AN ABSTRACT OF THE THESIS OF

Erik W. Brasher for the degree of Master of Science in Horticulture presented on April 16, 2002. Title: Effect of Crop Level on Yield Components, Fruit and Wine Composition, and Wood Carbohydrate Reserves of Pinot noir Grapes.

Abstract Approved:

Carmo Vasconcelos

Crop thinning trials were studied during two seasons at two locations in the northern Willamette Valley of Oregon. At Willakenzie Estate (site #1), research vines were Pinot noir clone Dijon 113 on 3309 rootstocks trained to a double Guyot. Vines were established in 1996 at a spacing of 2.5 x 1.67 m (5 x 7.5 ft). The soil type was a Willakenzie silt loam. At Hyland Vineyard (site #2), the experimental vines were Pinot noir clones (Coury selection) on their own roots trained to a modified Lenz-Moser with two short arms supporting two canes each, similar to the standard Chablis training system. The first fruiting cane arises from the proximal part of the arm (closest to the trunk), and the second from the distal part of the permanent arm. In this training system, there is no overlapping of the four canes. Vines were established in 1974 at a spacing of 3.33 x 3.33 m (10 x 10 ft). The soil type was a Jory silt loam. At both sites, crop was reduced at véraison (50% color). At site #2, on the second season, vines were thinned at bloom or at véraison in a factorial design. Wine was made from both thinning dates from the highest and lowest crop load levels. Yields ranged from 2.2 to 6.6 tonnes / ha (0.98

to 2.95 tons/ acre). Yield components at both sites that were significantly affected by crop level were those expected to be strongly correlated with cluster thinning such as yield per vine, clusters per shoot, and Ravaz Index (grams of fruit / grams of 2-year old prunings). Berries per cluster and cluster weights were significantly increased in response to increases in cluster thinning severity at site #1 in the first season. At site #2 the grape cluster weights increased in response to increases in cluster thinning severity during both seasons. In the same vineyard, the number of berries per cluster increased in response to increases in cluster thinning severity. These changes in cluster weights and the number of berries per cluster in response to fruit thinning were an artifact caused by selectively removing underdeveloped, late maturing clusters, thus increasing the mean cluster weight of the remaining clusters. Berry weights did not increase when clusters were thinned at véraison indicating that yield compensation did not occur. At site #1 during the first season, juice pH increase from 3.14 to 3.16, when thinning reduced yield from 2.77 to 1.25 tons / acre. During the second season at site #1, soluble solids increased from 23.2 to 24 °Brix when thinning reduced yield from 3.17 to 1.43 tons / acre. There was no response to cluster thinning on fruit composition at site #2. Despite the wide range of crop load, cluster thinning had no impact on vine vigor or wood carbohydrate reserves over the two-year period at both vineyards. There was an increase in total anthocyanins and color intensity in wine from fruit thinned at bloom as compared to véraison thinning.

Effect of Crop Level on Yield Components, Fruit and Wine Composition, and Wood Carbohydrate Reserves of Pinot noir Grapes

By

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

Erik W. Brasher, Author

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Dr. Carmo Vasconcelos was involved in the design and writing of this thesis. Dr. Bernadine Strik and Barney Watson assisted in the writing and the statistical evaluation of the data. Daniel Fey and Jack Trenhaile assisted in the maintenance of the vineyard trials.

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INTRODUCTION

A broad range of factors influence wine grape quality and the manipulation of these factors to improve quality has been of interest among grape growers, wine makers, and research scientists alike. Of all factors affecting fruit ripening, crop level is one of the most important one which growers can manipulate (Winkler *et al.*, 1974). Many experiments have been conducted to determine the ideal crop load of several cultivars grown in various climates (Winkler *et al.*, 1974; Bravdo *et al.*, 1984 and 1985; Edson *et al.*, 1995; Reynolds *et al.*, 1989, 1994 and 1996; Koblet *et al.*, 1996; Miller *et al.*, 1993, 1996 and 1998). The majority of these studies however have examined the effects of thinning clusters at fruit set. Results from these studies showed that the vines exhibited yield compensation, producing heavier clusters with larger berries, a trait not necessarily desirable for red wine production. To avoid yield compensation, clusters can be thinned at véraison, after the final number of cells per berry has been established. At this point, further growth is by cell enlargement due to the import of sugars and water. This growth is accompanied by other changes in fruit composition such as a decrease in acid levels, an increase in anthocyanin levels, and accumulation in aroma and flavor compounds (Winkler *et al.*, 1974) each contributing to the quality of the grape. Another process occurring simultaneously with fruit ripening is the replenishment of carbohydrate reserves in the permanent structure, crucial for plant survival and yield stability (Candolfi-Vasconcelos and Koblet, 1990). Heavy or unbalanced crop loads affect the level of reserves available in the following spring.

Of all the wine-grape varieties, Pinot noir has the reputation of being one of the most challenging to grow, both for the grape grower and the wine maker. Heat summation plays an important role in the accumulation of sugar and the rate of other metabolic processes occurring during ripening. In cool climate regions, some cultivars are slow to ripen and cluster thinning may be employed to advance ripening (Winkler *et al.*, 1974; Reynolds *et al.*, 1989). In cool climate regions with rainy harvest seasons, where poor canopy management and fungus infestation threatens fruit soundness, cluster thinning to advance maturity is a common practice. In addition, Oregon wineries prefer to buy grapes from low yielding vineyards, encouraging growers to thin their crop. While this practice is acceptable, an optimal yield for a targeted quality has yet to be determined in Pinot noir. The objectives of this research project were to study the effect of cluster thinning on fruit yield, yield components, fruit and wine composition and carbohydrate content of the permanent structure in Pinot noir vines.

LITERATURE REVIEW

CROP LOAD IMPACTS ON FRUIT QUALITY

As stated in the introduction, cluster thinning, among many reasons, is employed primarily to eliminate clusters less advanced in ripening, which in turn hastens ripening or evens out ripening by removing clusters that are behind. Within a region whose growing season often is punctuated by cold autumn rains, the earlier the harvest, the less susceptible the fruit is to bunch rot. There are several tools the viticulturist can use to hasten ripening and reduce disease. Thinning flower clusters around the time of bloom, as well as maintaining an open canopy, are ideal methods to reduce the susceptibility of disease. Reynolds *et al.* (1986) found that postbloom thinning treatments were effective at controlling bunch rot with decreases in infected clusters per vine and percent infection when compared to prebloom thinning. Winkler (1974) proposed that flower cluster thinning increases the length of the remaining clusters, thereby improving airflow between berries, reducing disease potential. Cluster thinning at bloom also improves the fruit set of those inflorescences remaining on the vine. The percentage of fruit that sets on any given cluster is determined by the availability of carbohydrates and other organic nutrients to the developing cluster (Mullins *et al.* 1979). Research has shown that a reduction in fruit set could be due to the competition for carbohydrates between vegetative and reproductive tissues (Coombe, 1973 and Edson *et al.* 1995). Fruit thinning can lead to imbalances between vegetative and reproductive growth. Fruit thinning 'de Chaunac' before anthesis (cap fall) increased vine vigor as measured by annual increases in pruning weights per vine over 15 years of crop thinning (Fisher *et al.*, 1989). As mentioned previously, early thinning does provide advantages in reducing disease. However, thinning at bloom may lead to yield compensation (Bravdo *et al.*, 1984; Reynolds *et al.*, 1989 & 1994). Weaver and Pool (1974) indicated that for maximum increase in berry size, fruit thinning should be done between bloom and fruit set. For table grapes, size is important. However, for wine grapes, it is preferable for berry size to remain small allowing for greater concentrations of solute per unit berry. Smaller berries increase the skin:juice ratio during fermentation, a desirable attribute allowing for greater levels of phenolic compounds to be extracted (Boulton *et al.*, 1998). Physiological responses to the timing of thinning is a subject that has been rarely addressed in cool climates.

It has been demonstrated that excessive crop loads reduce fruit quality (Koblet *et al.*, 1996) and maturity (Bravdo *et al.*, 1984 & 85; Edson et al., 1995; Freeman and Kliewer, 1993; Kliewer and Ough, 1970 and Ough and Nagaoka, 1984) and that fruit thinning hastens ripening rates, leading to advanced maturity during harvest (Reynolds *et al.*, 1989). Juice components of the fruit vary in their response to crop thinning. Previous studies have found contradictory results. Bravdo *et al.*, (1984 and 1985), Buttrose (1968), and Reynolds *et al.*, (1986) did not find a response of soluble solids to cluster removal. Edson *et al.* (1995), Fisher *et al.* (1977), Miller *et al.* (1998), Reynolds *et al.*, 1989, Reynolds *et al.* (1994) and

Reynolds and Wardle, (1989) in contrast reported negative correlation between crop level and sugar accumulation. The added increase in soluble solids in response to thinning must be economically advantageous to warrant removal of clusters during the growing season. Similar to sugar content, must pH and titratable acidity has had varied responses to fruit thinning. Bravdo *et al.* (1984) and others (Freeman and Kliewer, 1983 and Reynolds *et al.*, 1986) monitored no change of juice pH with increases in crop load. Still others (Edson *et al.*, 1995; Kliewer and Ough, 1970; Ough and Nagaoka, 1984; Reynolds, 1989; Reynolds *et al.*, 1994 and Reynolds and Wardle, 1989) report a negative correlation between pH and crop load. Sugar accumulation within the berry itself will not insure a high quality harvest. Other juice constituents are affected by crop level as well. Reynolds (1989) found that thinning 'Gewürztraminer' thirty days after bloom increased the levels of free volatile terpenes (FVT) in the must compared to un-thinned vines. Reynolds *et al.* (1986) also found that Brix, pH and anthocyanin levels of must as well as hue and color intensity was negatively correlated with crop load. From the studies presented, it is apparent that juice composition can be manipulated, directly or indirectly, by crop load.

CROP LOAD IMPACT ON VINE CANOPY

Yield has been negatively correlated with shoot maturity (Edson et al., 1995; Freeman and Kliewer, 1983; Ough and Nagaoka, 1984; Reynolds, 1989; and Reynolds *et al.*, 1994) and vine size (Edson *et al.*, 1995; Ough and Nagaoka, 1984;

Reynolds, 1989; Reynolds *et al.*, 1994 and Reynolds and Wardle, 1989). Miller *et al.* (1996) noticed that by véraison, increasing crop load caused a reduction in the rate of shoot elongation. The length of the shoot will determine the amount of leaf area and ultimately the level of carbohydrate production in the leaves. Jackson and Lombard (1993) reported that weak shoots of 30 cm or less produced wine with less sugar, color and phenolics whereas healthy shoots of 1.2 m produced wines that were fruity, less vegetative and had more varietal character than weak vines. Miller and Howell (1998) showed that reducing yields caused the vine to become vegetative at the approach of stage three when sugar influx increases to its highest rates. Since leaves are born on shoots, which lignify and become canes, greater cane weight is thought to equal more leaves and a larger canopy. Miller and Howell (1998) found no significant difference between crop load treatments in the quantity of Concord cane tissue. As the crop load becomes balanced with the vine's capacity, total dry matter production per unit leaf area per vine increases, maximizing the vine's production potential. Miller and Howell (1998) reported no significant effect on yield components or fruit composition in response to varying vine capacity.

CROP LOAD IMPACTS ON WINE QUALITY

Conflicting data have been reported concerning the relationship of crop load and wine quality. Ough and Nagaoka (1984) working with 'Cabernet sauvignon' along with Reynolds *et al.* (1994) working with 'Riesling' found that the pH levels of wines from vines thinned two-weeks after bloom tended to be lower. This finding conflicts with other reports (Reynolds *et al.*, 1986). Ough and Nagaoka, (1984), Reynolds (1989), and Reynolds *et al.* (1986) found that titratable acidity was positively correlated with crop level. Reynolds *et al.* (1994) observed that increasing clusters per shoot in Riesling decreased aromatic trans-3-hexen-1-ol in young Riesling wines and citronellol and linalool compounds in aged Riesling wines. In the same study, sensory panelists perceived reductions in ripe fruit character and sweetness, and increases in green fruit flavor and acidity due to increases in crop level. Substantial increases in crop load seem to have little impact on wine sensory differences unless accompanied by major increases in canopy density, crop level and shading (Reynolds *et al.,* 1994). The authors concluded that increased canopy shading from high shoot density has more influence on wine grape composition than crop level. They found no perceived compositional difference in wines made with different thinning treatments. In the same study, wine preference tended to be slightly higher in wines from the unthinned vines for two out of five years than wine from vines with a reduced crop. However, five-year averages showed no correlation between crop load and perceived improvement in wine quality. Reynolds and co-workers (1994) concluded that wine quality did not improve due to cluster thinning per se. Shoot densities directly influence fruit zone environment by the degree of fruit shading.

IMPACT OF CROP LOAD ON NUTRITIONAL ALLOCATION

Fruit thinning may be indirectly affecting wine quality by altering the balance between carbohydrate reserves in the perennial tissues (source), photosynthetic capacity (source) and the vegetative and reproductive growth (sinks). Buttrose (1968) found that overcropping reduced the amount of leaf area per berry. Research has found that in cool climates, the leaf area to fruit weight ratio to maximize sugar accumulation and fully ripen the fruit is 15 cm^2 of leaf area per gram of fruit, below which sugars begin to decline (Jackson and Lombard, 1993, Kliewer and Antcliff, 1970, and Kliewer and Ough, 1970). The leaf area that is required for adequate ripening of the fruit is the same as the leaf area required for proper maturation of fruiting canes (Weaver, 1963). The value of this ratio can be thought of as a gauge to measure the vine's ability to ripen the crop as well as mature shoot periderm. If the length of the growing season is not a limiting factor, high crop loads can be left to ripen on the vine when there is sufficient leaf area to support the developing fruit. Hence, thinning fruit may hasten ripening rates and advance wood maturity due to the increase in the leaf area to fruit weight ratio. Jackson (1986) found that in Cabernet sauvignon, there was little increase of total sugar concentration per berry in response to thinning when the unthinned vines had a sufficient ratio (10cm^2/g) of leaf area per gram of fruit. Data suggests that fruit quality as measured by sugar concentration is improved with thinning only in situations where the act of thinning adjusts the leaf area to fruit weight ratio to a value between 10-15cm^2 of leaf area /gram of fruit. Miller *et al.* (1996) found no differences in fruit maturity between the crop load treatments consisting of vines with one shoot and one cluster, four shoots and one cluster, four shoots and three clusters and lastly, four shoots and four clusters. Even the highest crop load treatments had over 15 cm^2 leaf / g fruit. This suggests that the ratio of leaf area to quantity of fruit is greatly influential in the vine's ability to ripen the grapes. In a study by Kliewer and Weaver (1971) on Tokay grapevines, fruit thinning was compared to shoot thinning. Thinned treatments were established at bloom. The authors concluded that changes in berry weight, proline juice concentration of proline and coloration in response to treatment would be explained by variations in leaf area per weight of fruit. Kliewer and Ough (1970) found that proline, arginine and total nitrogen in the juice of 'Thompson Seedless' were maximized when the ratio of leaf area to crop weight was 10 to 14 cm^2 per gram of fruit. Kliewer and Weaver (1971) in their defoliation experiments with Tokay showed that fruit maturity and quality parameters were improved by adjusting the leaf area to fruit ratio which in turn balanced vine growth and optimized vine health. Data indicate that for Tokay vines grown at the U.C. Davis, 10 to 14 cm^2 /g fruit is the optimum range for maximizing berry weight, fruit coloration, and juice proline, arginine and nitrogen levels. In cool climates, Pinot noir requires at least 15 cm^2 /g of fruit [Vasconcelos, personal communication].

BALANCE BETWEEN CROP LOAD AND VEGETATIVE GROWTH

The examples previously discussed underscore the idea that ripening ability depends ultimately on the proper microclimate created within the fruit zone of the canopy. Research from Smart (1985) lends credence to this idea by showing that high yields can be consistently maintained provided that the ratio of leaf area to quantity of fruit is optimized. This helps explain why canopy management, including control of shoot spacing and positioning, leaf pulling and hedging, is one of the most powerful tools a viticulturist has in maintaining healthy, balanced vines and improving fruit quality. Practices such as reducing shoot density and increasing the percentage of new, fully expanded leaves increase the efficiency in light interception by the canopy and therefor increases the availability of photoassimilates for fruit clusters and perennial storage organs such as the trunk and roots (Vasconcelos and Castagnoli 2000). Weaver (1963) found that in Carignane and Zinfandel vines, lateral shoots have enough leaf area to more than double the canopy's surface area. These lateral shoots are the canopy's most active source for fully expanded young leaves (Candolfi-Vasconcelos and Koblet 1990,Vasconcelos and Castagnoli 2000;). Candolfi-Vasconcelos *et al.* (1994) showed that young, fully-expanded leaves are the most efficient in carbon assimilation and are the most important contributors to fruit ripening.

The importance of the balance between the vegetative and reproductive growth for fruit yield and quality was first pointed out by Ravaz (1903). Ravaz noticed the close relationship between leaf area and cane weight and concluded that cane weights can be used to estimate leaf area. The Ravaz index can be used the same way as leaf area to fruit ratio with the benefits of being easier to quantify and avoiding the destructive harvest of the foliage (Ravaz, 1903). Kliewer and Weaver (1971) showed that cluster thinned vines had lower indicies as a result of both lower yield and an increase in pruning weight. Bravdo *et al.* (1984) using high yielding, irrigated Carignane vines found that moderately thinned vines produced more consistent pruning weights, balanced Ravaz indicies and wine quality than the unthinned or severely thinned treatments. Jackson and Lombard (1993) reported that wine produced from vineyards that had the least fruit variability was superior in quality when compared to wine made from fruit that was highly variable in composition.

The range of Ravaz index values to promote balanced vine growth and optimal wine quality can be thought of as a long-tailed bell shaped curve [Bravdo, 2001, personal communication]. Jackson and Lombard (1993) explained that fruit thinning will increase soluble solid levels up to a specific Ravaz index, below which will have a negligible effect. Bravdo *et al.* (1985) found that when the Ravaz index of Cabernet sauvignon was reduced from 6.7 to 4.6 wine quality differences were not detected. Using the bell curve model, thinning within the low crop level range does not have a drastic impact on wine quality. Similar to the findings of Kliewer and Weaver (1971) as well as Kasimatis (1977) who found that when the Ravaz index of Zinfandel was reduced from 14.3 to 10, the values below 10 displayed an increase in taste intensity and aroma quality. However, no differences in wine quality were perceived at Ravaz indices between 4.24 to 7.48. In Ontario, Fisher *et al.* (1989) studied cluster thinning effects on de Chaunac vines and found that thinning did not reduce fruit yield/vine. This can be attributed to yield compensation as described earlier. However thinning did reduce the Ravaz index from 11.2 to 6.9, increasing vine vigor and improving fruit quality. Increases in wine quality of Cabernet Sauvignon were achieved by reducing the vine's Ravaz index from 19.6 to 12.0 (Bravdo *et al.*, 1985). Increases in wine quality of de Chaunac was achieved by adjusting the Ravaz index from 11.2 to 6.9 (Fisher *et al.*, 1989). Bravdo *et al.* (1984) found that Ravaz index values of 10 or higher (overcropping) were negatively correlated with wine quality in Carignane and this relationship did not hold when the Ravaz index dropped below 10. The authors concluded that the leaf area was not ample enough to produce superior fruit composition. A study conducted by Van Zyl and Weber (1977) in South Africa showed that wine quality of Chenin blanc was unaffected when yield was increased by 50 percent while maintaining a balanced Ravaz index range between 7 to 8. Reynolds *et al.* (1994) showed that increases in yield and decrease in maturity were results of shoot density increases despite similar crop loads and cluster numbers per vine. Similar results by Reynolds *et al.* (1986) found that regardless of crop level, high shoot density was associated to a green, unripe fruit flavor in the wine. Large increases in canopy density have a major impact on wine quality, despite small differences in juice composition. Substantial increases in crop load can occur without large measurable differences in fruit composition or wine quality. In the same study, the use of the Scott Henry training system resulted in fruit composition equal or better than vertical canopies of 10 and 20 shoots/m despite a 31% yield increase. Thus, yields can be maximized while achieving consistently high wine quality. These studies further substantiate the bell shape curve function of balance and quality. Bravdo *et al.* (1985) observed that low crop load increased vine water uptake from soil substantiating the claim that thinning increases vegetative growth. Freeman *et al.* (1986) showed that thinning level had no influence on pruning weight of either irrigated or nonirrigated Shiraz vines, indicating that water stress was more important than crop level in determining vegetative growth and ultimately, carbohydrate reserves. The authors concluded that irrigation had a greater effect on vegetative production than on crop yield shown by a reduced Ravaz index.

The optimal range of Ravaz index values depends on the cultivar studied. In Pinot noir growing in a cool climate, balanced vines should have a Ravaz index between 5 and 7 (Vasconcelos & Castagnoli 2000). A Ravaz index higher than 7 indicates overcropping which can lead to progressive devigoration of the vines. A Ravaz index less than 5 means that the crop load is too small for the vine's potential and leads to a progressive increase in vine vigor (Vasconcelos & Castagnoli 2000). This sets the vine into a vegetative growth cycle, favoring wood and leaf production.

Crop load and its impact on vine balance and fruit quality is a fundamental concept that will be ultimately dictated by the uniqueness of regional climate, operating cost considerations and the level of wine quality desired. As illustrated in the text above, crop load influences the perennial health of the vine, yield, as well as fruit composition and wine quality. Research has shown that fruit quality can be maintained over multiple years by maintaining an adequate balance between leaf area, shoot density and crop level. Adjusting crop level to vineyard site requirements, clonal type and environmental factors can be one of the most effective management tools in viticulture.

MATERIALS AND METHODS

EXPERIMENT I

This study was conducted from 1999-2000 in a commercial vineyard (Willakenzie Estate) at an elevation of 500 ft. The experimental vines were Pinot noir clone Dijon 113 on Couderc 3309 rootstock trained to a double Guyot. Vines were established in 1996 at a spacing of 2.5 x 1.67 m (5 x 7.5 ft). The soil type was a Willakenzie silt loam. Experimental vines were selected based on the average number of clusters per vine during the 1999-growing season. Number of clusters per vine was determined for each vine within the research block by counting and re-counting until the same number of clusters was determined over two consecutive counts. The mean number of clusters per vine within the research block was 30. Selected vines had 30 clusters (±2). Vines were thinned to 25 (control), 20, 15 and 10 clusters per vine. There were sixteen single-vine replicates per treatment totaling 64 vines in a completely randomized design. Thinning criteria consisted of removing underdeveloped green clusters, then clusters that were lagging in ripeness, until target yield was achieved. Clusters with less than 20 berries were removed from the vines and were not counted. Treatments were imposed August 27 in 1999 and August 21 in 2000, at the onset of ripening (véraison). Hedging and drip irrigation was performed on all of the data vines in the block as part of the vineyard manager's standard maintenance protocol. Fruit was harvested on October 4, 1999 and September 29, 2000.

EXPERIMENT II

This study was conducted in 1999 in a commercial vineyard (Hyland vineyard) at an elevation of 500 ft. The experimental vines were Pinot noir clones (Coury selection) on their own roots trained to a modified Lenz-Moser with two short arms supporting two canes each, similar to the standard Chablis training system. The first fruiting cane arises from the proximal part of the arm (closest to the trunk), and the second from the distal part of the permanent arm. In this training system, there is no overlapping of the four canes. Vines were established in 1974 at a spacing of 3.33 x 3.33 m (10 x 10 ft). The soil type was a Jory silt loam. Experimental vines were selected based on the average number of clusters per vine during the 1999-growing season. Clusters per vine were counted as described previously. The mean number of clusters per vine within the research block was 60. Selected vines had 60 clusters (± 2). Thinning treatments were imposed September 2, 1999, at the onset of ripening (véraison). Four thinning treatments were implemented on 13 single-vine replicates in a completely randomized design. Vines were thinned to 60 (control), 50, 40 and 30 clusters per vine using the thinning criteria described in experiment one. Hedging was performed on all of the data vines in the block as part of the vineyard manager's standard maintenance protocol. Fruit was harvested on October 18, 1999.

EXPERIMENT III

This study was conducted in the same vineyard as in experiment two. New data vines were selected in 2000. A factorial design was used to vary cluster thinning level and timing of thinning. Experimental vines were selected based on the average number of clusters per vine during the 2000-growing season as described previously. The mean clusters per vine within the research block was 50 clusters per vine. Selected vines had 50 clusters (± 2). Vines were thinned at bloom or véraison. Thinning treatments were imposed June 27 at the onset of anthesis (cap fall) and on September 1 in 2000, at the onset of ripening (véraison). There were forty single-vine replicates per treatment combination. Vines were thinned to 45 (control), 35 and 25 clusters per vine bloom or véraison totaling 240 vines. For the véraison thinning, criteria used were the same as described in experiment one. For the bloom thinning, inflorescences farthest or distal to the base of the shoot were removed first followed by primary inflorescences closest to the base of the shoot until target yield was achieved. Hedging was performed on all of the data vines in the block as part of the vineyard manager's standard maintenance protocol. Fruit was harvested on October 9, 2000.

YIELD COMPONENTS AND FRUIT COMPOSITION: EXPERIMENTS I, II AND III

The number of clusters per vine was counted again at harvest. Each vine was harvested separately and mean cluster weight was determined using yield per vine and the number of clusters per vine. After harvest, clusters per shoot were obtained from clusters per vine and shoots per vine. The number of berries per cluster was calculated from the cluster weight to berry weight ratio. Five clusters from each vine were randomly selected for determination of mean berry weight by randomly removing 20 berries from each cluster and weighing the 100 berries. Seven clusters per vine were randomly selected and crushed by hand and filtered through a sheet of Myrcloth™ to determine total soluble solids using a digital refractometer (Palette, Atago CO., LTD, 32-10 Honcho, Itabashi-ku Tokyo 173, Japan). Titratable acidity (TA) and pH were analyzed using an auto-titrator (Mettler DL21, Mettler-Toledo AG, Analytical, Sonnenbergstrasse 74, CH-8603, Schwerzenbach). After determination of mean berry weight, the 100 berry sample was used to determine skin anthocyanin levels. The skins were separated from pulp and seeds and were placed in 200ml jars and soaked in 50ml of acidified methanol (1% hydrochloric acid). The jars were then placed on a shaker and shaken for four hours at room temperature. The extractant was then decanted and the skins were taken through the extraction process two more times with 40ml of solution for a duration of three hours during the last two sets. The combined extractants were then brought to a final volume of 200ml with the extract solution. This solution was diluted 1:50 with the MeOH/HCl solution. Absorbance was measured at 530nm using a spectrophotometer. Detailed methods used to determine anthocyanin concentration can be found in Candolfi-Vasconcelos and Koblet (1990).

PRUNING WEIGHTS AND CARBOHYDRATE CONTENT: EXPERIMENTS I, II AND III

During winter dormancy of the 1999/00 and 2000/01 seasons, total cane weight per vine was measured. a one-inch wood sample from the previous season fruiting canes close to the head of the vine was collected from each vine. The sample was dried and ground through a number 10 mesh screen into a fine powder. Percent sugars and starches were extracted and analyzed from the dried powder sample using the methods described by Candolfi-Vasconcelos and Koblet (1990).

WINE COMPOSITION: EXPERIMENT III

Fruit from the 25 and 45 clusters per vine treatments thinned at bloom or véraison were separated into randomized lots and processed into wine. On October 10, grapes were crushed, destemmed and 50mg/L SO_2 was added. Must was inoculated with 1 g/L of Lalvin RC 212 Bourgorouge yeast on October 12 and punch down was performed two times a day. Fermentation temperature and rates were monitored every 48 hours reaching a maximum temperature of 24^{o}C. On October 24, the wine was gently pressed from the skins using up to 400 kPa (4 bars) of pressure. The wine then settled and racked off the gross lees and was then inoculated with 5 mg/L (0.02g/gal) of OSU Lalvin freeze-dried malolactic bacteria. Once malolactic acid fermentation was complete, the wine was cold stabilized and bottled. The wine was analyzed for total phenols by the Folin-Ciocalteu method (Singelton, 1988). Anthocyanin content was determined by diluting 1ml of wine with 9ml of pH < 1 buffer and reading the absorption in a 1mm cuvette at 520nm. This value was adjusted to the dilution factor and was divided by an extinction coefficient of 380 (Singelton, 1982). Color analysis at wine pH was determined by measuring the absorption at 420nm and at 520nm in a 1mm cuvette and then multiplied by a factor of 10 to account for the path length. Color intensity was obtained from the sum of the absorption at 420nm and 520nm whereas wine hue was the quotent of absorbancies at 420nm and 520nm (Singelton, 1982).

STATISTICAL ANALYSIS

The statistical package Staview 5.01 (SAS Institute Inc.) was used for data analysis. Because the treatment (clusters/vine) was a continuous variable, data were analyzed using regression analysis (Chew, 1976). In all experiments, data vines that showed more than a 10% difference between the intended number of clusters per vine and the actual number counted at harvest, were eliminated from the data set. The number of replicates used in the statistical analysis was 16 for experiment I, year one, 11 for experiment I, year two, 13 for experiment II, and 36 for experiment III. Homogeneity of variance was tested prior to analysis. The yield/vine in experiment I, year one, and experiments II and III, was log-transformed prior to analysis. The clusters/shoot in experiment I, year two, and experiments II and III as well as the Ravaz index in experiment I year one, were also log-transformed prior to analysis.

RESULTS AND DISCUSSION

YIELD COMPONENTS

The number of clusters per shoot and yield per vine decreased with increased thinning levels for all three experiments (Tables 1, 2 and 3). Within experiment I, average crop load ranged from 1.0kg per vine (1.27 tons per acre) for the lowest crop level treatment to 2.09kg per vine (2.68 tons per acre) in 1999. In 2000, average yield ranged from 1.11kg per vine (1.42 tons per acre) to 2.47kg per vine (3.17 tons per acre). It should be noted that these vines had not yet reached full maturity and were thus still carrying light crop loads as evidenced by the cropping level range. Yields for experiment II during the 1999 season ranged from 3.19kg per vine (1.53 tons per acre) to 5.52kg per vine (2.65 tons per acre). Experiment III thinning treatments resulted in yields that ranged from 2.54kg per vine (1.22 tons per acre) to 4.28kg per vine (2.05 tons per acre). The range of yields displayed within the experiments is typical of commercial vineyards in northern Oregon, with the majority of growers keeping yield between 1.5 and 2.5 tons per acre [Vasconcelos, personal communication]. Research vines within experiments II and III at Hyland Vineyard were planted in 1974 and were spaced 10 X 10, giving the vines the potential to carry higher numbers of clusters per vine. This spacing is not indicative of typical vineyard layouts in the northern Willamette valley as is the

Table 1) Yield and yield components of Pinot noir vines submitted to cluster thinning at Willakenzie vineyard during the 1999 and 2000 seasons (Experiment I)

1999		Yield (kg/vine)	Yield (ton/a)	Berries / cluster	Berry weight (g)	Cluster weight (g)	Clusters / shoot
Clusters/vine	n =						
10	16	1.00	1.27	92	1.10	100	0.7
15	16	1.40	1.79	90	1.05	94	1.2
20	16	1.91	2.44	87	1.09	94	1.4
25	16	2.09	2.68	80	1.08	86	1.8
Linear regression	R^2	0.7350	0.7370	0.0760	0.0000	0.0820	0.9210
	p	***[1]	***	*	ns	*	***

2000		Yield (kg/vine)	Yield (ton/a)	Berries / cluster	Berry weight (g)	Cluster weight (g)	Clusters / shoot
Clusters/vine	n =						
10	11	1.11	1.42	83	1.23	100	0.71
15	11	1.47	1.88	83	1.27	106	0.98
20	11	2.01	2.58	93	1.25	110	1.31
25	11	2.47	3.17	91	1.22	107	1.67
Linear regression	R^2	0.7430	0.7440	0.0590	0.0100	0.0030	0.9240
	p	***	***	ns	ns	ns	***

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 2) Yield and yield components of Pinot noir vines submitted to cluster thinning at véraison at Hyland vineyard during the 1999 season (Experiment II).

		Yield (kg/vine)	Yield (ton/a)	Berries / cluster	Berry weight (g)	Cluster weight (g)	Clusters / shoot
Clusters/vine	n =						
30	13	3.19	1.53	75	1.41	106	0.791
40	13	4.44	2.13	81	1.36	106	1.067
50	13	4.93	2.37	72	1.36	98	1.250
60	13	5.52	2.65	68	1.37	94	1.524
Linear regression	R^2	0.5610	0.5610	ns	ns	0.0580	0.9130
	p	***[1]	***	ns	ns	*	***

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 3) Yield and yield components of Pinot noir vines submitted to cluster thinning at bloom or véraison at Hyland vineyard during the 2000 season (Experiment III).

		Yield (kg/vine)	Yield (ton/a)	Berries / cluster	Berry weight (g)	Cluster weight (g)	Clusters / shoot	Shoots/ vine
Clusters/vine	n =							
25	80	2.54	1.22	79	1.27	100	0.8	31
35	80	3.40	1.63	76	1.27	97	1.1	31
45	80	4.28	2.05	75	1.27	95	1.5	31
Linear regression	R^2	0.7530	0.7530	0.0240	ns	0.0230	0.8380	ns
	p	***[1]	***	*	ns	*	***	ns
Timing	n =							
bloom	120	3.3	1.6	76	1.28	97	1.1	31
veraison	120	3.3	1.6	78	1.27	98	1.1	31
Significant F		ns	ns	ns	ns	ns	ns	ns
Interaction								
Thining x timing		ns	ns	ns	ns	ns	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

the vine spacing in experiment I at Willakenzie vineyard. The number of berries per cluster as well as cluster weight increased significantly with decreasing yields during the 1999 season in experiment I (Figures 1 and 2). Results from experiment II showed increases in cluster weights with decreasing yields (Figure 3). In experiment III, fruit thinned at véraison displayed increases in both the number of berries per cluster as well as cluster weights with decreasing yields (Figures 4 and 5). The differences in berries per cluster as well as cluster weight was probably an artifact resulting from the selection criteria for cluster thinning. Selectively removing underdeveloped clusters thus increased the mean cluster weight of the remaining clusters. The higher the number of second and third distal clusters on a shoot that were thinned leads to more below average clusters that were removed, further increasing the mean weight of the remaining clusters. This should be taken into account when implementing yield-forecasting models. Data collected from all three experiments showed that mean berry weight was not affected by cluster thinning, indicating that there was no yield compensation. It was also expected that yield compensation would be displayed in fruit from bloom thinned vines in experiment III. This was however not the case (Table 3). Yield compensation is not a desirable phenomenon in the production in red wine grape cultivars because it creates large grape berries and a more compact cluster. Smaller berries increase the skin:juice ratio during fermentation, a desirable attribute in the production in red wine allowing for greater levels of phenolic compounds to be extracted (Boulton *et al.*, 1998).

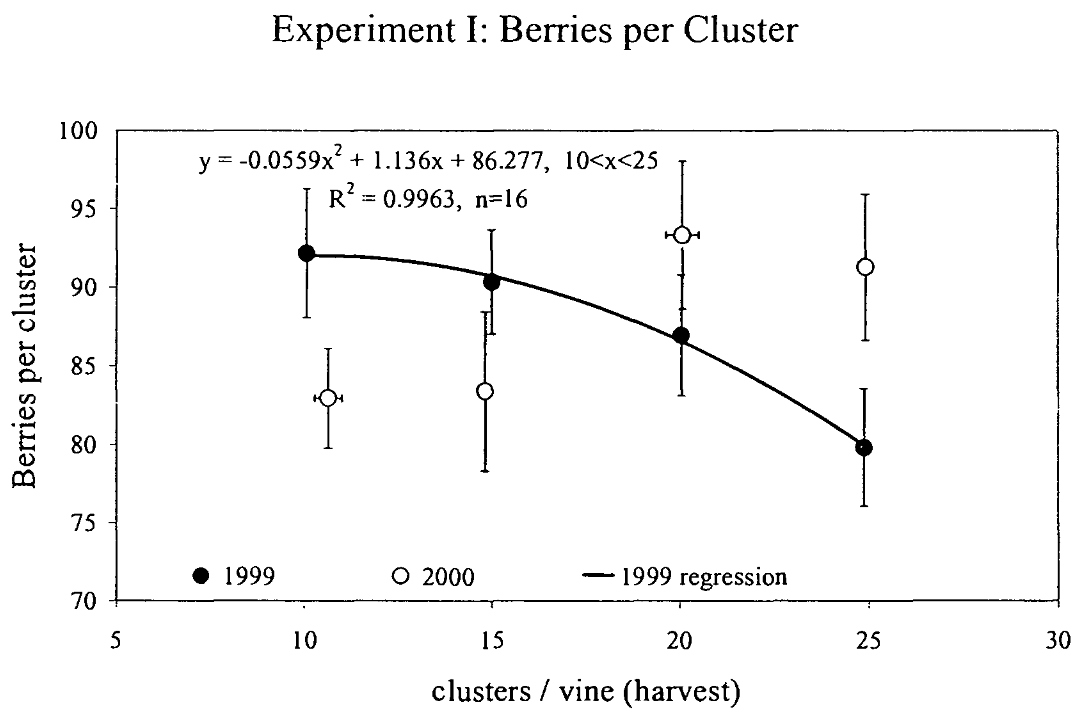

Figure 1) Berries per cluster of Pinot noir vines submitted to cluster thinning at véraison during the 1999 (full circles) and 2000 (open circles) seasons at Willakenzie vineyard (experiment I). Each point is the average of 16 (1999) or 11 (2000) measurements. Vertical bars represent ±SE of the dependent variable and horizontal lines represent ±SE of number of clusters per vine counted at harvest.

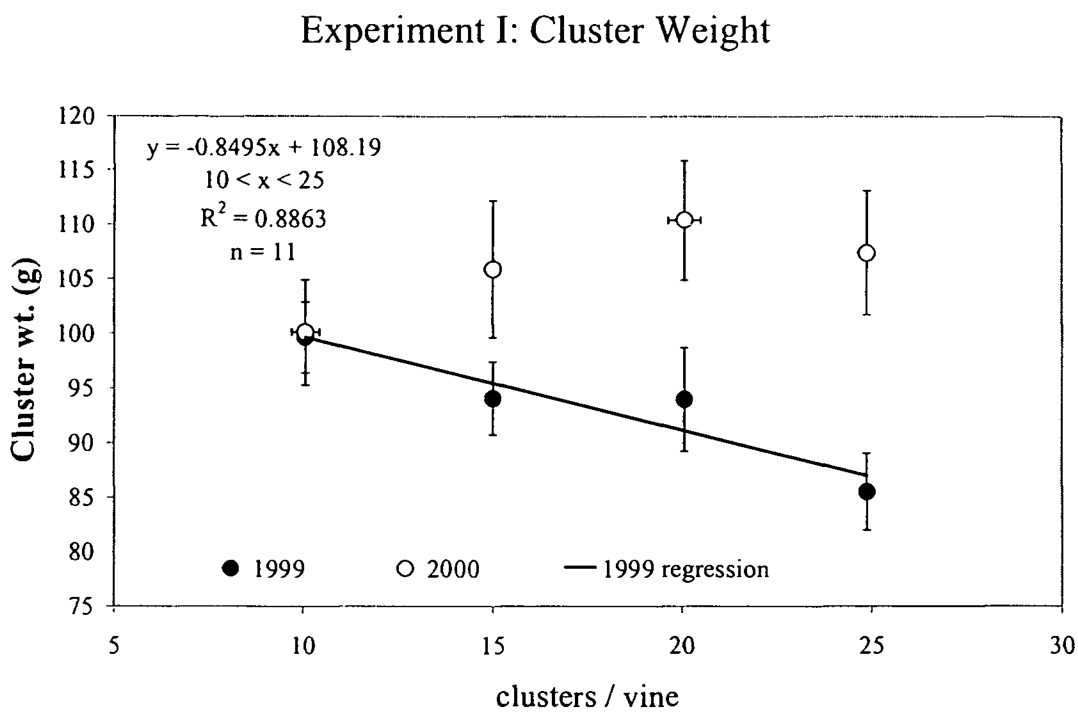

Figure 2) Cluster weight of Pinot noir vines submitted to cluster thinning at véraison during the 1999 (full circles) and 2000 (open circles) seasons at Willakenzie vineyard (experiment I). Each point is the average of 16 (1999) or 11 (2000) measurements. Vertical bars represent ±SE of the dependent variable and horizontal lines represent ±SE of number of clusters per vine counted at harvest.

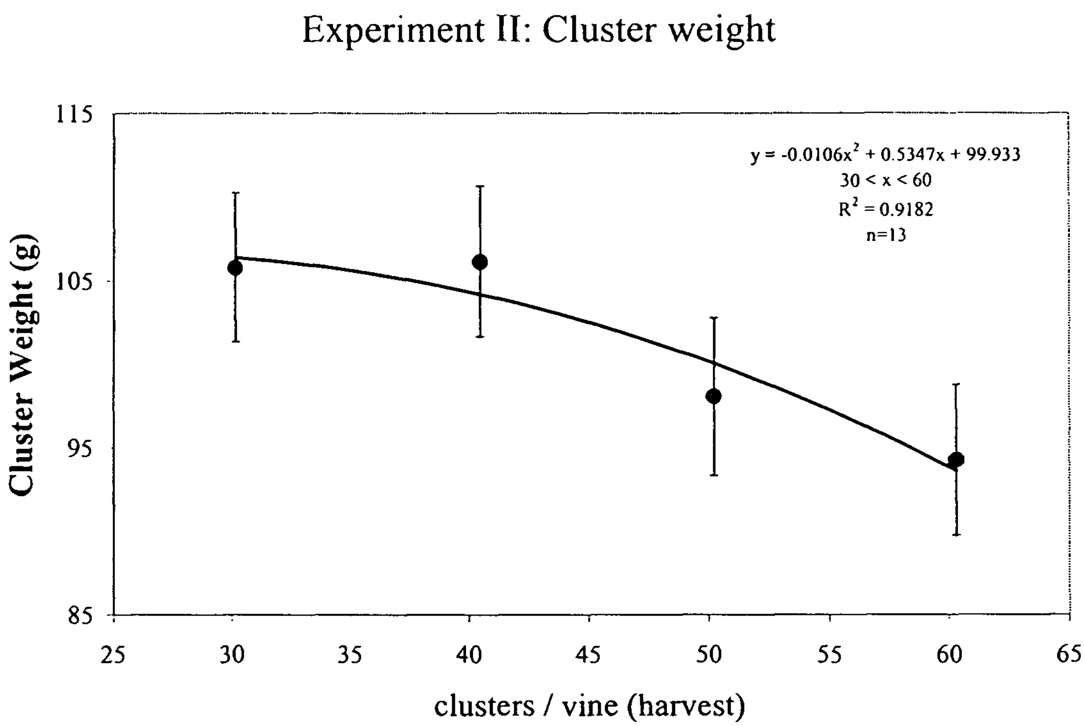

Figure 3) Cluster weight of Pinot noir vines submitted to cluster thinning at vėraison during the 1999 season at Hyland vineyard (experiment II). Each point is the average of 13 measurements. Vertical bars represent ±SE of the dependent variable and horizontal lines represent ±SE of number of clusters per vine counted at harvest.

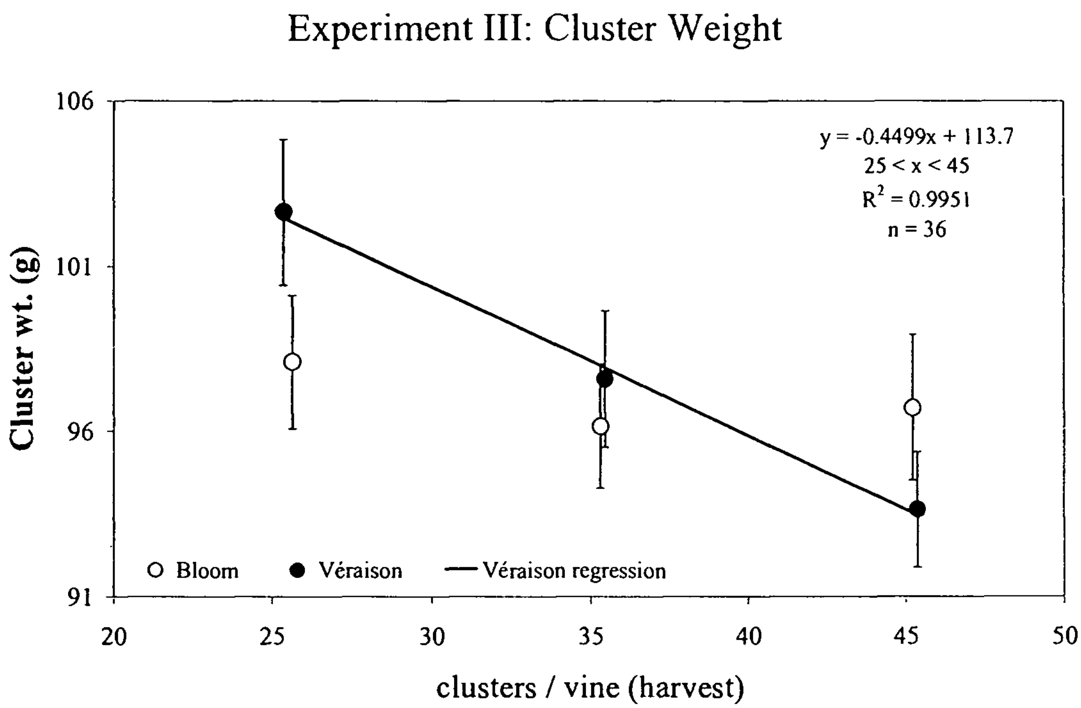

Figure 4) Cluster weight of Pinot noir vines submitted to cluster thinning at bloom (open circles) or véraison (full circles) during the 2000 season at Hyland vineyard (experiment III). Each point is the average of 36 measurements. Vertical bars represent ±SE of the dependent variable and horizontal bars represent ±SE of number of clusters per vine counted at harvest.

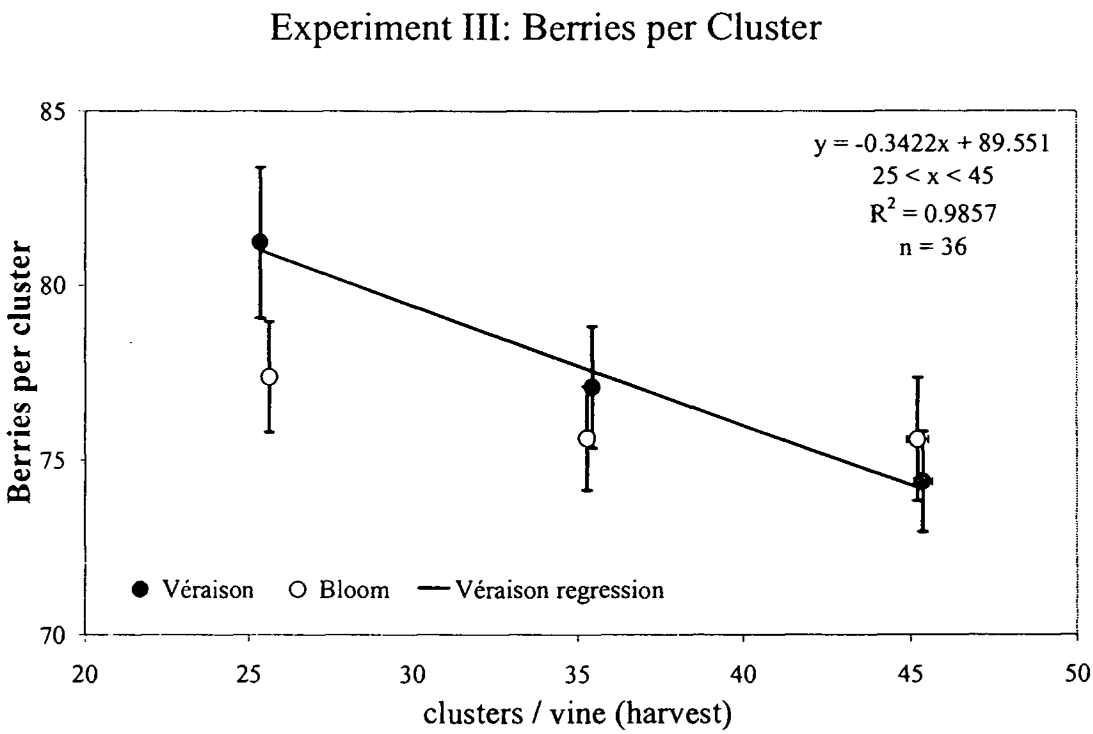

Figure 5) Berries per cluster of Pinot noir vines submitted to cluster thinning at bloom (open circles) or véraison (full circles) during the 2000 season at Hyland vineyard (experiment III). Each point is the average of 36 measurements. Vertical bars represent ±SE of the dependent variable and horizontal bars represent ±SE of number of clusters per vine counted at harvest.

JUICE COMPOSITION

Fruit harvested from experiment I during the 1999 season responded to cluster thinning with increases in must pH (Table 4). In 2000, however, must soluble solids were found to increase with increasing thinning severity. No changes were measured in juice titratable acidity and skin anthocyanin content in experiments I, II and III (Tables 4, 5 and 6). Our results do not agree with previously published research. It has been demonstrated that anthocyanin content in grape skins vary with time of thinning, with variety and vintage (Mazza *et al.* 1999). Cluster removal has been shown by some researchers to have no impact on juice soluble solids (Bravdo *et al.*, 1984 & 85; Buttrose, 1968 and Reynolds *et al.*, 1986) or has been negatively correlated to sugar accumulation by others (Edson *et al.*, 1995; Fisher *et al.*, 1977; Miller *et al.*, 1998; Reynolds *et al.*, 1989, Reynolds *et al.*, 1994 and Renyolds & Wardle, 1989). Similarly, contradictory reports on the response of sugar content, must pH and titratable acidity to fruit thinning have been published. Bravdo *et al.* (1984) and others (Freeman & Kliewer, 1983 and Reynolds *et al.*, 1986) monitored no change of juice pH with increases in crop load. Still others (Edson *et al.*, 1995; Kliewer & Ough, 1970; Ough & Nagaoka, 1984; Reynolds, 1989; Reynolds *et al.*, 1994 and Reynolds & Wardle, 1989) report a negative correlation between pH and crop load, in agreement with our results from experiment I. Thinning experiments should ideally be observed over an extended period of time to determine the long-term impact of yield adjustment on juice composition.

Table 4) Juice and skin composition of Pinot noir vines submitted to cluster thinning at Willakenzie vineyard during the 1999 and 2000 seasons (Experiment I).

1999		Soluble Solids °Brix	pH	TA (mg/L)	Anthocyanins (mg/g berry)	Anthocyanins (mg/berry)
Clusters/vine	n =					
10	16	23.4	3.16	7.9	1.06	1.15
15	16	23.5	3.16	7.6	1.15	1.18
20	16	23.2	3.11	8.3	1.15	1.23
25	16	23.2	3.12	7.9	1.05	1.12
Linear regression	R^2	0.004	0.0630	0.0130	0.0004	0.0000
	p	**	*	ns	ns	ns

2000		Soluble Solids °Brix	pH	TA (mg/L)	Anthocyanins (mg/g berry)	Anthocyanins (mg/berry)
Clusters/vine	n =					
10	11	24.0	3.15	6.9	0.86	1.02
15	11	23.8	3.10	6.8	0.83	1.05
20	11	23.5	3.11	7.0	0.80	0.93
25	11	23.2	3.10	7.0	0.80	0.96
Linear regression	R^2	0.1410	0.0350	0.0060	0.0150	0.0220
	p	**	ns	ns	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 5) Juice and skin composition of Pinot noir vines submitted to cluster thinning at véraison at Hyland vineyard during the 1999 season (Experiment II).

		Soluble Solids °Brix	pH	Titratable acigity (g/L)	Anthocyanins (mg/g berry)	Anthocyanins (mg/berry)
Clusters/vine	n =					
30	13	22.9	2.93	9.9	1.27	1.78
40	13	22.6	2.91	9.9	1.26	1.69
50	13	22.5	2.93	9.3	1.26	1.70
60	13	22.3	2.94	9.3	1.24	1.70
Linear regression	R^2	0.0300	0.0100	0.0250	0.0050	0.0170
	p	ns[1]	ns	ns	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 6) Juice and skin componentsfor pinot noir vinessubmitted to cluster thinning at bloom and véraison at Hyland vineyardduring the 2000 growing season (Experiment III).

		Soluble solids °Brix	pH	Titratable acigity (g/L)	Anthocyanins (mg/g berry)	Anthocyanins (mg/berry)
Clusters/vine	n =					
25	80	22.7	3.00	7.5	0.94	1.19
35	80	22.7	3.00	7.4	0.91	1.15
45	80	22.6	2.98	7.7	0.90	1.15
Linear regression	R^2	0.0110	0.0100	0.0160	0.0040	0.0050
	p	ns	ns	ns	ns	ns
Timing	n =					
bloom	120	22.7	3.00	7.5	0.92	1.17
veraison	120	22.7	2.99	7.6	0.92	1.15
Significant F		ns	ns	ns	ns	ns
Interaction						
Thining x timing		ns	ns	ns	ns	ns

[1] ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

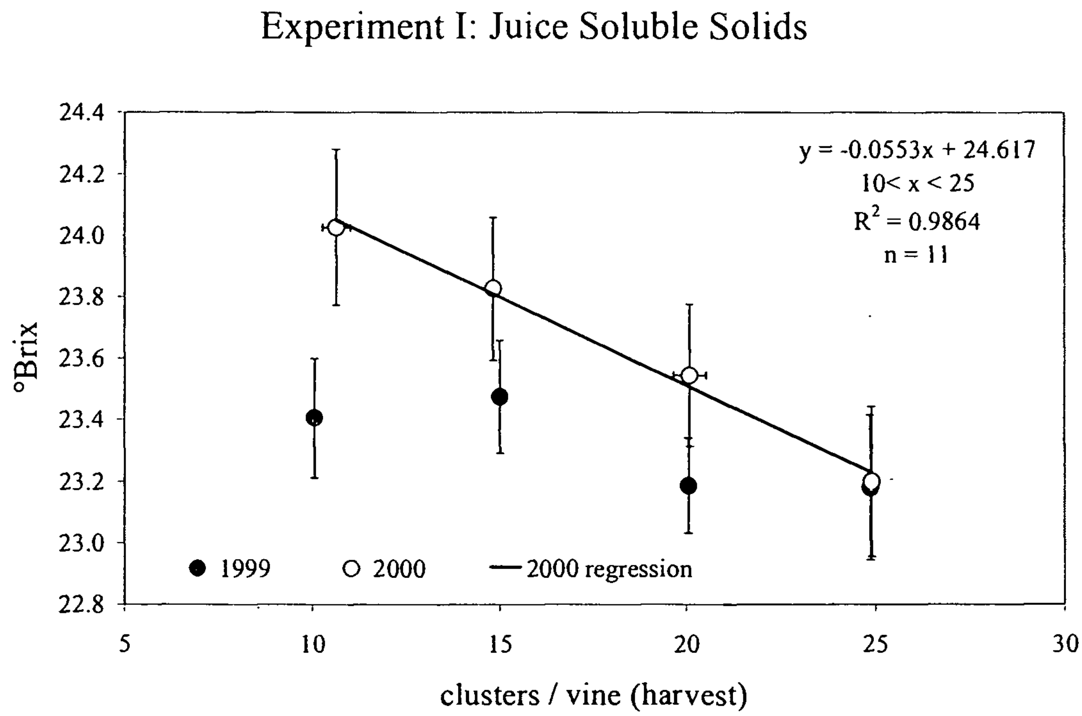

Figure 6) Juice soluble solids of Pinot noir vines submitted to cluster thinning at véraison during the 1999 (full circles) and 2000 (open circles) seasons at Willakenzie vineyard (experiment I). Each point is the average of 16 (1999) or 11 (2000) measurements. Vertical bars represent ±SE of the dependent variable and horizontal lines represent ±SE of number of clusters per vine counted at harvest.

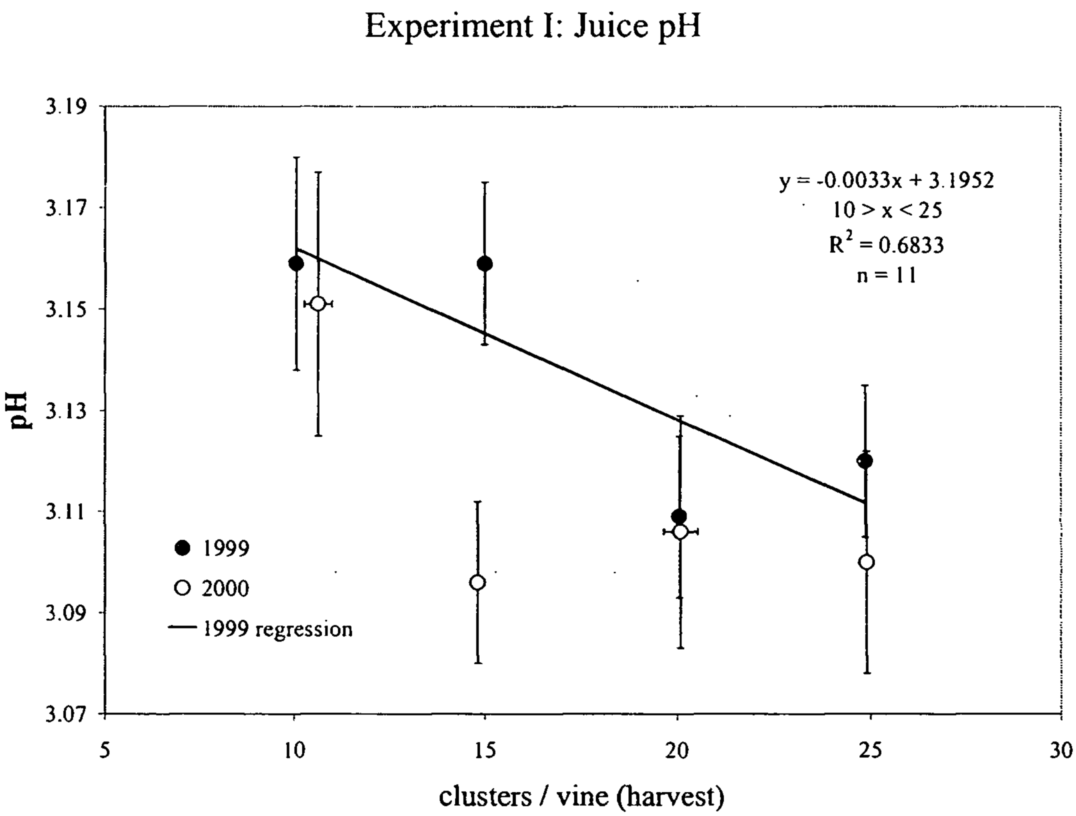

Figure 7) Juice pH of Pinot noir vines submitted to cluster thinning at véraison during the 1999 (full circles) and 2000 (open circles) seasons at Willakenzie vineyard (experiment I). Each point is the average of 16 (1999) or 11 (2000) measurements. Vertical bars represent ±SE of the dependent variable and horizontal lines represent ±SE of number of clusters per vine counted at harvest.

VINE VIGOR

Vine pruning weights and individual cane weights showed no response to cluster thinning (Tables 7, 8 and 9). Vines in balance should have canes in the 30 to 40 g range, 40 g being preferred in cool climates (R. E. Smart, personal communication). It is interesting to note that in experiment I, cane weights decreased over time reflecting the progress in the establishment of the vines. In the 1999 season of experiment I, canes tended to be heavier than optimum with means above 100g for all thinning levels where cane weights during the 2000 season tended to be lighter with mean cane weight between the upper sixties to upper seventies in grams (Table 7) In experiments II and III, cane weight tended to be lower than optimum (Tables 8 and 9). This may be due to vine age and the yield history of the vineyard prior to the experiments. The Ravaz index represents the ratio between reproductive and vegetative growth. It is then assumed that the Ravaz index would show a significant change with changing crop thinning level (Tables 7, 8 and 9). Based on multi-season averages obtained at the OSU experimental vineyard Woodhall III, balanced Pinot noir vines should have a Ravaz index between 4 and 6. Vines at Willakenzie were still in the establishment period and did not produce a full crop. Small yields and high pruning weights can give rise to a very low Ravaz index and excessively vigorous canes. Cane weights will decrease and the Ravaz index will increase as the vines mature and reach full production. Miller & Howell (1998) showed that low cropping levels cause the vine to become vegetative at the approach of berry developmental stage three when sugar influx

Table 7) Vine vigor and carbohydrate content of Pinot noir vines submitted to cluster thinning at Willaken vineyard during the 2000 season (Experiment I).

1999		Pruning wt. (kg/vine)	Cane wt. (g)	Ravaz Index (kg fruit/kg wood)	% Sugar in wood	% Starch in wood	% TNSC in wood
Clusters/vine	n =						
10	16	1.22	97	0.8	8.7	14.0	22.7
15	16	1.15	102	1.2	8.5	14.6	23.1
20	16	1.23	105	1.5	8.4	14.0	22.4
25	16	1.18	95	1.8	8.5	14.4	22.8
Linear regression	R^2	0.0004	0.0003	0.4800	0.0360	0.0020	0.0003
	p	ns[1]	ns	***	ns	ns	ns

2000		Pruning wt. (kg/vine)	Cane wt. (g)	Ravaz Index (kg fruit/kg wood)	% Sugar in wood	% Starch in wood	% TNSC in wood
Clusters/vine	n =						
10	11	1.10	71	1.0	9.9	10.5	20.4
15	11	1.03	69	1.4	10.2	10.6	20.8
20	11	1.03	67	2.0	9.9	10.3	20.3
25	11	1.06	68	2.4	10.0	10.1	20.1
Linear regression	R^2	0.0060	0.0130	0.5980	0.0005	0.0280	0.0030
	p	ns	ns	***	ns	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 8) Vine vigor and carbohydrate content of Pinot noir vines submitted to véraison cluster thinning at Hyland viney during the 1999 season (Experiment II).

		Pruning weight (kg/vine)	Cane weight (g/cane)	Ravaz Index (kg fruit/kg wood)	% Sugar in Wood	% Starch in Wood	% TNSC in Wood
Clusters/vine	n =						
30	13	0.796	23	4.8	10.5	11.7	22.2
40	13	0.735	20	6.8	10.5	11.7	22.2
50	13	0.669	19	7.8	10.6	11.7	22.5
60	13	0.750	21	8.3	10.6	11.7	22.3
Linear regression	R^2	0.0040	0.0120	0.1940	0.0080	0.0001	0.0030
	p	ns[1]	ns	***	ns[1]	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 9) Vine vigor and carbohydrate content of Pinot noir vines submitted to bloom and véraison cluster thinning at Hyland vineyard during the 2000 season (Experiment III).

		Pruning weight (kg/vine)	Cane weight (g/cane)	Ravaz Index (kg fruit/kg wood)	% Sugar in Wood	% Starch in Wood	% TNSC in Wood
Clusters/vine	n =						
25	72	0.744	28	4.1	7.8	9.8	17.6
35	72	0.741	28	4.9	7.8	9.6	17.4
45	72	0.735	27	5.9	7.7	10.0	17.7
Significant regression	R^2	0.0010	0.0010	0.1720	0.0040	0.0050	0.0010
	p	ns[1]	ns	***	ns[1]	ns	ns
Timing	n =						
bloom	108	0.762	28	4.9	7.7	9.8	17.5
veraison	108	0.719	27	5.1	7.9	9.8	17.6
Significant F		ns	ns	ns	ns	ns	ns
Interaction							
Thining x timing		ns	ns	ns	ns	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

increases to its highest rates. Miller *et al.* (1996) also noticed that by véraison, crop load caused a reduction in the rate of shoot elongation in the heavily cropped vines. Substantial increases in crop load seem to have little impact on wine sensory quality unless accompanied by major increases in canopy density, vine vigor, crop level and shading (Reynolds *et al.*, 1994). It is then assumed that increases in canopy shading from highly vigorous vines have more influence on wine grape composition than crop level. This is one reason to be skeptical that the minimal crop gives the best wine as crop load is reduced (Boulton *et al.*, 1998).

CARBOHYDRATES

Cluster thinning had no impact on the carbohydrate content of two-year old wood over the two-year period of this thinning project (Tables 7, 8 and 9). It was thought that excess photosynthates that would have been transported to the thinned fruit would instead be fixed into the perennial organs of the vine for future use. These data agree with a 1996 study by Koblet and Candolfi-Vasconcelos who found that there was a clear trend towards lower photosynthetic rates on cluster-thinned vines where there was a down-regulation of photosynthesisto match the smaller sink size. However, overcropped vines produced low quality grapes and accumulated insufficient reserves within the vine's storage organs. Total non-structural carbohydrate reserves (TNSC) within the perennial tissue of the vine are very important for maintaining vine vigor and fruit quality. This is due to the fact that vine canopy development early in the season depends soley on reserve carbohydrates. Early spring growth requires carbohydrates in the form of starch to be remobilized and sent to the shoot apex (Weaver, 1963). When these highly dominant apex sinks are removed during bloom, developing clusters increase in percent fruit set, berries per cluster, cluster weight, yield per shoot and yield to pruning ratio (Vasconcelos & Castagnoli, 2000). Kliewer & Antcliff in 1970 found that as much as 40% of the total sugar in the fruits of grapevines could be supplied by the perennial structure of the vine. This hypothesis is further supported in a study where labeled carbon was retranslocated from trunk and roots into ripening Pinot noir fruit at high rates during the middle of the ripening period (Candolfi-Vasconcelos *et al.*, 1994). During midsummer, photosynthate is stored as starch in the roots, recharging the vine's food reserves for the following year. At this time, fruit sink strength is still exerting a weak pull on carbohydrate allocation. Prior to véraison, shoot apicies represent the bulk of the sink strength within the shoot. It is only during the onset of véraison that fruit clusters become a dominant sink within the shoot and sugar accumulation is dependant on the active leaf area during the period between véraison and harvest (Candolfi-Vasconcelos & Koblet, 1990). Growing seasons that follow a year of heavy overcropping will cause the perennial tissue of the parent vine to be depleted of reserves, due to the previous years depleted of food reserves within the root system (Candolfi-Vasconcelos *et al.*, 1994). In this situation, crop yields will be lower and fruit quality will be reduced.

WINE COMPOSITION

Total anthocyanins and color intensity were higher in wine from fruit thinned at bloom (Table 10 and Figures 8 and 9). There was no crop load effect on wine anthocyanin content or total phenols. These findings agree with previous research on Sangiovese Grosso in Tuscany (Bucelli, 1996) and with Pinot noir and Merlot in British Columbia (Mazza, 1999). In the latter study, bloom thinning gave slightly higher wine phenolic and anthocyanin content compared to véraison thinned wines. One must ask if changes in wine composition can be directly attributed to cluster thinning or if the act of thinning changes the canopy microclimate and the physiological response of the vine. The timing of thinning seems to have little bearing on improving wine composition. Previously published research showed that wine color and phenolic components were elevated in Cabernet sauvignon wines thinned at bloom (Bravdo, 1985,A), fruit set (Collalto, 1991) or véraison (Mazza, 1999).

Table 10) Anthocyanin, color and phenolic content of Pinot noir wines submitted to véraison cluster thinning at Hyland vineyard during the 1999 season (Experiment II).

	Total Anthocyanins mg/L	Color Intensity 420+520 nm	Hue 420/520 nm	Total Phenols mg/L
Clusters/vine				
25	217	3.5	7.7	1494.8
45	219	3.6	7.4	1428.5
Significant F	ns[1]	ns	ns	ns
Timing				
bloom	232	3.9	7.5	1481.2
veraison	204	3.3	7.6	1442.0
Significant F	***	***	ns	ns
Interaction				
Thining x timing	**	ns	ns	ns

1 ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

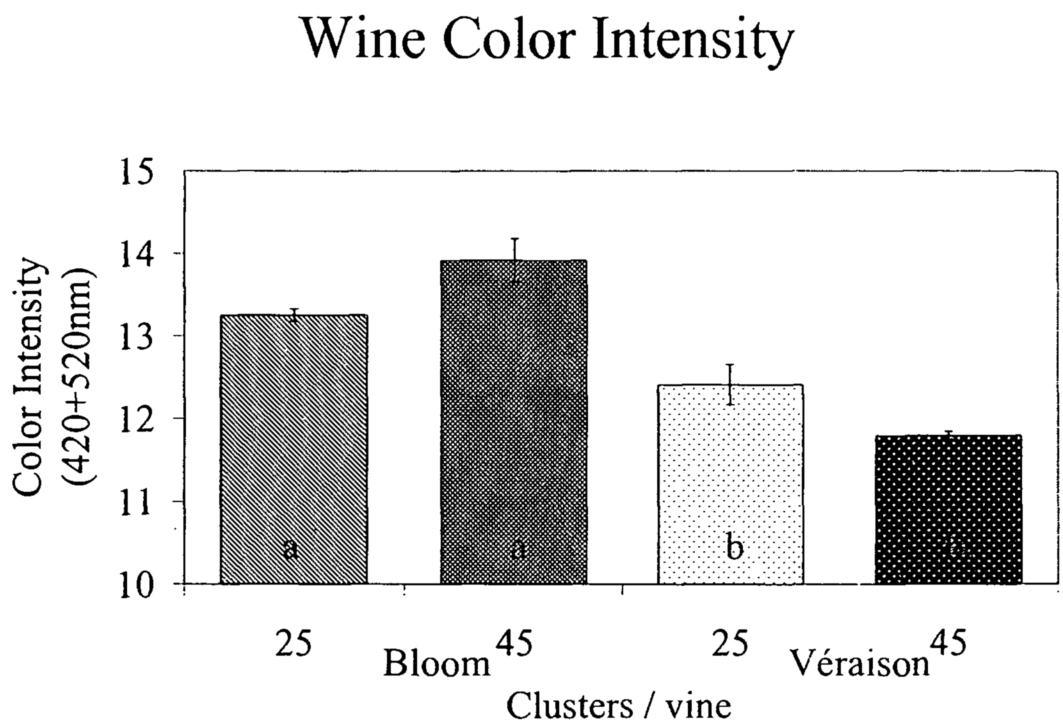

Figure 8) Color intensity of wine made from Pinot noir vines submitted to cluster thinning at bloom or véraison during the 2000 season at Hyland vineyard (experiment III). Each point is the average of 3 measurements. Vertical bars represent ±SE.

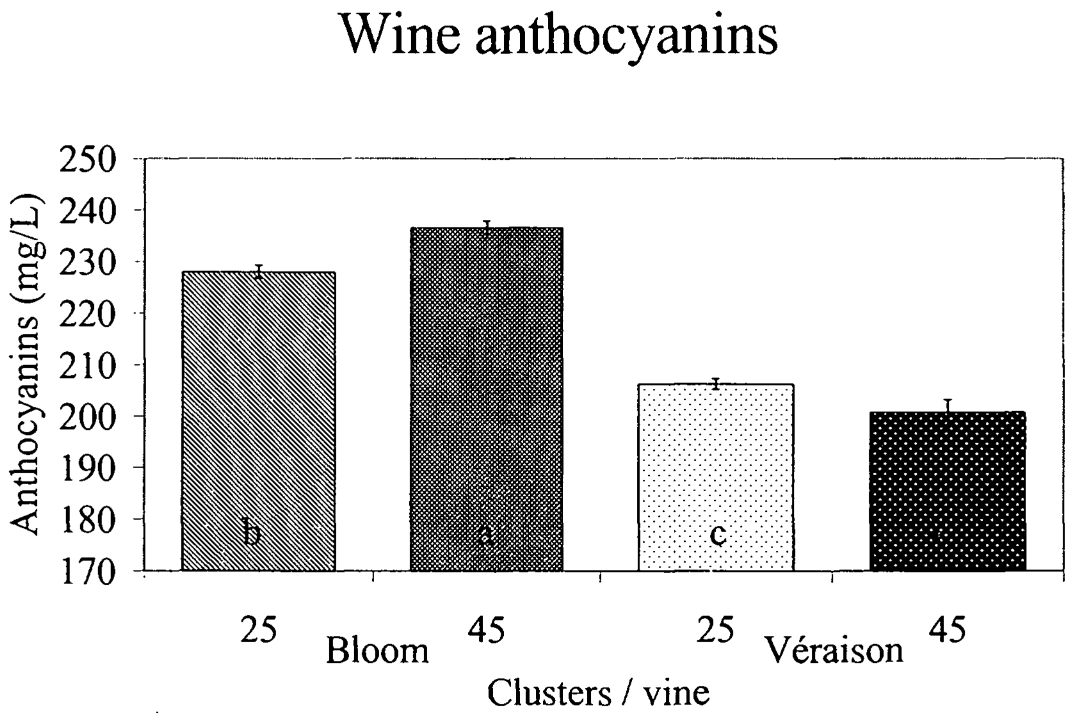

Figure 9) Total anthocyanins of wine made from Pinot noir vines submitted to cluster thinning at bloom or véraison during the 2000 season at Hyland vineyard (experiment III). Each point is the average of 3 measurements. Vertical bars represent ±SE.

CONCLUSIONS

Cluster thinning is often employed as a means of improving wine grape composition as well as a method of hastening maturation. During the two years of this study, average yield per acre stayed below three tons per acre and never reached levels that would be associated with overcropping. Ideally, thinning treatments would represent undercropped vines as well as overcropped vines. Although not representative of commercial practices, a greater range of crop levels with higher yields could have exhibited greater treatment differences within the parameters measured. Within the yield levels represented in this vineyard over the two growing seasons, we did not find a strong response to cluster thinning from fruit composition, carbohydrate reserves or vine vigor. Further research into cluster thinning practices may allow for growers and winemakers to evaluate the validity of the current thinning standards used to optimize juice quality. One must decide if the changes in juice composition caused by cluster thinning justifies reducing crop yield. The quality gained due to thinning is a factor that should be weighed carefully against the losses in yield and revenue within a mid-cropping range.

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