and clearly indicated that a direct correlation exists between the measured Color Intensity and the sensory analyses of Overall Color Intensity and Purple Hue. Soil N application and no irrigation contributed most to the high color intensity of Willamette Valley Pinot noir wine studied.

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I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

Kelly L. Helms, Author

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Chapter 1: Introduction

I. Making Red Table Wine

A range of environmental and applied factors largely determines wine quality and composition. In addition, different wine making practices will affect the final product.

There are numerous types of red grapes used to produce table wines. In Oregon, Pinot noir is the most dominant variety. Red wines around the world are produced in the following general fashion.

A. Harvest

Grape harvest occurs in the late fall in Oregon; anytime from late September to early November. Depending on the size of the vineyard, harvest can take one or several days. The precise date of harvest is determined by several factors like the soluble solids content (°Brix), acidity, berry pH and development of varietal aromas, flavor and color. Ordinarily, Pinot noir grapes are ready for harvest at a °Brix reading of 21.5-24.0°, an acidity ranging from 6.5-7.5 g tartaric/L and a pH of 3.2-3.4 (2).

B. Berry Picking and Transport

The grapes are usually picked by hand or in rare cases they are mechanically removed from the vine to clean baskets or crates and transported back to the winery. The grapes are handled very carefully as to prevent any crushing or damage to the berries. Oftentimes, the grapes are cooled overnight before further processing.

C. Crushing and Destemming

The grapes are crushed and destemmed to release juice without totally macerating the berries. The grapes are loaded into the grape crusher and recovered in bins. The crushing machine is adjusted so that the berries are crushed without the seeds being broken. Stems and leaves are removed because they contain undesirable compounds that contribute to astringency and bitterness in the wine. The remaining product is a combination of skin, seeds, and must.

D. Must Handling

In red musts, it is important to keep the seeds and skins together because essential colors and flavors are extracted. This mixture is fermented in large vats or barrels for 1-2 weeks. This is the first opportunity in which wine makers can modify their product. Usually a must will be treated with one or more of the following: 1. Nutrient addition 2. Sulfur dioxide addition 3. Acidity adjustment and 4. Enzyme addition (2). These modifications are determined by a particular grape cultivar and are strictly regulated by guidelines set by the Bureau of Alcohol, Tobacco and Firearms (BATF). Nutrient additions provide those vitamins and compounds needed by the yeast and bacteria that a must may lack. Additions include ammonium salts, amino acids and/or vitamins like biotin and thiamin (2). Sulfur dioxide is added at 50 PPM and is a preventative measure that inhibits oxidation and kills natural yeast and bacteria from the grape skins. Acidity adjustments are steps taken to either increase or decrease the levels of titratable acids so the resulting wine is acceptable. Methods to adjust the acidity are acid additions, carbonate salt additions or ion exchange treatments (2). Enzymes may also be added to a must to induce color extraction from the berry skins, enhance aroma or prevent oxidation.

During must handling the concentrated yeast starter culture is added. Alternatively, the must is allowed to ferment with indigenous yeast. Some yeast are preferred over others depending on their rate of fermentation, temperature preference or nutrient requirements. Several different strains of *Saccharomyces cerevisiae* are used for wine fermentation.

E. Aeration and Mixing

Once the yeasts are added and the desired modifications have been made, the juice is continually mixed, also termed, "punching the cap." The must gets very warm during fermentation and the high temperatures have been found to help leach red color from the berry skins (2). To avoid excessively hot temperatures, punching the cap is also used to cool the juice and mix the yeast with the crushed grapes to help aerate the juice. Precise records are kept regarding the time the cap was punched, the temperature of the juice and the °Brix. This routine is repeated 2-3 times per day.

F. Drawing Off and Pressing

When the winemaker has decided that enough color and tannin have been extracted through fermentation, the free run juice is drawn off the caps. In addition, the remaining must is pressed through a pressing machine so that pure juice is recovered. Two types of pressing machines are used, a batch press or a continuous press. Batch pressing is more commonly used for premium-quality wines because it is gentler on the grapes with respect to how pressure is applied in the machine, the type of screen used and the movement of the skins in relation to the screen.

G. Post-Fermentation Racking and Aging

The juice (or wine) product is very dry at this point so there is very little sugar left. The sugar levels are around 0.15%. The sugar level is used as a marker to indicate the end of fermentation. At this point, the yeast and other sediment may be filtered from the wine. Many higher-quality wines are not filtered; instead they clarify naturally by gravity. The wine is racked and stored in oak or steel tanks and aged according to the desired flavors.

H. Malolactic Fermentation (MLF)

Most red wines undergo a second fermentation by adding malolactic bacteria, usually *Oenococcus oeni*. The bacteria are introduced into the wine during fermentation or in the barrel during aging. For colder regions, where acid levels tend to be higher at harvest, the malolactic bacteria can lower the acidity. In warmer regions, acidity is not as much of a concern but the malolactic bacteria provide stability to the wine. After this fermentation is complete, the wine may be filtered and racked a second time. If the wine clears naturally, filtration is avoided.

I. Fining and Clarification

Winemakers sometimes use fining and clarification to finalize the wine. These practices remove excessive levels of specific wine components that may cause physiochemical changes later in the wine and help obtain the ideal, crystal-clear wine product. Polish fining is sometimes used and is the addition of proteinaceous agents like casein or egg whites.

II. Environmental Factors that Influence Wine and Grape Quality

A. Climate

The climate has a substantial effect on the grape and the final wine product. Climate can be subdivided into four basic levels: global, regional, mesoclimate and microclimate. From the global perspective, wine grapes thrive in temperate zones of the Northern and Southern hemispheres but can't survive extreme zones of hot or cold like the polar caps and the equator. Regional climate is related to parts of a country, state of district that is more or less suitable for grape growing. The mesoclimate refers to the actual vineyard and its relation to neighboring vineyards or even plots within the same vineyard. For example, drainage, wind and sun exposures are parts of the mesoclimate. Lastly, the microclimate refers to the immediate environmental factors within the canopies of specific vines. These factors include airflow, sunlight, and/or humidity. No matter the climate, the most influential period of grape physiology is during the fruit-growing season. A range of environmental factors can affect the grape, but most important are temperature, sunlight, soil composition and moisture.

B. Temperature

Grapes have optimal growth within a temperature range of 50-85°F, and in some cases higher. As mentioned previously, it is crucial that the temperature be within this range during grape growth. Vines tend to flourish in the springtime when the temperature reaches 50°F. A system of "degree days" was developed in California by Amerine and Winkler (1). This is a way to classify vineyards based on the number of degrees above 50°F everyday of the growth season. According to a region's classification, a particular grape is recommended or denied. These classifications have been very useful for California and extrapolate well for other regions around the world. In some cases, too much heat may cause the grapes to ripen too quickly and eventually "sunburn" the grapes (14). This affect causes the wine to have a baked or singed flavor and aroma.

C. Sunlight

Closely related to temperature is sunlight. Studies have shown that sunlight is an important environmental factor that influences grape ripening (8). Hrazdina and Keller (8) found that low levels of sunlight during veraison actually restricted the accumulation of phenolic compounds. Phenolic compounds are important for the color and flavor of wine. Since sun is a factor that can't readily be controlled by man, regions with constant sunlight are optimal for yielding high-quality and high-color grapes.

D. Soil

Rich, fertile soil is not ideal for grape growing (2). In fact, dry, low fertility soils are optimal for producing grapes that yields the highest quality wines. Although less fertile soil is recommended, micro and macronutrients are critical for wine grape vitality. In addition, trace minerals contribute to subtle flavor enhancements (1), (2), (14). Cover crop management is an important component of soil-nutrient content. Cover crop may compete with the vines for water and nutrients (3). To prevent this competition, mowing or tilling alternate rows has been suggested (3).

E. Moisture Received

The soil-type directly influences the accumulation of moisture around the roots of the vine. Deep, well-drained soil prevents excess rainfall from flooding the vine. The roots will die if they lack oxygen as a result water logging. For example, some clay soils may be too dense for vine growth because the soil swells when it is saturated with water and suffocates the roots. However, controlled irrigation during certain growth periods is recommended (3). Oregon soils are clay-based and few vineyards in Oregon have irrigation systems. In summary, the best soils for grape growing are those of low fertility that are well drained yet supply necessary micronutrients.

III. Chemical Compounds Related to Overall Wine Quality

A. Phenolics

Phenolics are important compounds in red wine grapes that contribute to wine quality and characteristics. This group of chemicals is responsible for red pigment, astringency, brown-forming substances and bitterness in grapes and in wine.

Wine phenolics are either classified as flavonoids or non-flavonoids. In the grapes nonflavonoids are typically located in the pulp whereas flavonoids are concentrated in the skins and seeds of grapes. For this project, we were mainly concerned with the flavonoids since they are found in high concentrations in red wines.

Flavonoids are a group of four primary compounds including anthocyanins, flavonols, flavan-3-ols and flavan-3,4-diols (5). In particular, anthocyanins contribute to the deep red colors in red wines. The major anthocyanins in dark *Vitis vinifera* grapes are the 3-glucosides of peonidin, petunidin, malvidin, delphinidin and cyanidins (8). The malvidin 3-glucosides are most related to the color of the wine since they are influenced by pH. At a pH of 3.0 (normal wine pH) nearly 50% of the malvidins are in their colored form (2). The anthocyanins are in grape skins and seeds and their concentration varies according to environmental conditions. Hrazdina (6) reported that sugar accumulation in the grapes during veraison is related to anthocyanin synthesis. Alternatively, high nitrogen and lack of sunlight have been observed to inhibit anthocyanin accumulation (8). Because anthocyanins are the color pigments of wine, they are an essential component for making a high quality wine.

B. Berry pH and Cation Concentration

The pH of the grape at harvest also plays an important function in the color quality and color stability of the wine. Low berry pH has been found to enhance sulfur dioxide's antimicrobial affects. Alternatively, higher pH is associated with increased solubility of proteins that helps to polymerize browning pigments (2).

Grapes ideal for red table wine are harvested when berries are a pH of 3.0-3.3. Tartaric and malic acids are the main acids involved in grape growth and maturity (6). Cation concentration also influences the pH of the berries. K+, Na+, Ca++, Mg++, Cu++ and Mn++ are present in grapes at significant levels (6). These ions are constituents of the cell wall, lamella, and most cellular membranes in the grape. Although these compounds have little effect on pH, they are required for activation of enzymes that induce berry maturation (6).

C. Nitrogen

Nitrogen is essential for providing nutrients to the yeast during fermentation and affects haze formation in white wines. Most significant is the nitrogen necessary used by yeast for fermentation. Without plentiful assimible nitrogen, the yeast will stop or slow the fermentation process. This problem is termed 'stuck' or 'sluggish' fermentation and could possibly be controlled by vineyard management practices. The readily fermentable nitrogen in juice originates from ammonia (NH_3) and the alpha amino acids (arginine, serine, glutamate, threonine, aspartate and lysine). Without adequate levels of assimible nitrogen, the fermentation will stick and sulfur compounds may develop (15). These sulfur compounds are responsible for off-odors like garlic and rotten eggs (1).

IV. Sensory Assessments of Wine Quality

Thus far, we have seen that many factors contribute to wine quality. Everything from soil type to vineyard management practices may influence the color, flavor or aroma of wine. Wine consumers ultimately determine the success or failure of a wine. Therefore, it is important to pay attention to the four sensory attributes, appearance, aroma, texture and flavor that can seduce a consumer into buying another bottle of wine.

A. Appearance

The color and clarity of a red wine is oftentimes masked by the green or dark colored bottles in which they are contained. The dark glass is necessary to prevent light from reacting with chemicals in the wine causing oxidation. Nevertheless, color is the first impression made when a red wine is poured into a wineglass. A bright red wine often indicates youthfulness whereas aged wines are red-brown (1). The clarity of a wine is also recognized. A hazy wine may be the result of several things like bacterial spoilage, tartrate crystallization, or oxidation to name a few.

The standard method of judging a wine's appearance is like an art. The wine is poured to the apex of a suitable wineglass and held to the light. When the glass is tilted, the 'rim' or the 'edge of the wine' can be observed. Young red wines will have some color on the rim while aged wines tend to have lighter rim (14).

B. Aroma and Bouquet

This step in evaluating a wine is getting a feel for its smell. This is the first true, qualitative assessment in wine evaluation. Approximately one-third of the glass is filled with wine. The glass is gently swirled in a circular motion such that the volatile compounds are released into the headspace of the glass. The person will immediately sniff the wine by putting his or her nose at the rim and breathing in. Usually unpleasant sensations are first recognized (14). Off-odors like vinegar, rotten eggs or a just-struck match might indicate spoilage. If there are no off-odors, red wines are famous for being described as having aromas like flowers, berries and fruits. Some wines are more complex than others are in that they display a medley of spicy, flowery and fruity aromas at once.

C. Texture

The next step is to take a sip of the wine. By filling the mouth with wine and allowing it to cover one's tongue and palate, one can detect the body and viscosity of the wine. Body is the mouth feel of a wine; it is the smooth feeling associated with sweet wines or the rough feeling of dry, acidic wines. Bitterness and astringency are also characteristics of a wine's texture. Alcohol, glycerol and wine extracts are responsible for the mouth feel of a wine (14). The texture of a wine may or may not be in balance with the other sensory components but this balance is essential for high quality wines.

D. Flavor

The flavor is the final sensory quality observed in wine tasting. An experienced wine taster will fill their mouth with wine, purse their lips and inhale to release the vapors in the wine. The warmth of the mouth in combination with the vapors spreading through the nasal canal and into the olfactory bulb will allow the wine taster to experience every part of the wine's flavor. The flavor of a good wine will coincide with the aroma. Once the wine is swallowed, the lingering flavors and mouth feels are called the 'finish.' Oftentimes, new flavors and tastes will be discovered in the finish of the wine.

All of the combined sensory components create the 'impression' or 'structure' of the wine. A high-quality wine is one that has its appearance, aroma, mouthfeel and flavor in fine balance.

Chapter 2: 1999 Oregon Pinot noir Wine Studies

Oregon, California and Washington winemakers are concerned with 'stuck' or 'sluggish' yeast fermentation. This behavior is due to a lack of fermentable nitrogen from ammonia and alpha-amino acids in the grape juice and must. Low levels of nitrogen cause the yeast fermentation to slow and total cell biomass production to be low which results in a 'stuck' fermentation before all of the fermentable sugar is utilized. Hydrogen sulfide may build up and will cause sulfur aromas and other "off" odors. 'Stuck' fermentation may produce wines with a detectable residual sugar as well.

The purpose of this study was to determine how three different vineyard practices influenced the composition and quality, including color, of the resulting Pinot noir wine. Specifically, three different field applications were installed in a factorial combination to yield 12 different treatments of irrigation, tillage and nitrogen applications. Controlled irrigation during fruit ripening is thought to enhance vine growth and quality (3). Tillage was a method to determine if competition for water and nutrients between the vines and the cover crop was disrupted. Finally, the different nitrogen applications were observed to determine if stuck fermentation was prevented and how nitrogen influences the color of the wine.

I. Materials and Methods

A. Sample Preparation: Experimental Design

The Pinot noir grape samples were harvested in 1999 from Benton Lane vineyard in the Southern Willamette Valley. The vines were treated using a randomized block design of irrigation, nitrogen application and soil cultivation. Each treatment combination was replicated 5 times in groups of 11 vines. Irrigation began on August 17, 1999, and continued through the lag phase. Irrigation was applied through a drip system at a rate of 0.5 gal/hr for 200 hours such that 3.2" of water was delivered in total. The nitrogen applications included an unfertilized control, two N-foliar treatments and a soil treatment. The foliar applications were applied via hand spray in the form of wetted urea. The first foliar application was on September 8, 1999, and the second was applied when the berries had undergone a 50% color change. The soil-N was applied on May 4, 1999 as urea (46-0-0).

The grapes were harvested in late October. With three replications of the twelve treatments, 36 wine samples were made. One sample was lost during processing so only 35 wines were completely analyzed. They were fermented on the skins for two weeks. The skins were punched twice daily at scheduled times. The wines were pressed to dryness from the skins and malolactic fermentation (MLF) was induced with the addition of *Oenococcus oeni* and allowed to sit for several weeks. After the completion of MLF, the wines were settled and cold stabilized for one month at 38°F. They were racked and bottled with addition of 25 PPM of sulfur dioxide (SO_2).

B. Spectrophotometry

The wine samples were removed from the wine stored at 38°F and allowed to warm to room temperature. 1.5 ml samples were centrifuged for 10 minutes. A Shimadzu 4000 spectrophotometer was used. The spectrophotometer was calibrated at 420nm and 520nm using deionized water. The absorbance of each sample was recorded and printed as they were measured. The "Color Intensity" is taken as the sum of the 420nm and 520nm absorbance readings. The "Hue" is the ratio of the absorbance at 420nm and 520nm.

C. Sensory Assessment

10 untrained panelists from the Food Science and Technology department were selected to rate the color of the 35 wine samples. The panelists rated the following three attributes: Overall Color Intensity, Purple Hue and Garnet Hue. The traditional 16-point intensity scale (0=none, 15=extreme) was used to rate the wines. The wines were observed and rated in replication. The two controls used were samples that represented the least and most extreme color intensities. The controls were selected on the basis of the "Color Intensity" reading (420nm + 520nm) calculated from the spectrophotometer. The largest valued-sample was used to represent the "purple" hue control and the smallest valued-sample represented the "garnet" hue control. Forty ml of each sample was poured into traditional, crystal wineglasses. The wines were observed in an open room such that natural sunlight was the only light provided.

D. Statistical Analysis

The data were analyzed using the SPSS statistical analysis software. ANOVA tables were generated with respect to the three individual attributes and within each replication of each treatment. Using Tukey's method, the LSD was also determined for all of the wines separately and within the twelve treatment types. The "Color Intensity" and "Hue" values from the spectrophotometer were correlated with the twelve treatments and with the panelists' ratings of "Overall Color Intensity."

II. Results and Discussion

A. Sensory Analysis

The sensory analyses were generated from panelists that observed and rated color of the wine samples. Using the traditional 16-point scale, panelists rated three attributes, Overall Color Intensity, Purple Hue and Garnet Hue, see Table 1 for ANOVA statistics.

1. Overall Color Intensity

In this experiment, overall intensity was based on color intensity of each wine. It is an intensity rating of lightness or darkness of a wine. Regarding the three different field treatments, tillage had no significant effect on the Overall Color Intensity of the wines ($p>0.05$) (Table 2 and 3). Alternatively, nitrogen and irrigation significantly influenced the rating of Overall Color Intensity for these wines (Table 4 and 5).

Among the three nitrogen treatments, those wines with soil-applied-N generally had higher mean overall Color Intensities than the other N treatments (Table 4). Two foliar-N treatments (Treatment 9 and 12) had relatively high Overall Color Intensities as well. Perhaps this is related to the mode of N-assimilation being more efficient in the roots versus the leaves and vines. Interestingly enough, both of these samples were not irrigated. Since the N treatment was analyzed separately from the influences of irrigation and/or tillage, substantive conclusions were not made regarding the multivariate interactions of the treatments. N levels are related to phenolics accumulation, which ultimately may contribute to the color of a wine (8). As expected, Tukey's HSD analysis revealed that more intensely colored wines, for the most part, received soil-N application (Table 6). Those wines rated least intense were generally those batches that received zero or foliar-N application.

Irrigation resulted in less-intensely-colored wines. Those wines rated with the lowest Color Intensity were irrigated (Table 6). Those wines that were not irrigated had a higher mean overall Color Intensity than those that were irrigated

TABLE 1:ANOVA Table of Three Color Attributes, Overall Color Intensity, Purple Hue and Garnet Hue, Rated by Sensory Panel

Attributes		Sum of Squares	Degrees of Freedom	Mean Square	F-Value	Sig
Overall Color Intensity	Treatments	1416.81	11	128.80	19.53	0.00
	Error	4497.91	682	6.60		
	Total	5914.72	693			
Purple Hue	Treatments	1304.47	11	118.59	17.92	0.00
	Error	4513.91	682	6.62		
	Total	5818.38	693			
Garnet Hue	Treatments	99.73	11	9.07	1.06	0.39
	Error	5820.78	682	8.54		
	Total	5920.50	693			

TABLE 2: Table of Significance of Three Field Applications vs. Sensory Panel Ratings of Three Attributes: Overall Color Intensity, Purple Hue and Garnet Hue

Treatment	Overall Color Intensity	Purple Hue	Garnet Hue
Nitrogen	0.00	0.00	0.047
Irrigation	0.00	0.00	0.55
Tillage	0.97	0.85	0.68

TABLE 3: Table of Means (standard deviation) of Tillage Treatment vs. Sensory Panel Ratings of Three Attributes: Overall Color Intensity, Purple Hue and Garnet Hue

Tillage Treatment	Overall Color Intensity	Purple Hue	Garnet Hue
No Tillage	8.77(2.63)	8.27(2.66)	7.80(2.81)
Tillage	8.76(3.18)	8.23(3.11)	7.89(3.03)

TABLE 4: Table of Means (standard deviation) of Three Nitrogen Treatments vs. Sensory Panel Ratings of Three Attributes: Overall Intensity, Purple Hue and Garnet Hue

Nitrogen Treatment	Overall Intensity	Purple Hue	Garnet Hue
No Nitrogen	7.81(2.70)	7.37(2.48)	7.55(2.56)
Foliar Nitrogen	8.57(2.83)	7.98(2.84)	7.78(2.87)
Soil Nitrogen	9.88(2.85)	9.38(2.98)	8.20(3.27)

TABLE 5: Table of Means (standard deviation) of Irrigation Treatments vs. Sensory Panel Ratings of Three Attributes: Overall Intensity, Purple Hue and Garnet Hue

Irrigation Treatment	Overall Intensity	Purple Hue	Garnet Hue
No Irrigation	9.44(2.99)	8.91(2.96)	7.91(3.05)
Irrigation	8.05(2.67)	7.55(2.66)	7.78(2.78)

TABLE 6: Means*(standard deviation) of Pinot noir Wines' Appearance Ratings as Affected by Nitrogen, Irrigation, and Tillage Practices

Treatments	Nitrogen	Irrigation	Tillage	Overall Intensity	Purple Hue	Garnet Hue
1	None	Yes	Yes	7.44^{a}(2.73)	6.95^{ab}(2.50)	7.45 (2.60)
2	Soil	Yes	Yes	8.83^{bcd}(2.44)	8.35^{bcd}(2.43)	8.17 (2.59)
3	Foliar	Yes	Yes	7.10^{a}(2.64)	6.83^{ab}(2.67)	7.39 (2.71)
4	None	Yes	No	8.17^{abc}(2.24)	7.45^{abc}(2.18)	7.85 (2.40)
5	Soil	Yes	No	9.2^{cd}(2.64)	8.72^{cd}(2.98)	8.20 (3.38)
6	Foliar	Yes	No	7.27^{ab}(2.72)	6.73^{a}(2.54)	7.50 (2.94)
7	None	No	Yes	7.24^{a}(2.91)	6.76^{a}(2.33)	7.50 (2.65)
8	Soil	No	Yes	12.32^{e}(2.47)	11.73^{e}(2.81)	8.55 (4.28)
9	Foliar	No	Yes	9.53^{cd}(2.46)	8.67^{cd}(2.75)	8.27 (2.85)
10	None	No	No	8.38^{abcd}(2.77)	8.28^{abcd}(2.65)	7.40 (2.62)
11	Soil	No	No	9.17^{cd}(2.38)	8.69^{cd}(2.39)	7.88 (2.55)
12	Foliar	No	No	9.95^{d}(2.37)	9.27^{d}(2.52)	7.86 (2.97)

*16-Point-Intensity Scale Used: 0=none, 15=extreme

*Samples with the same superscript letter in the same column are not significantly different (p>0.05)

(Table 5). These results may be linked to irrigation and its affect on berry size at harvest. Irrigation has been found to increase the berry size because the water flow enables nutrient flow to the vine roots. Although the berries grow larger with irrigation, their chemical make-up remains constant. Therefore, larger berries have diluted chemical compounds and less color as opposed to smaller berries with a more concentrated compound make-up (2).

2. Purple Hue

The panelists rated 'Purple Hue' based on the dark-purple colors of each wine. The darkest wine, based on the spectrophotometer readings, was used as the control to represent the most intense purple hue.

Purple hues were most influenced by nitrogen and irrigation treatments, (Table 2, 4 and 5). Soil tillage did not appear to have a significant affect on the purple hues of the wines.

Like Overall Color Intensity, soil-N application had the largest effect on the purple color of the wine. A majority of the wines that were rated as having the most intense purple hues were generally those treated with soil-N. The wines having the least intense ratings were those that received zero or foliar-N in the field (Table 6). Perhaps these results indicate that soil-N is assimilated into the vine more efficiently than foliar-applied-N. N-uptake is directly related to phenolics accumulation, which are those compounds that influence the color of a wine (8).

Wines that came from irrigated blocks were rated less intense in purple color than those that were not irrigated (Table 5). As stated previously, irrigated soils have been found to produce larger berries because of the water flow to the roots. Larger berries are more dilute in their color-compound make-up so it would be expected that irrigated soils have less intense purple color (2). If the water uptake is not efficient, berries tend to be smaller and have more concentrated levels of the color compounds (2).

3. Garnet Hue

Garnet Hues are those light red colors in a wine. Often, garnet is also described as red or brick red. Garnet hues were considered lighter than the purple hues for this experiment. The control wine used to represent garnet color was one that received the lowest "Color Intensity" reading on the spectrophotometer.

Irrigation and tillage had no significant effect on the Garnet Hues in these wines and while nitrogen was significant, ($p=0.047$) (Table 2). Soil-N was again generally associated with those wines that were rated with most intense Garnet Hues (Table 6).

A. Instrumental Data

Instrumental data are those readings taken from the spectrophotometer in the laboratory. Although several different readings were made, the "Color Intensity" and "Hue" readings were selected as the most relevant to this experiment (Table A in Appendix).

1. Color Intensity

Color Intensity was closely related with the panelists' judgments of two sensory attributes, Overall Color Intensity and Purple Hue. These results were expected because the correlation between Color Intensity and Overall Color Intensity has been previously recognized (2).

Color Intensity readings from the spectrophotometer measure those red and orange colors that are observed by the human eye. A linear relationship was observed between Color Intensity and Overall Color Intensity and Purple Hue (r^2= 0.84, r^2=0.86) respectively (Fig. 1 and 2).

1. Hue

The instrumental readings for this attribute were not closely related to sensory responses as the color intensity readings (Table 7, Fig. 1and 2).

TABLE 7: Means* (standard deviation) of Pinot noir Wines' Spectrophotometer Readings at 420nm and 520nm Affected by Nitrogen, Irrigation and Tillage

Treatments	Nitrogen	Irrigation	Tillage	Color Intensity	Hue
1	None	Yes	Yes	6.6^{bc}(0.39)	0.74 (0.01)
2	Soil	Yes	Yes	7.0^{cde}(0.52)	0.79 (0.07)
3	Foliar	Yes	Yes	6.42^{ab}(0.95)	0.77 (0.07)
4	None	Yes	No	7.35^{e}(0.77)	0.74 (0.00)
5	Soil	Yes	No	7.45^{ef}(0.35)	0.70 (0.12)
6	Foliar	Yes	No	6.07^{a}(0.14)	0.75 (0.00)
7	None	No	Yes	6.79^{bcd}(0.70)	0.79 (0.05)
8	Soil	No	Yes	8.79^{h}(0.74)	0.72 (0.03)
9	Foliar	No	Yes	7.04^{cde}(0.80)	0.79 (0.08)
10	None	No	No	7.3^{e}(1.40)	0.72 (0.09)
11	Soil	No	No	7.21^{de}(0.42)	0.74 (0.04)
12	Foliar	No	No	7.82^{g}(0.92)	0.72 (0.10)

*16-Point-Intensity Scale Used: 0=none, 15=extreme

*Samples with the same superscript letter in the same column are not significantly different (p>0.05)

Figure 1: Relationship of Sensory Attribute (Overall Color Intensity) to Spectrophotometer Readings (Color Intensity and Hue)

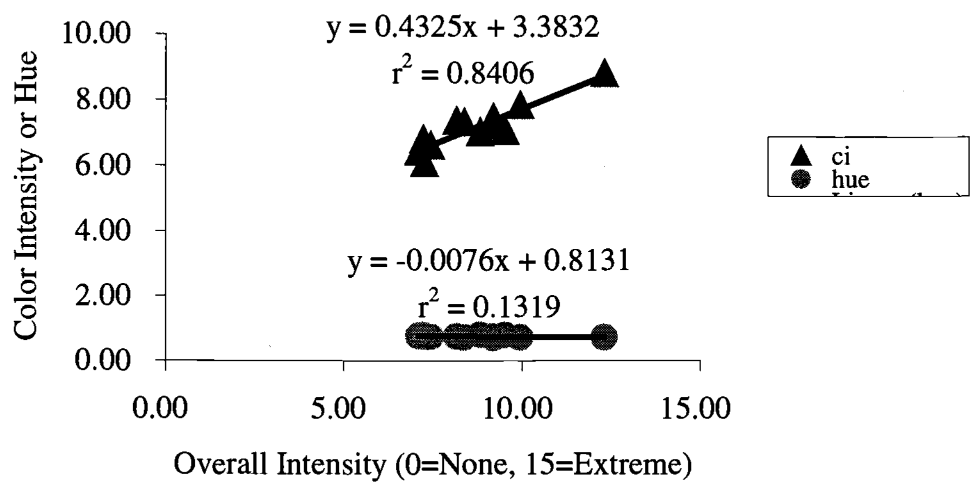
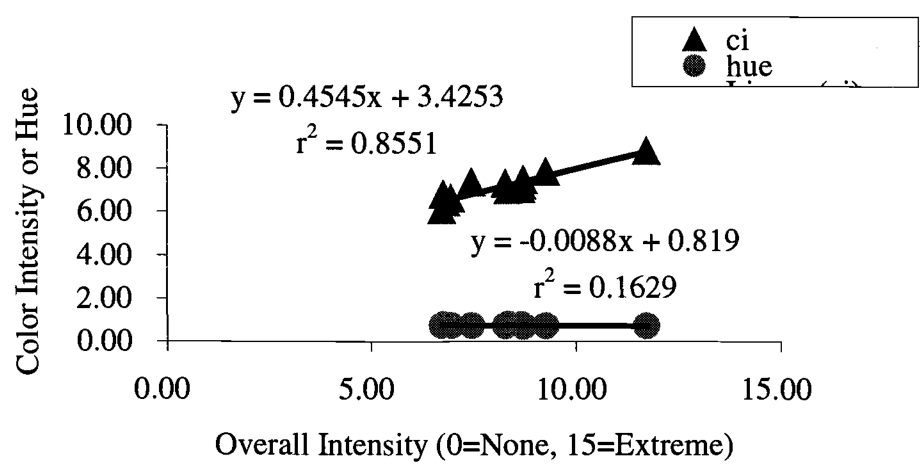


Figure 2: Relationship of Sensory Attribute (Purple Hue) to Spectrophotometer Readings (Color Intensity and Hue)



Chapter 3: Conclusion

The objective of this project was to learn more about the effects of specific vineyard practices on the color quality of Pinot noir wine. The timing and amount of nitrogen applied and irrigation are important factors influencing the Overall Intensity and Purple Hue of the wines studied. Soil-applied-N was related to more intense-colored wines. Nitrogen may be assimilated into the grape more easily when applied to the soil since that treatment was generally associated with more intense-colored wines. Nitrogen assimilation may also be related to phenolic synthesis in the grape (6). Since phenolics are necessary precursors for color pigments, improved nitrogen accumulation may lead to a better-colored wine, thus improving its quality. However, irrigated samples were related to less-intense wine color. Since irrigation is related to increased berry size, the color compounds are diluted in the wine. Tillage was not observed to influence the color of the wines as an independent treatment. Multivariate analysis may reveal that tillage does in fact, have a role in the color of wine. Instrumental Color Intensity values were found to closely mimic the panelists' ratings of Overall Color Intensity and Purple Hues. These results indicate that instrumental analyses may replace panel observations if need be.

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APPENDIX

TABLE 8: Spectrophotometer Readings Made on 35 Pinot noir Wines

Wine Code #	Color Intensity (520nm + 420nm)	Hue (420nm/520nm)
1	9.01	0.62
2	6.57	0.75
3	6.53	0.81
4	6.51	0.7
5	6.17	0.73
6	7.18	0.7
7	6.59	0.66
18	6.11	0.76
19	5.93	0.74
20	6.89	0.78
21	6.21	0.74
22	6.11	0.7
23	7.7	0.66
24	9.25	0.6
26	8.09	0.68
27	7.28	0.71
28	7.6	0.69
29	6.34	0.75
30	6.94	0.76
31	6.83	0.82
42	7.07	0.89
43	6.8	0.85
44	6.03	0.78
45	7.12	0.72
46	7.6	0.75
47	7.94	0.71
48	7.8	0.69
49	7.93	0.66
50	7.74	0.73
51	8.35	0.7
52	8.69	0.77
53	6.19	0.87
54	5.49	0.87
55	7.13	0.94
56	9.73	0.75

Pinot noir Color Assessment

April 4, 2000

Please rate the displayed wine samples using the traditional, 16-point Intensity scale. Two samples are available for you to use as controls. You may pick up the wineglasses to observe the color, but please be careful to only handle the stem of the glass. As you rate each sample, please be sure to write down the corresponding sample number in the correct column. You will judge each sample according to Overall Color Intensity, Purple Hue and Garnet Hue.

The traditional 16-point Intensity Scale:

0	3	7	13	15
None	Slight	Moderate	Large	Extreme

Sample #	Overall Color Intensity	Purple Hue	Garnet Hue