**The Fruiting and Berry-Chemistry Responses of
Zinfandel Grapes to Cluster Thinning**

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By
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Title: **The Fruiting and Berry-Chemistry Responses of Zinfandel Grapes to Cluster Thinning**

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Abstract

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A field experiment was conducted in the Rockpile appellation of Sonoma County during 2007 and 2008. The experimental design was a randomized complete block with five replicates. Zinfandel vines were subjected to three levels of cluster thinning during the lag phase of berry growth: vines were thinned to 2 clusters per shoot with shoulders retained if present (2CS), 1 cluster per shoot with shoulders retained if present (1CS), or 2 clusters per shoot with shoulders removed if present (2CNS).

Cluster thinning Zinfandel grapevines during lag phase led to reductions in yield and crop load and increased °Brix of the fruit. In both years, wines that were made from vines with the lowest crop load had consistently higher amounts of small and large polymeric pigments, tannins and total iron-reactive phenolics.

Cluster thinning vines to 2CNS at lag phase consistently decreased the number of berries per cluster and cluster weight. Thinning vines to 1CS resulted in fewer clusters per vine in 2008.

Botrytis bunch rot tends to develop between the shoulder or wing and the main cluster in certain varieties. Shoulder removal in areas with a high risk of *Botrytis* should conclusively determine if this thinning method helps to decrease

disease incidence. Additional research is also recommended with other varieties to assess possible differences between shoulder thinning and removing entire clusters on berry composition, yield, subsequent wine composition and crop load.

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Chapter One

Introduction

Statistics

Zinfandel acreage represents a dynamic component of California's wine grape production. Some of the leading producers of Zinfandel in California by county are Mendocino, Sonoma, Napa, El Dorado, San Joaquin, Madera, Fresno, San Luis Obispo and Kern counties (Sullivan, 2003). During the 1970's, approximately 90,000 tons of Zinfandel grapes were crushed in California with prices averaging \$200 to \$300 per ton. In 1974, producers from Sonoma and Napa counties had the highest average prices per ton at \$472.

In 2000, over 400,000 tons of Zinfandel grapes were crushed in California with an average value of \$464 per ton. Sonoma County's average price per ton was \$2,493 (Sullivan, 2003). In 2000, the yields ranged from 3.3 tons/acre in Sonoma County to 11.5 tons/acre in the Central Valley. Prices per ton tend to be low because of the production of large tonnages of low fruit quality in hot-climate regions such as Fresno County (Sullivan, 2003). In 2000, premium growing regions such as Sonoma and Napa counties contained 29% of the bearing acreage, but only produced 12% of the Zinfandel wine made in California (Sullivan, 2003). In 2007, Zinfandel grapes accounted for 17% of the bearing red wine acreage in California (CDFA, 2008).

Cluster Classification

Grape clusters are classified by shape, weight and compactness of the berries (Galet, 1979). Cluster shape is determined by the number and length of lateral branches within the cluster. Some common shapes are: cylindrical, conical, shouldered and winged (Galet, 2002). Cluster weight is determined by the number and size of the berries. Cluster density or compactness involves the amount of space between the berries, length of the pedicels, and the structure of the lateral branches. Clusters deemed to be compact have short pedicels attached to lateral branches with berries pressed tightly together (Galet, 1979).

Many factors affect cluster shape, making it difficult to describe a cultivar as always producing a particular type of cluster. Factors such as soil, fertilization, irrigation method, rainfall, severity of pruning, and weather at bloom and flowering may affect cluster shape (Galet, 1979). Clusters with well-developed laterals near the peduncle are said to have shoulders, and a cluster may have more than one. If a shoulder grows as large as the main cluster, the cluster is said to be winged.

For wine grapes, compact clusters are not preferred due to the possibility of increased bunch rot [*Botrytis cinerea* (DeBary) Whetzel]. The repressed berries of the clusters are under pressure which makes them prone to splitting, providing entry points for *Botrytis* (Smart and Robinson, 1991). This is important as even in the absence of dampness, compact clusters may still develop significant *Botrytis* rot via berry to berry spread of the fungus.

Zinfandel tends to have shouldered and/or winged clusters that have compact berries with thin skins (Patterson, 2007; Christensen et al., 2003) making it highly susceptible to *Botrytis* bunch rot (Patterson, 2007; Christensen et al., 2003). Due to wind and/or vineyard practices, the shoulder can rub on the main cluster causing the skins to split. The shoulder may also shade underlying berries which may interfere with their development (Chapman et al., 2004).

Botrytis

Botrytis can dramatically reduce yield by causing the early loss of clusters, and later, by reducing berry juice (Smart and Robinson, 1991). *Botrytis* infections also decrease the surface area of the skin available for tannin extraction (Rosenquist and Morrison, 1989), negatively affecting berry and wine chemistry. Wines made from grapes infested with grey rot have off-flavors, unstable color, are prone to oxidation, and age quickly (Smart and Robinson, 1991).

The *Botrytis* fungus reproduces asexually (Flaherty, 1981). It produces abundant hyaline conidia which are borne on tree-like conidiophores. The conidia are dispersed by wind and rain. *Botrytis* survives harsh conditions by producing sclerotia. The fungus may also over-winter on the canes, dormant buds and bark of grapevines.

Botrytis can lead to grey rot and noble rot infections in wine grapes. Grey rot occurs during wet and/or humid conditions and may result in the loss of clusters. Under extreme conditions, losses may be high enough to jeopardize a

crop. However, when wet conditions are followed by dry, the grapes desiccate and, when fermented, produce some of the most sought-after dessert wines in the world such as Sauternes and Tokay. Whether grey or noble rot occurs, both can be detrimental to crop health; however, grey rot has more potential to ruin a vintage due to negative effects on berry and wine chemistry.

Rockpile

Rockpile is a new appellation (A.V.A.) in Sonoma County in which predominately thin-skinned, red wine grape cultivars are grown. It is located in the northeast corner of Sonoma County overlapping the Dry Creek Valley appellation. Rockpile was first recognized as a viticultural area on April 29, 2002. Rockpile is distinct from Dry Creek Valley because of its elevation requirements. All vineyards in Rockpile must be located at an 800-2000 ft. elevation, which is a unique characteristic for an appellation. Rockpile is approximately 13 miles from the Pacific Ocean, and is heavily influenced by coastal breezes due to its elevation (ATF, 2002). The Rockpile appellation sits on top of the ridge between the Dry Creek and Rancheria Creek arms of Lake Sonoma (Fig. 1). The inversion layer which forms above the lake generates a cooling effect by pulling fog below the vineyards exposing the vines to the morning sun (Fig. 2).

Fig. 1. A Rockpile vineyard sitting above the Rancheria Creek arm of Lake Sonoma (photo courtesy of A. Opperman).

Fig. 2. The Rockpile Ridge Vineyard above the morning fog that sits on top of the Rancheria Creek arm of Lake Sonoma (photo courtesy of W. Weese).

Objectives of Study

Grapevines produce clusters of various shapes and sizes and the type or types produced must be considered during preharvest management of the vines. The objective of this study was to assess the effects of differential methods of cluster thinning on Zinfandel grape composition, disease incidence, yield, crop load, and subsequent wine composition.

Rockpile grape prices are consistently in the top 5% of grapes sold in Sonoma County (CDFA, 2007). However, the majority of vineyards in Rockpile are less than fifteen years old and, consequently, there is no published research on grapes from this area. There is a need to assess and improve grape quality in the Rockpile A.V.A. to assist both grape growers and wine makers.

Chapter Two

Literature review

Classification

Grapevines are in the kingdom Plantae, division Magnoliophyta, class Magnoliopsida and are flowering plants. Grapevines are in the order Vitales and the class Vitaceae which further describes it as dicotyledonous, meaning the seed typically contains two embryonic leaves (Mullins et al., 1992). The characteristics of this genus are that the plants are perennial shrubs, annually producing shoots that always have tendrils, and which never produce tuberous roots. Grapevines may possess dioecious or polygamodioecious, reproductive capabilities. Grapevines have $2n = 38$ chromosomes and all crosses between species will produce viable, fertile descendants.

Vitis vinifera L. is the grape of commerce. It was indigenous to Central Europe, the Mediterranean region, and southwestern Asia and may be found from Morocco and Spain north to southern Germany and east to northern Iran (Mullins et al., 1992). *V. vinifera* is one of approximately 65 species worldwide (Winkler et al., 1974) and most are found predominately in North America and China (Galet, 1979; Mullins et al., 1992). Most species of the genus *Vitis* are not grown commercially, but are used as rootstocks for *V. vinifera* and *V. muscadina* (Mullins et al., 1992). The genus *Vitis* was named in 1700 by French botanist Joseph Pitton de Tournefort. The word *Vitis* is derived from the Latin *Viere*, to

attach, alluding to the plant's innate ability to climb by attaching its apical tendrils to anything with which it comes in contact (Galet, 1979).

Zinfandel

Zinfandel was long thought to be “California’s Grape” (Christensen et al., 2003). Scientists insisted that Zinfandel could not be native to California, or even North America, because of its propensity to produce hermaphroditic flowers, which was unknown for North American grape species. Zinfandel is in fact a cultivar of *V. vinifera* but it is only grown under this name in California. The grape thought to be “California’s grape” was brought to California in the 1850’s and has become a keystone of the California wine industry.

In the late 1960’s, Dr. Austin Goheen, a USDA-ARS plant pathologist, was in Italy and tasted a local wine reminiscent of Zinfandel. In 1993, scientists and industry collaborated to investigate the genetic background of various grape cultivars. Bowers (1993) and his team of researchers concluded that Primitivo, an Italian cultivar, and Zinfandel were genetically-identical based on indistinguishable DNA electrophoretic banding patterns.

This was the first step in a long process to determine the origin of Zinfandel. Dr. Lamberti of Bari had suggested to Goheen in 1976 that Primitivo might be the Croatian cultivar Plavic mali (Sullivan, 2003). Deductively, scientists identified Croatia as a starting point in their search for the parents of Zinfandel (Calo et al., 2008; Mirošvić and Meredith, 2000). Scientists at UC Davis and the University of Zagreb pooled resources and discovered that Crljenak (Tzerl-yen’-aak)

Kastelanski, known as the reddish grape from Kastela, was genetically identical to both Zinfandel and Primitivo (Maletiae et al., 2003). Maletiae and his team of researchers discovered that Zinfandel and Dobricic were the parents of Plavac Mali (Maletiae et al., 2004). Viticulturalists long thought Plavic Mali was an old Dalmatian Coast cultivar, which further indicated that Crljenak Kastelanski was originated in Croatia.

Although Zinfandel's journey to California is not certain, the most conceivable path started at the Austrian Imperial Nursery in Vienna. A horticulturist named George Gibbs brought the grape from the Nursery to Long Island in the 1820's. There it was used as an East Coast greenhouse table grape (Sullivan, 2003). Zinfandel vines probably came to the West Coast during the California Gold Rush (Sweet and Wolpert, 2007).

Berry Growth

Berry growth, when plotted, is a double sigmoid (Staudt et al., 1986; Fanizza and Colonna, 1996) (Fig. 3) and many fruits, such as peaches, apricots, cherries and blueberries, grow in a similar fashion (Patterson, 2007). For these fruit, growth does not proceed at a constant rate through development. Phase (I) starts just after flowering (Fig. 3), the period when the blossom is fully open and functional. During this period, there is rapid cell division for about 3 weeks followed by rapid cell enlargement (Winkler et al., 1974). The berries remain green and firm, and there is a high rate of respiration as well as rapid acid accumulation in the fruit (Mullins et al., 1992). At the end of Phase (I), the growth

of the nucleus and endosperm are complete and seeds have formed and may be fully grown. Cell division of the fruit is completed during this phase. Phase (I) may last 45-65 days depending on environmental conditions and cultivar (Mullins et al., 1992).

Phase (II), also known as the lag phase, is characterized by slow pericarp growth and seed maturation (Fig 3). The lag phase may last from 7-40 days and

Fig 3. Grape berry growth curve (adapted from Anderson et al., 2005).

during this period respiration and photosynthesis slow noticeably (Mullins et al., 1992). Berries reach their highest levels of acidity and begin to accumulate sugars. Near the end of Phase (II), berries will begin véraison, which is the shift from berry growth to berry ripening (Winkler et al., 1974).

Phase (III) begins with berry softening followed by véraison and another stint of cell enlargement (Mullins et al., 1992) (Fig. 3). Anthocyanins and pigments accumulate in the skins and seeds, and are precursors of flavor and aroma compounds. As the berry continues to reach physical maturity, sugars increase while acids decrease (Winkler et al., 1974).

Cluster Thinning and Crop Load

Cluster thinning increases phenolic composition by altering the leaf area/fruit ratio, or by speeding up fruit maturity (Prajitna et al., 2007). The resulting change in phenolic composition is strongly dependant on the timing of the thinning. The optimal time to cluster thin is during the lag phase (Phase (II)) of berry growth (Fig. 3). Cell division occurs during Phase (I) and is terminated by hormonal control during the beginning of the lag phase (Patterson, 2007). At this time the vine has completed cell division, and has begun storing reserves for berry maturation. By thinning after cell division is complete, yield compensation can be limited.

Inherently, grape vines are capable of producing remarkably high yields. Grape growers must find a balance between quantity and quality. For wine grapes, the balance occurs when the grape crop can be ripened to an

appropriate composition for the targeted wine style. If the grapes are not of the appropriate composition, the vineyard yield levels are too high and the vineyard is over cropped (Anderson et al., 2002). However, the opinion that vines with high yields produce wines with low perceived quality suggests different standards for wine based on crop load and region (Smart and Robinson, 1991, Schalkwyk et al., 1995).

Timely cluster thinning may result in fruit with a chemical composition more appropriate for wine making. Cluster thinning can increase resveratrol (Prajitna et al., 2007), as well as the anthocyanins and phenolic composition of grape must (Guidoni et al., 2002).

The Ravaz index (crop load) is the ratio of the yield per vine to the average pruning weight of the same vines. The weight of canes pruned from a vine during one growing season indicates vine vigor.

In some vineyards, thresholds for the Ravaz index indicated that crop loads above 10 had negative effects on berry composition and this was attributed to poor canopy management (Smart and Robinson, 1991; Reynolds et al., 2007). By setting minimums and maximums for crop load, viticulturists can optimize vine balance thereby increasing fruit quality and improving crop consistency. Most berry pigments develop late in the growing season (Fig. 3) and a proper crop load promotes this development by slowing the rate of sugar accumulation in the fruit (Jackson, 1986). Additionally, a proper crop load can promote the accumulation of flavor and aroma compounds in the mature berries (Mattii, et al., 2005; Coombe and Iland 2002).

Determining crop load is a practical method for predicting quantitative wine quality during field experiments (Anderson et al., 2002; Bravado et al., 1985; Kliewer et al. 1983) The Ravaz index indicates vine size by comparing vegetative growth (pruning weight per vine) to reproductive growth (fruit harvested per vine). Alternatively, crop level is determined as tons/acre or tons/hectare, with no indication of vine size (Naor et al., 2002). However, vine size is an important factor to consider when assessing quality.

Crop level ignores a vine's micro-climate because crop level gives no indication of vine size. Vineyards with high yields and high vigor are typically associated with undesirable wine characteristics (Smart and Robinson, 1991). These vines are overgrown, tend to be self-shaded and often have poor fruit and leaf exposure to sunlight. This negatively affects the grape must, and subsequent wine composition. Negative effects of a shady canopy include decreased: sugar, anthocyanins, tartaric acid, and monoterpene flavor compounds resulting in reduced varietal character. A shady canopy may also increase: the incidence of *Botrytis* bunch rot, the ratio of malic to tartaric acids in grape must, potassium levels in wine, and wine pH, all negative factors of wine composition. Vines with low yield and low vigor tend to produce fruit with the chemical characteristics that wine makers request.

Cluster thinning may not change yield if the grapevines are thinned before the berry lag phase, due to yield compensation. By cluster thinning cool-climate Chardonnay Musqué to 1 cluster/shoot in late bloom/early set, there was no difference in vine yield or yield/ha (Reynolds et al., 2007). Yield compensation

resulted in more berries/bunch as well as increased berry size as vines put more of their stored energy into cell division and cell enlargement.

Over a 4-year period, cluster thinning cool-climate Chardonnay Musqué vines during or after late Phase (I) berry growth consistently resulted in smaller yields compared to the yields from vines which were not thinned or which were thinned during 1) late bloom/early set, 2) early Phase (I) berry growth, 3) the lag phase of berry growth or 4) véraison (Reynolds et al., 2007). For vines thinned during or after late Phase (I), berry size was smaller resulting in more complex chemical characteristics in subsequent wine composition. However, cluster thinning had minimal effects on the sensory attributes of wine made from the grapes (Reynolds et al., 2007).

Wines were made from the fruit of vines that were cluster thinned at different stages of berry growth and compared to wine made from fruit of vines which were not thinned. In addition, some of the fruit from vines that were not cluster thinned were subjected to several novel fermentation treatments using different yeasts and enzyme products (Reynolds et al., 2007). Making wines using the novel fermentation treatments resulted in noticeable effects on sensory attributes, while wines made from the fruit of vines that were cluster thinned during different phases of berry growth had only modest changes in their sensory profiles. In a similar study in 1995 (van Schalkwyk et al.), only minor effects on sensory attributes were noticed for wines made vines thinned to 33% and 66% of the fruit at 17° Brix and 19° Brix. No improvements in must and wine composition were noted.

Crop loads between 5:1 and 10:1 (yield:pruning weight) suggest optimal yields and vine balance, aiding in periderm formation which causes canes to lignify, preventing winter injury (Bravdo et al., 1984). Crop load indicates vine size and is an accurate predictor of vine balance relating to perceived fruit quality (Bravdo et al., 1984). Crops loads ranging from 5:1 and 10:1 are associated with sustainable yields that optimize crop yield and perceived wine quality (Staudt et al., 1986).

In a cluster thinning study for the cultivar Carignane, a crop load below 12 resulted in no effect on subsequent wine quality (Bravdo et al., 1984). Cluster thinning after bloom reduced crop load without significantly affecting yield. The vines put more energy into the fruit itself, increasing cell division and enlargement, rather than vine vigor.

Yield per unit leaf area correlates well with yield/unit pruning weight (Smart and Robinson, 1991). If crop load indicates the yield per unit leaf area, it is not necessary to perform both procedures (Noar et al., 2002). The Ravaz index is more practical for field measurements because less expensive equipment is required (Smart and Robinson, 1991).

Cluster thinning decreases the photosynthetic sink (fruit) in order to concentrate the same amount of stored carbohydrates into less fruit (Reynolds et al., 2007). Cluster thinning may increase total anthocyanins if the vines are thinned during the fruit lag phase.

Resveratrol and other phenolics are antioxidants in wine, capable of slowing or preventing chemical reactions that transfer electrons to an oxidizing agent

(oxidation) (Minussi et al., 2003). Oxidation reactions produce free radicals (ions with unpaired electrons) that can cause chain reactions capable of damaging cells. Antioxidants reduce the number of these chain reactions neutralizing the free radicals by pairing them with electrons. Antioxidants in wine protect against cardiovascular diseases, cancer, macular degeneration, and diabetes (Lopez-Velez et al., 2003). Additionally, in a study on mice, resveratrol improved the health and survival of mice on high-calorie diets by improving mitochondrial number, inherently increasing the function of motor skills (Baur et al., 2006).

Though cluster thinning has minimal effects on sensory analysis, cluster thinning increased both antioxidant and total phenolics in wine. Cluster thinning increased antioxidant levels in grapes by 42% on vines thinned to 10 clusters/vine compared to vines thinned to 30 clusters/vine (Prajitna et al., 2007).

Summary

If vines are thinned before late phase (I) of berry growth it may decrease yield and total phenolics may increase. Additionally, a decrease in acid and an increase in °Brix may be noted (Reynolds et al., 2007). Cluster thinning does not affect sensory components unless crop loads are in excess of 10:1 (Reynolds et al., 2007; Smart and Robinson, 1991; Noar et al., 2002; Bravdo et al., 1984). In some instances, cluster thinning may not be an economically feasible method of improving fruit quality and the subsequent wine composition for either the grape grower or wine makers (Reynolds et al., 2007; Schalkwyk et al., 1995).

Chapter Three

Materials and Methods

Site Description

A field experiment was conducted during the 2007 and 2008 growing seasons using *Vitis vinifera* L cv. Zinfandel grapevines. Vines consisted of the St. Peter's Church selection of Zinfandel grafted onto 1103 Paulsen rootstock (*V. berlandieri* x *V. rupestris*). Grapes came from the Rockpile appellation (Rockpile) in western Sonoma County, California (38°43'05.45" N, 123°04'11.85" W., elevation 1174 ft.-1294 ft.) and were located at the Rockpile Ridge Vineyard. The same vines were sampled in both growing seasons. Vines were planted in 1998 and were spaced 8 ft. (in-row) by 6 ft. (between row) apart on a West facing slope, resulting in a population of approximately 908 vines per acre.

The soil at the vineyard site was a Josephine loam (JoF) which is deemed a well drained soil (JM Lord, Fresno, CA). Josephine loams occur on slopes ranging from 30-50 percent and receive annual precipitation of 50 inches per year. The soil profile for JoF soils consists of 0-13 inches of gravelly loam followed by 13-35 inches of gravelly clay loam, 35-45 inches of gravelly fine sandy loam and 45-60 inches of paralithic bedrock.

Vineyard Practices

Vines were trained on a unilateral cordon approximately 40 inches above the ground. Vines averaged fourteen spurs, and were pruned to one bud per spur (Fig. 4). Vines were trellised on a vertical shoot positioning system. All vines were shoot thinned to one shoot per spur and suckered at flowering.

Vines were not irrigated in 2007 or 2008. Vines were sprayed prophylactically each year to control powdery mildew and *Botrytis*, with no insect control necessary in either season. The vineyard was strip sprayed for weed control. The vineyard was fertilized after harvest each year with monoammonium phosphate (11-52-0) at the rate of 1 lb. per vine, supplemented with potash (0-0-50) at 2 lb. per vine. Composted chicken manure was also surface-applied to the vine rows after each harvest at the rate of approximately 1.5 tons per acre (Azevedo, 2007)

Experimental Design

The experimental design was a randomized complete block. Vine rows were treated as blocks to account for variability due to changes in soil type. There were three fruit thinning treatments with five replicates, and twenty vines per replicate. Thinning treatments were vines thinned to 1) one cluster per shoot with shoulders, 2) two clusters per shoot with shoulders or 3) two clusters per shoot with no shoulders. Block size was sufficient to provide enough grapes for a small commercial fermentation of the combined fruit of the treatment plots (3

Fig. 4. A Zinfandel vine trained on a unilateral cordon, pruned to 1 bud spurs (photo courtesy of A. Opperman).

fermentations, total). Clusters were thinned during phase II of the berry growth curve (lag phase) to minimize yield compensation.

Cluster Thinning Treatments:

All treatments were shoot thinned to one shoot per spur, with approximately 14 spurs/vine. Vines were cluster thinned during lag phase (Fig. 5). In the control treatment, two bunches with shoulders (if present) per shoot were retained on the vines (2CS) (Fig. 6). In the severely thinned treatment, vines were thinned to one cluster per shoot, with shoulders retained on the bunch if present (1CS) (Fig. 7). In the minimally thinned treatment, vines were thinned to

two clusters per shoot, and shoulders were removed if present (2CNS) (Fig. 8). Clusters that were removed during lag phase were weighed.

Fig. 5. A Zinfandel cluster removed from a vine during lag phase.

Fig. 6. A Zinfandel vine thinned to two clusters with shoulders per shoot were retained if present (2CS) (photo courtesy of W. Weese). Leaves were removed for photo purposes.

Fig. 7. A Zinfandel vines thinned to one cluster per shoot, shoulders were retained if present (photo courtesy of W. Weese). Leaves were removed for photo purposes.

Fig. 8. Vines thinned to two clusters per shoot, shoulders were removed if present (photo courtesy of W. Weese). Leaves were removed for photo purposes.

Harvest Measurements

During the 2007 growing season, 100 clusters (with or without a shoulder) were randomly chosen from each replicate and individually weighed. Samples of 100 berries per replicate, randomly selected from the clusters, were also weighed. Clusters from vines thinned to 2CS or 1CS were pooled and 100 clusters with shoulders were randomly selected, after which the shoulders were removed and weighed. The effect of either thinning treatment on the incidence of clusters with shoulders was not determined.

During the 2008 growing season, the same measurements were taken as in 2007 with the following additions:

1. Samples of 100 clusters were randomly chosen and the main clusters were separated from their shoulders, if shoulders were present.

2. For those clusters with shoulders, both the main cluster and shoulder weights were recorded.
3. Shoulders and main clusters were then de-stemmed and crushed.
4. For each replicate, the °Brix was determined by refractometer for both the main cluster and shoulder.
5. °Brix was individually measured for thirty berries taken from each block to estimate between-berry variability.

Grape Analysis

In 2007 and 2008, harvest date was determined by measuring the °Brix, pH and acid contents of 100 randomly selected berries from each replicate. °Brix was measured using a hydrometer (Thermo-Fisher Science, Dubuque, IA). Total acidity (TA) was determined by titration. The vineyard was harvested when the averages of these measurements were: °Brix: 24.5, pH: 3.4 and TA: 0.65 mg organic acids.

Wine Analysis

Grape must was collected after the fruit from each plot was destemmed and crushed. Juice panels were performed by Vinqury (Windsor, CA) and measured °Brix by refractometer, pH, titratable acidity (g/100mL), ammonia (mg/L), assimilable amino nitrogen (mg/L), potassium (mg/L), tartaric acid (g/100mL), malic acid (g/100mL), lactic acid (g/100mL), acetic acid (g/100mL), total organic acid (g/100mL), and *Botrytis* risk assessment. Tannin assays also were

performed at Vinquiry after alcoholic fermentation. Tannin assays included total tannins (mg/L catechin equivalents), total anthocyanins (mg/L malvidin-3-glucoside equivalents), and total iron-reactive phenolics (mg/L catechin equivalents) as determined by High Pressure Liquid Chromatography (HPLC) and absorbance at 510 nm. Small and large polymeric pigments were also determined by HPLC via absorbance at 520 nm.

Winemaking

Commercial fermentation: In 2007, grapejuice from all plots for each thinning treatment was combined in one ton macrobins. The juice was cold soaked on the skins for four days prior to inoculation. The juice was fermented using the yeast VQ 15 (*Saccharomyces cerevisia*) which was isolated by Vinquiry in a spontaneous fermentation from a Rockpile Syrah. If necessary, wines were re-inoculated with Uvaferm 43 (Lallemand Wine, Montreal, Canada) to help wines ferment to dryness.

Microscale fermentation: In 2008, wine from each plot for each thinning treatment was made using microscale fermentors (Sampaio et al., 2007). Each fermentor consisted of a 4-L plastic container with a Teflon-lined cap (Olshens Bottle Supply, Portland, OR) a fermentation airlock and food-grade plastic plate cut to size (Fig. 9). The food-grade plate was used to submerge the fermentation cap in order to better simulate extraction from large scale fermentations (Sampaio et al., 2007). To prevent overflow fermentation, vessels were not filled completely.

After the grapes were crushed, the must was collected and three liters were added to the fermentation vessels. Two cubes of dry ice were added to each vessel to alleviate oxidation (oxygen ingress). Sulfur dioxide was added at a rate of 70mg/kg juice. Fermentors were rolled approximately 5 yards during maceration and fermentation instead of using the punch down or pump over methods of cap submersion (Sampaio et al., 2007). Temperature was maintained at approximately 40°F during cold soak. The temperature of the wine was measured daily after which dry ice was added to each fermentor. Wines were inoculated six days after harvest using the yeast VQ 15 and the nutrient GO-FERM® (Lallemand Wine, Montreal, Canada). Diammonium phosphate was added at the rate of 6g/L of juice after the wines were inoculated. The °Brix of the must was

Fig. 9. Four liter plastic containers were used as microscale fermentors during maceration and fermentation in 2008.

measured every two days using a hydrometer. Wines were pressed 12 days after inoculation.

A commercial fermentation using excess fruit from vines thinned to 2CS was monitored following the same guidelines used with the microscale fermentations. Tannin assays were used to compare phenolic extraction between the commercial fermentation and microscale fermentations of grapes thinned to 2CS.

Winter Pruning

Winter pruning was conducted when vines were completely dormant, and all vines were pruned to one bud spurs. Trimmings from each vine were weighed

Fig. 10. Cane diameter measured on a Zinfandel vine at the base of the cut. The cane was measured using a brake caliper.

and the weights used to calculate the Ravaz index (crop load). Cane diameters were measured using a brake caliper (Fig. 10). Cane diameters were measured at three different spurs on each vine.

Statistical Analysis

Data was analyzed using the PROC GLM procedure of the Statistical Analysis Software program (SAS Inst., Cary NC). Means were separated using Tukey's HSD Post Hoc Test. Both analyses were performed at the 0.05 percent confidence interval.

Chapter Four

Results and Discussion

Harvest

In 2007 and 2008, the highest yields were obtained from vines where the shoots were cluster thinned to 2 clusters with shoulders (2CS) (Table 1). Yields were equivalent to 6.4 and 6.6 tons per acre, respectively. In 2007, vines thinned to 1 cluster with shoulders per shoot (1CS) tended to yield more than vines thinned to 2 clusters without shoulders per shoot (2CNS). In 2007, yields averaged 4.8 and 4.4 tons per acre, respectively. However, in 2008 vines thinned to 1CS tended to yield less (4.4) tons per acre than vines thinned to 2CNS (4.9) tons per acre.

In 2007, vines thinned to 2CNS yielded fruit that weighed less than fruit harvested from vines thinned to 2CS and 1CS (Table 1). In 2008, vines thinned to 1CS yield less than vines thinned to 2CS and 2CNS.

The difference in yield from year to year for vines thinned to 1CS and 2CNS is attributable to both berry weight and number of berries per cluster (Table 1). Vines thinned to 1CS produced berries that weighed less in 2007 than berries produced in 2008; however, the number of berries per bunch remained constant in both years. In 2008, vines thinned to 2CNS produced fewer berries per bunch than vines thinned to 2CS and 1CS. Vines thinned to 2CNS produced berries that were heavier in 2008 than in 2007. Additionally, these berries were consistently heavier than berries from vines thinned to 1CS and 2CS. Overall,

Table 1. The effect of cluster thinning on individual cluster weight, yield per vine, berry weight, clusters per vine and berries per cluster.

Year	Cluster Treatment	Cluster Wt. (g)	yield/ vine (kg)	Berry Wt. (g)	Crop load (kg) ^y	Berries/ Cluster
2007	Two clusters with shoulders	230 ab ^z	6.16 a	2.51 a	7.35a	93.93 a
2007	One cluster with shoulders	250 a	5.22 ab	2.48 a	6.41 a	102.60 a
2007	Two clusters, no shoulders	200 b	4.35 b	2.48 a	6.17 a	83.75 a
2008	Two clusters with shoulders	238 a	6.59 a	2.40 a	8.42 a	100.59 a
2008	One cluster with shoulders	242 a	4.39 b	2.32 a	5.11 b	101.09 a
2008	Two clusters, no shoulders	188 b	4.85 ab	2.55 a	7.14 a	66.39 b

^z Means in a column with the same letter are not significantly different within a year at the 95% confidence level according to Tukey's HSD Post Hoc Test.

^y Yield: Pruning weight (Crop Load)

yield differences per vine and per acre could be attributed to yield compensation as affected by thinning.

The highest crop load was found on vines thinned to 2CS in 2007 and 2008 (Table 1). Vines thinned to 1CS tended to have a Ravaz index (crop load) slightly lower than vines thinned to 2CS. In 2008, the same vines had the lowest crop load. Vines thinned to 2CNS had the lowest Ravaz index in 2007; however, in 2008 the same vines had a Ravaz index slightly less than vines thinned to 2CS.

The crop loads found on vines thinned to 1CS and 2CNS were very similar in 2007; however, in 2008 vines thinned to 1CS had a much lower ratio than vines thinned to 2CNS (Table 1). Vines thinned to 1CS were expected to have a lower crop load than vines thinned to 2CNS because they were thinned more severely. Additionally, shoulder thinning may have had less of a hormonal affect on the vines. Fruit thinning changes source:sink relationships and often results in increased vegetative growth. Shoulder thinning only removes a portion of a cluster, which appears to result in a less dramatic hormonal reaction.

Cluster weights for vines thinned to 1CS were greater than cluster weights for vines thinned to 2CNS (Table 1). In both 2007 and 2008, vines thinned to 2CS tended to produce clusters that weighed slightly less than the clusters from vines thinned to 1CS. In 2008, vines thinned to 2CS produced clusters that weighed more than the clusters from vines thinned to 2CNS. Vines thinned to 2CNS produced clusters that consistently weighed the least in both years.

Although it was not measured, cluster fruitfulness appeared to decline with increasing distance from the cordon. This often resulted in smaller clusters with less lateral branching and this phenomenon has been observed by both Galet (1979) and Winkler et al. (1974). During the lag phase when clusters were removed from vines thinned to 1CS, in general, the cluster proximal to the cordon was retained on the vine. This cluster did not usually become tangled in the trellis wire and was more likely to have a larger shoulder. When vines were cluster thinned to 2CNS, the clusters furthest from the cordon were routinely disentangled from the trellis wire during thinning.

In 2007 and 2008, very little *Botrytis* bunch rot was observed in the vineyard. When present, *Botrytis* did not affect vines that were shoulder thinned to 2CNS. When vines were thinned to 2CS, however, *Botrytis* was observed when the bunch furthest away from the cordon was entangled in the trellis wire. The trellis wire also forced the canes together which often caused the clusters to become entangled in the canes increasing berry damage.

Botrytis sometimes occurred between the shoulder and the main cluster. It appeared that the rubbing of the shoulder and main cluster due to wind or mechanical movement resulted in berry damage, increasing the risk of *Botrytis* infection. *Botrytis* was not observed on vines thinned to 2CNS. Though the distal cluster on vines thinned to 2CNS had a similar proximity to the trellis wire as vines thinned to 2CS, vines thinned to 2CNS were usually separated from the trellis wire during lag phase (berries were firm) when the shoulders were

removed. When *Botrytis* was noticed for vines thinned to 2CS, the infection was not actively growing.

The quality of shoot thinning may have affected yields. All vines were pruned to one bud per spur. The vines often produced water shoots which can be less fruitful, bearing clusters without shoulders or bearing only one or no cluster per shoot (Galet, 1979). Water shoots accidentally retained may have contributed to the variation in the number of clusters per vine in 2007. Although vines were shoot thinned the same in both years, it is possible in some cases that water shoots were left on the vine and that the more fruitful shoot produced by the primary bud at a node was trimmed.

In 2007, grapevines thinned to 2CNS had the same number of clusters per vine as vines thinned to 1CS, while vines thinned to 2CS produced more clusters/vine (Table 1). Vines thinned to 2CS and 2CNS were expected to have the same number of clusters per vine because they were thinned to produce the same number of clusters per shoot.

In 2008, each vine produced the expected number of clusters (Table 1). In 2007, vines thinned to 2CNS produced only 21 clusters/vine. Vines thinned to 2CS and 2CNS were expected to have 28 clusters/vine. The resulting change in yield between vines thinned to 1CS and 2CNS from 2007 to 2008 may have been due to the lower number of clusters per vine found in 2007. Shoulder weight does not appear to be a major source of weight variation (Table 2). During both growing seasons there were no differences in berry weight (Table 1). In 2007, the differences tended to be slight and this suggests that there was no

yield compensation due to cluster thinning (Reynolds et al., 2007). During the 2008 growing season, more variation was observed among berry weights. Vines thinned to 2CNS tended to have the heaviest berries while vines thinned to 1CS tended to have the lightest berries.

Cluster Analysis

In California, there was a late frost in the 2008 growing season that decimated many vineyards and altered crop loads in others. The research site suffered minimal damage. However, there were subsequent growth effects such as shoots with only one bunch and notable differences in uniformity between the main cluster and the shoulder. It is possible that shoots with only one cluster may be the result of the late frost, which may have destroyed primary buds. Secondary buds are typically less fruitful.

The main cluster was more mature at harvest than the shoulder in all plots where a shoulder was retained. This effect was first observed during bloom. Berries of the main cluster were either pollinated or had begun to grow, while the shoulders were still in early bloom (Fig. 11). The same sequence was observed during ripening (Fig. 12). Often the main cluster was completely colored while the shoulder was in the softening and véraison stages.

These observations prompted additional analysis during the 2008 growing season. After the grapes were harvested 100 bunches per block were weighed and, additionally, shoulders were separated from the main cluster, counted, and weighed. The °Brix was measured for the main cluster and the shoulder.

In 2008, for °Brix of clusters on vines thinned to 2CS, the main cluster was to be higher (24.1) than the °Brix of the shoulder (22.3). For vines thinned to 1CS, the °Brix for the shoulder was 23.3 while the main cluster was 24.0.

On vines thinned to 2CS, 44% of the clusters had shoulders, which accounted for 20% of the overall weight of the fruit (Table 2). This equated to 1.34 tons of shoulders per 6.6 tons of fruit. For vines thinned to 1CS, 62% of the clusters had shoulders and this represented 19.6% of the overall weight of fruit from these vines or 0.86 tons of shoulders per 4.4 tons of fruit.

°Brix was measured on individual berries within clusters. On vines thinned to 2CS and 1CS the standard error for °Brix was 0.58 and 0.60, respectively. Vines thinned to 2CNS had a standard error for °Brix of 0.46, indicating a larger variation of °Brix within clusters on vines where shoulders were retained ($\Pr \geq F = 0.073$).

The differences in °Brix found between the main cluster and the shoulder for vines thinned to 1CS and 2CS, and the variation found between berries within a cluster, suggest that vines thinned to 2CNS had more uniformity within clusters than vines thinned to 2CS and 1CS. Cluster uniformity is important as uneven berry ripening results in undesirable flavor characteristics, which negatively affect must composition, flavor and aroma compounds and subsequent wine composition (Molinari, 2008).

Table 2. The effect of cluster thinning on pruning weight, crop load, percent clusters with shoulders and shoulder weight of Zinfandel fruit: 2007 and 2008.

Year	Cluster Treatment	Shoulder Wt. (g)	% Clusters with Shoulders	Clusters/ Vine
2007	Two clusters with shoulders	123 a	-	26.38 a ^z
2007	One cluster with shoulders	114 a	-	20.86 a
2007	Two clusters, no shoulders	n/a	-	20.94 a
2008	Two clusters with shoulders	104 a	44. b	27.27 ab
2008	One cluster with shoulders	79 a	62.0 a	19.94 b
2008	Two clusters, no shoulders	n/a	n/a	28.87 a

^z Means in a column with the same letter are not significantly different within a year at the 95% confidence level according to Tukey's HSD Post Hoc Test.

Fig. 11. A Zinfandel cluster illustrating differences in growth between the shoulder and the main cluster during bloom and fruit set, respectively (photo courtesy of B. Mauritson).

Fig. 12. A Zinfandel cluster that has ripened unevenly. The main cluster is more mature than the shoulder (photo courtesy of W. Weese.)

Grape Must Composition

The °Brix of the grape must, in either 2007 or 2008, was not affected by thinning treatment. However, the °Brix of grape must from vines thinned to 2CNS tended to be higher in 2007 and 2008 than the must from grapes of the other treatments (Table 3).

In 2007 and 2008, cluster thinning tended to increase °Brix (Table 3). Though not measured in 2007, vines thinned to 1CS had 23.5 kg of fruit per block (1.7 kg/vine) removed at lag phase in 2008. At the same time, vines thinned to 2CNS had 12.6 kg per block (0.63 kg/vine) removed at lag phase. In theory, all vines started out with an equal amount of fruit. Vines thinned to 1CS should have produced fruit with higher °Brix than fruit produced from vines thinned to 2CNS due to lower fruit load.

Cluster thinning did not have an effect on must total acidity or pH in 2007 (Table 3). In 2008, the TA was higher and pH was lower for fruit from vines thinned to 2CS when compared to fruit from vines thinned to 1CS.

After véraison, acids decrease, replacing stored carbohydrates as the main source of energy for grape berries (Winkler et al., 1974). The inverse relationship between TA and pH accounts for the differences observed in 2008 (Table 3). The smaller TA and larger pH observed for fruit from vines thinned to 1CS is a result of the increased level of °Brix and overall maturity of the fruit.

Table 3. Effect of cluster thinning on must composition.

Year	Cluster Treatment	°Brix	pH	TA (g/100 mL) ^y	Malic Acid (mg/100mL) ^x	Tartaric Acid (mg/100mL) ^y
2007	Two clusters with shoulders	23.5 a ^z	3.32 a	0.68 a	0.41 a	0.39 a
	One cluster with shoulders	25.5 a	3.35 a	0.68 a	0.46 a	0.39 a
	Two clusters, no shoulders	25.6 a	3.37 a	0.65 a	0.43 a	0.37 a
2008	Two clusters with shoulders	23.5 a	3.32 b	0.68 a	0.41 a	0.39 a
	One cluster with shoulders	24.8 a	3.46 a	0.57 b	0.41 a	0.35 a
	Two clusters, no shoulders	24.9 a	3.39 ab	0.62 ab	0.41 a	0.37 a

^z Means in a column with the same letter are not significantly different within a year at the 95% confidence level according to Tukey's HSD Post Hoc Test.

^y As determined by autotitrator.

^x As determined by High Performance Liquid Chromatography.

In 2007, cluster thinning did not affect the amino acid, potassium, ammonia, acetic acid or organic acid levels in grape must (Table 4). In 2008, ammonia levels in the must were lower when vines were thinned to 1CS compared to 2CS. Ammonia serves as the primary form of nitrogen for yeast metabolism (Ritchie, 2007). As grapes mature, ammonia decreases. Ammonia levels in grape must obtained from vines thinned to 1CS were lowest because the fruit was most mature at the time of harvest. This is consistent with the generally higher pH and lower TA observed for this fruit in 2008.

Excessive levels of potassium in grape-must can have negative impacts on wine quality. High potassium levels decrease free tartaric acid levels increasing pH (Wood and Matthews, 2003). The potassium levels found in the grape must produced from vines thinned to 1CS were not considered excessive because both pH and tartaric acid were well within acceptable ranges (Ritchie, 2007).

It is interesting to note that acetic acid was only present in grape must produced from fruit harvested from vines thinned to 1CS. In 2007, acetic acid was measurable in one plot where vines thinned to 1CS (Table 4). However, in 2008, acetic acid was present in all five plots thinned to 1CS. Levels of acetic acid were not detected in vines thinned to 2CS or 2CNS in either year.

Acetic acid is produced by acetic-acid bacteria [*Acetobacter aceti*] and is undesirable for winemaking because of its potential to produce off-flavors in wine. The presence of acetic acid was attributed to these bacteria growing in shriveled berries within clusters (Molinari, 2008). In 2008, compared to 2007,

Table 4. The effect of cluster thinning on amino acid, potassium, ammonia, acetic acid and organic acid in grape must.

Year	Cluster Treatment	Amino Acid (mg/L)	Potassium (mg/L)	Ammonia (g/100mL)	Acetic Acid	Organic Acid (g/100mL)
2007	Two clusters with shoulders	107 a ^z	1138 a	86.2 a	0.0000 a	0.80 a
2007	One cluster with shoulders	111 a	1182 a	84.8 a.	0.0012 a	0.81 a
2007	Two clusters, no shoulders	118 a	1188 a	86.0 a.	0.0000 a	0.80 a
2008	Two clusters with shoulders	107 a	1138 a	86.2 a.	0.0000 b	0.80 a
2008	One cluster with shoulders	113 a	1276 b	64.0 b.	0.0076 a	0.77 a
2008	Two clusters, no shoulders	108 a	1188 ab	78.8 ab.	0.0000 b	0.79 a

^z Means in a column with the same letter are not significantly different within a year at the 95% confidence level according to Tukey's HSD Post Hoc Test.

fruit ripening was very uneven resulting in both shriveled and unripe berries occurring within clusters

Wine Composition

There were no differences in wine composition as affected by cluster thinning treatment in either 2007 or 2008. However, in 2007, large polymeric pigments (LPP), small polymeric pigments (SPP), tannins and total phenolics tended to increase as yield and crop load decreased (Table 5). Wine produced from vines thinned to 2CS tended to contain consistently lower concentrations of polymeric pigments, tannins and total phenolics in both years (Table 5). Wine produced from vines thinned to 2CNS tended to contain the largest amount of polymeric pigments, tannins and total phenolics. Wine produced from vines thinned to 1CS had the largest amount of anthocyanins, while wine from vines thinned to 2CS had the least amount of anthocyanins. Data was not statistically analyzed for the 2007 vintage because grape must was pooled for winemaking.

In 2007, wines from vines thinned to 2CNS tended to contain the largest amount of LPP, SPP, tannins and anthocyanins (Table 5). These vines also had the smallest crop load in 2007 (Table 1). In 2008, wines from vines thinned to 1CS tended to contain the largest amount of LPP, SPP, tannins, anthocyanins, and total phenolics (Table 5). These vines also had the smallest crop load in that year indicating the importance of crop load as an indicator of wine composition which has been correlated with wine quality (Bravdo et al., 1985). The same

Table 5. Effect of cluster thinning on the composition of wine produced from the grapes.

Year	Cluster Treatment	Large Polymeric Pigments ^z	Small Polymeric Pigments ^z	Anthocyanins (mg/L) ^y	Tannins (mg/L) ^x	Total Phenolics (mg/L) ^x
2007	Two cluster with shoulders	1.00 ^w	0.52	98	504	2115
2007	One cluster with shoulders	1.18	0.61	109	569	2455
2007	Two clusters, no shoulders	1.28	0.65	105	616	2592
2008	Two cluster with shoulders	0.42 a ^v	0.46 a	262.8 a	251.4 a	1105.8 a
2008	One cluster with shoulders	0.66 a	0.71 a	307.0 a	293.2 a	1235.4 a
2008	Two clusters, no shoulders	0.51 a	0.51 a	252.0 a	206.4 a	1110.0 a

^z Values represent absorbance units measured by High Performance Liquid Chromatograph at 520nm

^y mg/L malvidin-3-glucoside equivalents as determined by High Performance Liquid Chromatography at 510nm.

^x mg/L catechin equivalents as determined by High Performance Liquid Chromatography at 510nm.

^w Wine samples were pooled for 2007, only.

^v Means in a column with the same letter are not significantly different at the 95% confidence level according to Tukey's HSD Post Hoc Test.

relationship holds true for yield per vine: as yields decreased, wine components increased.

Wine composition changed from year to year. In 2007, the components of the wine were nearly double the amounts found in the wine produced in 2008. These values are puzzling as the maturity levels of the fruit, from year to year, were consistent based on °Brix, pH and acid (Table 1). It appears there were differences in the quality of the grapes in 2007 and 2008, and that normal methods to determine fruit maturity do not indicate these potential differences.

Commercial Wine 2008

In 2008, wine was made in a 1 ton macro bin or in 4L micro-fermentors using excess fruit from vines thinned to 2CS, only. Whether commercially fermented or fermented on a micro scale, the levels of components that were measured within the wines were essentially the same (data not shown). This indicated that microscale fermentation was an inexpensive and easy method of fermenting grape must for the purpose of quantitative analysis. This agrees with previous work by Sampaio et al., 2007.

Leaf Blade Analysis

In 2008, leaf blade analysis was performed during véraison and no differences in elemental content were found, regardless of thinning treatment (Table 6).

Table 6. The effects of cluster thinning on the nutrient composition of Zinfandel grape leaf blades: 2008.

Cluster Treatment	Boron (ppm)	Calcium (%)	Chloride (%)	Copper (ppm)	Iron (ppm)	Potassium (%)
Two cluster with shoulders	29.42 a ^z	1.89 a	0.22 a	5.29 a	268.6 a	0.89 a
One cluster with shoulders	28.54 a	1.79 a	0.21 a	5.13 a	225.2 a	0.94 a
Two clusters, no shoulders	28.22 a	1.87 a	0.20 a	5.11 a	245.4 a	0.88 a

Cluster Treatment	Mg (%)	Mn (ppm)	Nitrogen (%)	Sodium (%)	K (%)	Sulfur (%)	Zinc (ppm)
Two clusters with shoulders	0.31 a	194.0 a	2.70 a	0.00 a	0.15 a	0.16 a	16.02 a
One cluster with shoulders	0.33 a	186.0 a	2.78 a	0.00 a	0.15 a	0.16 a	15.21 a
Two clusters, no shoulders	0.34 a	209.6 a	2.76 a	0.00 a	0.15 a	0.16 a	15.04 a

^z Means in a column with the same letter are not significantly different at the 95% confidence level according to Tukey's HSD Post Hoc Test.

Chapter Five

Conclusions

Cluster thinning Zinfandel grapevines during lag phase in the Rockpile appellation led to reductions in yield and crop load and increased °Brix of the fruit. In both years, wines that were made from vines with the lowest crop load (Table 1) had consistently higher amounts of small and large polymeric pigments, tannins and total iron-reactive phenolics (Table 5).

In general, cluster thinning vines consistently increased polymeric pigments and total phenolics (Table 5). In both years, vines thinned to one cluster with shoulders per shoot produced grapes that had acetic acid while vines thinned to 2CNS and 2CS did not produce grapes that had detectable levels of acetic acid. Removing the shoulders of clusters resulted in improved uniformity within clusters compared to vines where shoulders were retained.

As expected, cluster thinning vines to 2CNS at lag phase consistently decreased the number of berries per cluster and cluster weight. Thinning vines to 1CS resulted in fewer clusters per vine in 2008.

Cluster thinning may be economically feasible in areas where vines are noticeably stressed such as dry-farmed vineyards, areas with a high incidence of *Botrytis* bunch rot, and/or vineyards that ripen late in the season. Shoulder thinning (vines thinned to 2CNS) resulted in higher yields than removing entire clusters (vines thinned to 1CS); however, shoulder thinning is more labor

intensive. If the cost of thinning could be sustained by an increase in grape prices, thinning could potentially increase berry uniformity and subsequent wine components leading to improved flavor. Further research is needed to determine overall effects of shoulder thinning on perceived grape quality and subsequent wine composition contributing to overall flavor.

Shoulder thinning should be investigated using other varieties and in areas with a high risk of *Botrytis* bunch rot. *Botrytis* tends to develop in vigorous varieties and in vineyards with poor canopy management. It also develops between the shoulder or wing and the main cluster in certain varieties. Shoulder removal in areas with a high risk of *Botrytis* should conclusively determine if this thinning method helps to decrease disease incidence.

Measuring °Brix, pH and total acidity of the primary (proximal to the cordon) and secondary clusters (furthest cluster from the cordon) for uniformity within the clusters would determine if proximity to the cordon influences uniformity at low yields. Additional research is also recommended with other varieties to assess possible differences between shoulder thinning and removing entire clusters on berry composition, yield, subsequent wine composition and crop load.

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Appendix A: 2007 Juice Panel

Analysis performed at Vinquiry:

Vinquiry, Inc.

7795 Bell Road

Windsor, CA 95492

Client: Keith Patterson

Work order number: W2007-090140040

Samples received: September 14, 2007

Vines thinned to 2 clusters per shoot with shoulders

1

Brix	25.1	°Brix	Refractometer*
pH	3.37		Autotitrator
Titrateable Acidity	0.617	g/100mL	Autotitrator
Ammonia	78	mg/L	ISE*
Amino Nitrogen	105	mg/L	Spectrometer*
Potassium	1155	mg/L	AA*
Tartaric Acid	0.406	g/100mL	HPLC*
Malic Acid	0.364	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.77	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders

2

Brix	22.8	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.747	g/100mL	Autotitrator
Ammonia	92	mg/L	ISE*
Amino Nitrogen	113	mg/L	Spectrometer*
Potassium	1199	mg/L	AA*
Tartaric Acid	0.373	g/100mL	HPLC*
Malic Acid	0.499	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.872	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders**3**

Brix	23.3	°Brix	Refractometer*
pH	3.25		Autotitrator
Titrateable Acidity	0.761	g/100mL	Autotitrator
Ammonia	85	mg/L	ISE*
Amino Nitrogen	109	mg/L	Spectrometer*
Potassium	1079	mg/L	AA*
Tartaric Acid	0.398	g/100mL	HPLC*
Malic Acid	0.435	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.833	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders**4**

Brix	23.2	°Brix	Refractometer*
pH	3.36		Autotitrator
Titrateable Acidity	0.639	g/100mL	Autotitrator
Ammonia	84	mg/L	ISE*
Amino Nitrogen	106	mg/L	Spectrometer*
Potassium	1137	mg/L	AA*
Tartaric Acid	0.382	g/100mL	HPLC*
Malic Acid	0.361	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.743	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders**5**

Brix	23.5	°Brix	Refractometer*
pH	3.33		Autotitrator
Titrateable Acidity	0.675	g/100mL	Autotitrator
Ammonia	92	mg/L	ISE*
Amino Nitrogen	105	mg/L	Spectrometer*
Potassium	1121	mg/L	AA*
Tartaric Acid	0.404	g/100mL	HPLC*
Malic Acid	0.399	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.803	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders**1**

Brix	26	°Brix	Refractometer*
pH	3.36		Autotitrator
Titrateable Acidity	0.675	g/100mL	Autotitrator
Ammonia	83	mg/L	ISE*
Amino Nitrogen	113	mg/L	Spectrometer*
Potassium	1209	mg/L	AA*
Tartaric Acid	0.396	g/100mL	HPLC*
Malic Acid	0.436	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.832	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders**2**

Brix	24.9	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.657	g/100mL	Autotitrator
Ammonia	75	mg/L	ISE*
Amino Nitrogen	102	mg/L	Spectrometer*
Potassium	1054	mg/L	AA*
Tartaric Acid	0.413	g/100mL	HPLC*
Malic Acid	0.394	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.85	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders**3**

Brix	24.5	°Brix	Refractometer*
pH	3.28		Autotitrator
Titrateable Acidity	0.706	g/100mL	Autotitrator
Ammonia	88	mg/L	ISE*
Amino Nitrogen	103	mg/L	Spectrometer*
Potassium	1061	mg/L	AA*
Tartaric Acid	0.423	g/100mL	HPLC*
Malic Acid	0.427	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.85	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders

4

Brix	27.7	°Brix	Refractometer*
pH	3.38		Autotitrator
Titrateable Acidity	0.702	g/100mL	Autotitrator
Ammonia	94	mg/L	ISE*
AsAmino Nitrogen	121	mg/L	Spectrometer*
Potassium	1206	mg/L	AA*
Tartaric Acid	0.383	g/100mL	HPLC*
Malic Acid	0.495	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0.006	detected	HPLC*
Orgc Acid	0.884	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders

5

Brix	24.4	°Brix	Refractometer*
pH	3.45		Autotitrator
Titrateable Acidity	0.681	g/100mL	Autotitrator
Ammonia	84	mg/L	ISE*
Amino Nitrogen	116	mg/L	Spectrometer*
Potassium	1381	mg/L	AA*
Tartaric Acid	0.34	g/100mL	HPLC*
Malic Acid	0.557	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.897	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders

1

Brix	26.8	°Brix	Refractometer*
pH	3.46		Autotitrator
Titrateable Acidity	0.639	g/100mL	Autotitrator
Ammonia	93	mg/L	ISE*
Amino Nitrogen	133	mg/L	Spectrometer*
Potassium	1285	mg/L	AA*
Tartaric Acid	0.359	g/100mL	HPLC*
Malic Acid	0.458	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.817	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders**2**

Brix	26.4	°Brix	Refractometer*
pH	3.45		Autotitrator
Titrateable Acidity	0.648	g/100mL	Autotitrator
Ammonia	95	mg/L	ISE*
Amino Nitrogen	133	mg/L	Spectrometer*
Potassium	1228	mg/L	AA*
Tartaric Acid	0.352	g/100mL	HPLC*
Malic Acid	0.449	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.801	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders**3**

Brix	24.2	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.666	g/100mL	Autotitrator
Ammonia	80	mg/L	ISE*
Amino Nitrogen	104	mg/L	Spectrometer*
Potassium	1158	mg/L	AA*
Tartaric Acid	0.404	g/100mL	HPLC*
Malic Acid	0.419	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.823	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders**4**

Brix	25.3	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.669	g/100mL	Autotitrator
Ammonia	81	mg/L	ISE*
Amino Nitrogen	110	mg/L	Spectrometer*
Potassium	1135	mg/L	AA*
Tartaric Acid	0.389	g/100mL	HPLC*
Malic Acid	0.416	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.805	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders

5

Brix	25.3	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.669	g/100mL	Autotitrator
Ammonia	81	mg/L	ISE*
Amino Nitrogen	110	mg/L	Spectrometer*
Potassium	1135	mg/L	AA*
Tartaric Acid	0.389	g/100mL	HPLC*
Malic Acid	0.416	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.805	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Appendix B: 2008 Juice Panel

Analysis performed at Vinqury:

Vinqury, Inc.
7795 Bell Road
Windsor, CA 95492

Client: Keith Patterson
Work order number: W2008-090140040
Samples received: September 112, 2008

Vines thinned to 2 clusters per shoot with shoulders

1

Brix	25.1	°Brix	Refractometer*
pH	3.37		Autotitrator
Titrateable Acidity	0.617	g/100mL	Autotitrator
Ammonia	78	mg/L	ISE*
Amino Nitrogen	105	mg/L	Spectrometer*
Potassium	1155	mg/L	AA*
Tartaric Acid	0.406	g/100mL	HPLC*
Malic Acid	0.364	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.77	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders

2

Brix	22.8	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.747	g/100mL	Autotitrator
Ammonia	92	mg/L	ISE*
Amino Nitrogen	113	mg/L	Spectrometer*
Potassium	1199	mg/L	AA*
Tartaric Acid	0.373	g/100mL	HPLC*
Malic Acid	0.499	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.872	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders**3**

Brix	23.3	°Brix	Refractometer*
pH	3.25		Autotitrator
Titrateable Acidity	0.761	g/100mL	Autotitrator
Ammonia	85	mg/L	ISE*
Amino Nitrogen	109	mg/L	Spectrometer*
Potassium	1079	mg/L	AA*
Tartaric Acid	0.398	g/100mL	HPLC*
Malic Acid	0.435	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.833	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders**4**

Brix	23.2	°Brix	Refractometer*
pH	3.36		Autotitrator
Titrateable Acidity	0.639	g/100mL	Autotitrator
Ammonia	84	mg/L	ISE*
Amino Nitrogen	106	mg/L	Spectrometer*
Potassium	1137	mg/L	AA*
Tartaric Acid	0.382	g/100mL	HPLC*
Malic Acid	0.361	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.743	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot with shoulders**5**

Brix	23.5	°Brix	Refractometer*
pH	3.33		Autotitrator
Titrateable Acidity	0.675	g/100mL	Autotitrator
Ammonia	92	mg/L	ISE*
Amino Nitrogen	105	mg/L	Spectrometer*
Potassium	1121	mg/L	AA*
Tartaric Acid	0.404	g/100mL	HPLC*
Malic Acid	0.399	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.803	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders**1**

Brix	24.1	°Brix	Refractometer*
pH	3.46		Autotitrator
Titrateable Acidity	0.569	g/100mL	Autotitrator
Ammonia	70	mg/L	ISE*
Amino Nitrogen	114	mg/L	Spectrometer*
Potassium	1271	mg/L	AA*
Tartaric Acid	0.347	g/100mL	HPLC*
Malic Acid	0.41	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0.012	detected	HPLC*
Orgc Acid	0.769	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders**2**

Brix	25.4	°Brix	Refractometer*
pH	3.5		Autotitrator
Titrateable Acidity	0.57	g/100mL	Autotitrator
Ammonia	66	mg/L	ISE*
Amino Nitrogen	118	mg/L	Spectrometer*
Potassium	1332	mg/L	AA*
Tartaric Acid	0.34	g/100mL	HPLC*
Malic Acid	0.418	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0.007	detected	HPLC*
Orgc Acid	0.765	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders**3**

Brix	24.6	°Brix	Refractometer*
pH	3.42		Autotitrator
Titrateable Acidity	0.57	g/100mL	Autotitrator
Ammonia	59	mg/L	ISE*
Amino Nitrogen	106	mg/L	Spectrometer*
Potassium	1170	mg/L	AA*
Tartaric Acid	0.357	g/100mL	HPLC*
Malic Acid	0.392	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0.006	detected	HPLC*
Orgc Acid	0.755	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders

4

Brix	25	°Brix	Refractometer*
pH	3.42		Autotitrator
Titrateable Acidity	0.592	g/100mL	Autotitrator
Ammonia	69	mg/L	ISE*
Amino Nitrogen	114	mg/L	Spectrometer*
Potassium	1211	mg/L	AA*
Tartaric Acid	0.407	g/100mL	HPLC*
Malic Acid	0.392	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0.006	detected	HPLC*
Orgc Acid	0.805	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 1 cluster per shoot with shoulders

5

Brix	25.1	°Brix	Refractometer*
pH	3.52		Autotitrator
Titrateable Acidity	0.573	g/100mL	Autotitrator
Ammonia	56	mg/L	ISE*
Amino Nitrogen	115	mg/L	Spectrometer*
Potassium	1398	mg/L	AA*
Tartaric Acid	0.333	g/100mL	HPLC*
Malic Acid	0.444	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0.007	detected	HPLC*
Orgc Acid	0.784	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders

1

Brix	26.8	°Brix	Refractometer*
pH	3.46		Autotitrator
Titrateable Acidity	0.639	g/100mL	Autotitrator
Ammonia	93	mg/L	ISE*
Amino Nitrogen	133	mg/L	Spectrometer*
Potassium	1285	mg/L	AA*
Tartaric Acid	0.359	g/100mL	HPLC*
Malic Acid	0.458	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.817	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders**2**

Brix	26.4	°Brix	Refractometer*
pH	3.45		Autotitrator
Titrateable Acidity	0.648	g/100mL	Autotitrator
Ammonia	95	mg/L	ISE*
Amino Nitrogen	133	mg/L	Spectrometer*
Potassium	1228	mg/L	AA*
Tartaric Acid	0.352	g/100mL	HPLC*
Malic Acid	0.449	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.801	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders**3**

Brix	24.2	°Brix	Refractometer*
pH	3.32		Autotitrator
Titrateable Acidity	0.666	g/100mL	Autotitrator
Ammonia	80	mg/L	ISE*
Amino Nitrogen	104	mg/L	Spectrometer*
Potassium	1158	mg/L	AA*
Tartaric Acid	0.404	g/100mL	HPLC*
Malic Acid	0.419	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.823	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders**4**

Brix	23	°Brix	Refractometer*
pH	3.38		Autotitrator
Titrateable Acidity	0.594	g/100mL	Autotitrator
Ammonia	63	mg/L	ISE*
Amino Nitrogen	85	mg/L	Spectrometer*
Potassium	1158	mg/L	AA*
Tartaric Acid	0.387	g/100mL	HPLC*
Malic Acid	0.378	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.765	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Vines thinned to 2 clusters per shoot without shoulders

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Brix	24.1	°Brix	Refractometer*
pH	3.35		Autotitrator
Titrateable Acidity	0.599	g/100mL	Autotitrator
Ammonia	63	mg/L	ISE*
Amino Nitrogen	87	mg/L	Spectrometer*
Potassium	1113	mg/L	AA*
Tartaric Acid	0.396	g/100mL	HPLC*
Malic Acid	0.364	g/100mL	HPLC*
Lactic Acid	0	detected	HPLC*
Acetic Acid	0	detected	HPLC*
Orgc Acid	0.76	g/100mL	HPLC*
Botr Risk Asse(+/-)	0	Negative	*

Appendix C: 2007 Tannin Assay

Keith Patterson*
Analysis Performed at:
Vinqury, Inc.
7795 Bell Road
Windsor, CA 95492

HCS 1 Grand Am
San Luis Obispo, CA 93407

Work Order # : W2007-09-27-099
Sample (s) Received: September 27, 2007
Report Printed: January 15, 2008

Preliminary Analysis Report

Vines thinned to 2 clusters per shoot with shoulders

1 Adam's Tannin Assay *

Large Polymeric Pigment:	1.2800	Absorbance Units
Small Polymeric Pigment:	0.65	Absorbance Units
Total Anthocyanins:	105	mg/L Malvidin-3-glucoside
Total Tannin:	616	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	2592	mg/L Catechin Equivalents

Vines thinned to 1 cluster per shoot with shoulders

1 Adam's Tannin Assay *

Large Polymeric Pigment:	1.1800	Absorbance Units
Small Polymeric Pigment:	0.61	Absorbance Units
Total Anthocyanins:	109	mg/L Malvidin-3-glucoside
Total Tannin:	569	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	2455	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot without shoulders

1 Adam's Tannin Assay *

Large Polymeric Pigment:	1.0000	Absorbance Units
Small Polymeric Pigment:	0.52	Absorbance Units
Total Anthocyanins:	98	mg/L Malvidin-3-glucoside
Total Tannin:	504	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	2115	mg/L Catechin Equivalents

Appendix D: 2008 Tannin Assay

Keith Patterson*
Analysis Performed at:
Vinquity, Inc.
7795 Bell Road
Windsor, CA 95492

HCS 1 Grand Am
San Luis Obispo, CA 93407

Work Order # : W2008-10-09-078
Sample (s) Received: October 09, 2008
Report Printed: October 13, 2008

Preliminary Analysis Report

Vines thinned to 2 clusters per shoot with shoulders

1 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.7700	Absorbance Units
Small Polymeric Pigment:	0.52	Absorbance Units
Total Anthocyanins:	242	mg/L Malvidin-3-glucoside
Total Tannin:	261	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1064	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot with shoulders

2 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.4900	Absorbance Units
Small Polymeric Pigment:	0.46	Absorbance Units
Total Anthocyanins:	236	mg/L Malvidin-3-glucoside
Total Tannin:	213	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1096	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot with shoulders

3 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.4400	Absorbance Units
Small Polymeric Pigment:	0.57	Absorbance Units
Total Anthocyanins:	282	mg/L Malvidin-3-glucoside
Total Tannin:	541	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1413	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot with shoulders

4 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.3800	Absorbance Units
Small Polymeric Pigment:	0.48	Absorbance Units
Total Anthocyanins:	321	mg/L Malvidin-3-glucoside
Total Tannin:	227	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1322	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot with shoulders

5 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.0400	Absorbance Units
Small Polymeric Pigment:	0.28	Absorbance Units
Total Anthocyanins:	233	mg/L Malvidin-3-glucoside
Total Tannin:	15	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	634	mg/L Catechin Equivalents

Vines thinned to 1 cluster per shoot with shoulders

1 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.7600	Absorbance Units
Small Polymeric Pigment:	0.51	Absorbance Units
Total Anthocyanins:	246	mg/L Malvidin-3-glucoside
Total Tannin:	460	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1456	mg/L Catechin Equivalents

Vines thinned to 1 cluster per shoot with shoulders

2 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.6500	Absorbance Units
Small Polymeric Pigment:	0.83	Absorbance Units
Total Anthocyanins:	362	mg/L Malvidin-3-glucoside
Total Tannin:	369	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1423	mg/L Catechin Equivalents

Vines thinned to 1 cluster per shoot with shoulders

3 Adam's Tannin Assay *		
Large Polymeric Pigment:	0.7500	Absorbance Units
Small Polymeric Pigment:	0.8	Absorbance Units

Total Anthocyanins:	321	mg/L	Malvidin-3-glucoside
Total Tannin:	355	mg/L	Catechin Equivalents
Total Iron-Reactive Phenolics:	1261	mg/L	Catechin Equivalents

Vines thinned to 1 cluster per shoot with shoulders

4 Adam's Tannin Assay *			
Large Polymeric Pigment:	0.5300		Absorbance Units
Small Polymeric Pigment:	0.8		Absorbance Units
Total Anthocyanins:	324	mg/L	Malvidin-3-glucoside
Total Tannin:	149	mg/L	Catechin Equivalents
Total Iron-Reactive Phenolics:	1083	mg/L	Catechin Equivalents

Vines thinned to 1 cluster per shoot with shoulders

5 Adam's Tannin Assay *			
Large Polymeric Pigment:	0.6200		Absorbance Units
Small Polymeric Pigment:	0.62		Absorbance Units
Total Anthocyanins:	282	mg/L	Malvidin-3-glucoside
Total Tannin:	133	mg/L	Catechin Equivalents
Total Iron-Reactive Phenolics:	954	mg/L	Catechin Equivalents

Vines thinned to 2 clusters per shoot without shoulders

1 Adam's Tannin Assay *			
Large Polymeric Pigment:	0.5000		Absorbance Units
Small Polymeric Pigment:	0.81		Absorbance Units
Total Anthocyanins:	296	mg/L	Malvidin-3-glucoside
Total Tannin:	212	mg/L	Catechin Equivalents
Total Iron-Reactive Phenolics:	1207	mg/L	Catechin Equivalents

Vines thinned to 2 clusters per shoot without shoulders

2 Adam's Tannin Assay *			
Large Polymeric Pigment:	0.5600		Absorbance Units
Small Polymeric Pigment:	0.45		Absorbance Units
Total Anthocyanins:	195	mg/L	Malvidin-3-glucoside
Total Tannin:	188	mg/L	Catechin Equivalents
Total Iron-Reactive Phenolics:	1000	mg/L	Catechin Equivalents

Vines thinned to 2 clusters per shoot without shoulders

3 Adam's Tannin Assay *			
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Large Polymeric Pigment:	0.5400	Absorbance Units
Small Polymeric Pigment:	0.37	Absorbance Units
Total Anthocyanins:	283	mg/L Malvidin-3-glucoside
Total Tannin:	134	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1156	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot without shoulders

4 Adam's Tannin Assay *

Large Polymeric Pigment:	0.56	Absorbance Units
Small Polymeric Pigment:	0.45	Absorbance Units
Total Anthocyanins:	241	mg/L Malvidin-3-glucoside
Total Tannin:	411	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	1296	mg/L Catechin Equivalents

Vines thinned to 2 clusters per shoot without shoulders

5 Adam's Tannin Assay *

Large Polymeric Pigment:	0.39	Absorbance Units
Small Polymeric Pigment:	0.51	Absorbance Units
Total Anthocyanins:	245	mg/L Malvidin-3-glucoside
Total Tannin:	87	mg/L Catechin Equivalents
Total Iron-Reactive Phenolics:	891	mg/L Catechin Equivalents