CROP LOAD MANAGEMENT IN WESTERN NEW YORK

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Crop load management in cool climate vineyards is important for the consistent production of both quality fruit and mature wood. In viticulture conversation the term "crop load" is often used as a descriptive term without reference to any specific vine measurement. "2003 was an overcrop year." or "Look at the growth in that vineyard, it must be undercropped." In an effort to better understand the effect of crop on vine growth and fruit development, viticulturists have given specific definition and measurement to the term crop load – and even this definition has changed with time. For the purpose of this article, "crop load" will be defined as the exposed leaf area to fresh fruit weight ratio (Kliewer and Dokoozlian 2000). For the past several years, we have been looking at past pruning research and current mid-season crop adjustment research to investigate the effect of crop load on Concord vineyards. The following discussion will show data specific for New York Concord production; however, I will comment on how the information translates to other wine varieties where appropriate.

Traditionally, vine size management has been (and still is) used to control vine leaf area and pruning severity has been used to control crop size. Therefore, pounds of cane pruning weight per foot of canopy and nodes retained per pound of pruning weight were the first measurements or indicators of crop load. In the 1950's and 1960's, different balanced pruning formulas were evaluated for effects on vine size, yield, and juice soluble solids (Kimbal and Shaulis 1958). Conservative formulas, such as retaining 22 nodes for each 500 g of dormant cane pruning mass (20 nodes/pound) with a maximum of 60 retained nodes/vine on standard vine spacings (2.7 m row x 2.4 m vine), were adopted because such formulas ensured an adequate exposed leaf area to fruit ratio to fully mature the crop in the cool New York climate, with weak vines, or poor growing seasons. However, the conservative formulas also limited the maximum potential crop which could be matured in warmer and longer-than-average growing seasons. Early studies suggest evaluating pruning formulas from site to site to match crop load with the growth and ripening characteristics of the region. For example, Clore in Washington and Morris in Arkansas found 50+10 pruning (50 nodes/vine for the first lb of pruning mass and 10 nodes for each additional lb) to be more suitable for Concord production in regions with relatively longer growing seasons than New York (Clore and Brummund 1961; Morris et al. 1984). The frequency of fixed node pruning at 80-100 nodes/vine increased in the New York Concord juice industry because the additional nodes/vine yielded higher crop levels, which could be fully matured in good seasons but struggled to reach minimum commercial juice soluble solids standards in poor seasons.

Mid-season crop adjustment in Concord by mechanical fruit thinning approximately one month after bloom has also been studied as an alternate approach to crop load management for higher retained node pruning practices (Pool et al. 1993; Fendinger et al. 1996). Concord berries reach approximately 50% of final berry fresh mass at 650 GDD (base $10^{o}C$). At this time, sub-sample vines can be stripped of fruit and weighed to estimate final harvest crop weight, a crop level decision can be made based on current season growing conditions, and the remaining crop mechanically adjusted to a desired crop level. Mechanical crop adjustment or "thinning" of

Concord fruit has gained popularity in the past decade for various reasons, one being the integration of mechanical crop load management into mechanical pruning practices.

So let's set the groundwork. The topic is grapevine crop load. Crop load is defined, in this case, as the exposed leaf area to fresh fruit weight ratio. Leaf area : fruit is influenced by vine size and can be manipulated by pruning severity or by mid-season crop adjustment, or by a combination of the two. The question is: What is the appropriate crop load for adequate vegetative and reproductive growth in a cool climate?

Measuring Crop Load

If we can measure exposed leaf area, fruit weight, and juice soluble solids, we can determine the effect of crop load on fruit maturation in Concord. We conducted a series of crop and leaf thinning experiments to create a range of leaf area to fruit ratios in Concord vines pruned to 120 nodes. Leaf area was calculated by measuring mid-rib leaf length of the leaves on sample vines and determining leaf area from a mathematical relationship between leaf length and leaf area. Of course, this is not something a commercial vineyard manger has the time to do but we wanted to get an accurate measurement of total vine leaf area. The vines were harvested during the middle of a normal harvest season and the crop load / ^{o}brix curve shows that desired fruit maturity was achieved when there were 15 square centimeters of exposed leaf area per gram of retained fruit (Figure 1). Undercropped vines (on the right side of the curve) did not have greater fruit maturity but tended to increase in pruning weight. Overcropped vines (on the left side of the curve) had lower fruit maturity and tended to have decreased pruning weight.

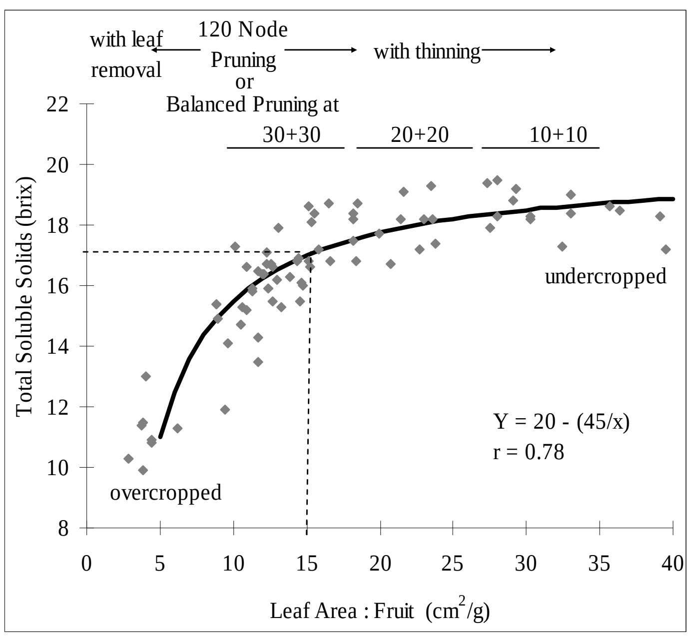

Figure 1. The effect of crop load (exposed leaf area to fruit ratio) on juice soluble solids in Concord.

For reference sake, in this particular vineyard block and growing season, 120 node unthinned vines yielded between 11 and 12 tons/acre, had a leaf area to fruit ratio of 10 and a fruit maturity of about 14.5-15.0^{o}brix. Therefore the unthinned vines were slightly overcropped and either needed to be crop adjusted or needed an extended growing season to reach our desired fruit maturity of 16^{o}brix. Thinning the vines down to 8-9 tons/acre increased the leaf area to fruit ratio to 15 and fruit maturity to 16-17^{o}brix.

When I went back and looked at some of the old balanced pruning experiments by Dr. Nelson Shaulis and recalculated the leaf area to fruit ratio based on pruning weight data, I could illustrate why 20+20 pruning was so popular with Dr. Shaulis. Going back to figure 1, 10+10 balanced pruning had high leaf area to fruit ratios, were well undercropped, and tended to be over vigorous. In contrast, 30+30 pruning put the vines on the shoulder of the crop load / ^{o}brix curve. In good growing seasons, 30+30 vines were ideal with high yield, good fruit maturity, and adequate vegetative growth. However, in poor years, 30+30 pruning ran the risk of overcropping. A good option would be to crop adjust the 30+30 vines in poor years to increase the leaf area to fruit ratio and more appropriately match the crop load with the growing season. Dr. Shaulis used 20+20 pruning in many of his experiments and we still used 20+20 pruning in many of our current experiments that we do not intend to crop adjust. We do this because 20+20 pruning keeps us on the "safe" side of the crop load / ^{o}brix curve. In good years, the vines tend to be undercropped and will gain pruning weight and in poor years the vines will be balanced without going off the crop load cliff.

Pruning for the Best Possible Season

The data from Figure 1 indicated that balanced pruning and fixed node pruning with crop adjustment can both be used to manipulate crop load in Concord vineyards. Research over the past five years has attempted to address issues that put that theory into practice. Balanced pruning (especially to 20+20) is rare in commercial Concord vineyards because it can be labor intensive and it does not take advantage of the good growing seasons where a larger crop can be harvested without sacrificing wood maturity. Fixed node pruning is more common but can easily create an overcrop situation, especially where crop adjustment is not being considered. Machine assisted pruning with or without hand pruning follow-up also lends itself to fixed node pruning but again raises questions about appropriate node number and crop adjustment.

Following our crop load theory and the goals of the Concord industry, efficient crop load management requires pruning for maximum crop for the best possible growing seasons and then crop adjusting down to match the vineyard potential with the particular growing season. Pruning for maximum crop does not mean not pruning at all and it also does not mean leaving the same number of buds on all the vines in a particular vineyard. In a cooperative research project between NY, MI, and WA, Concord vines were pruned to a range of bud numbers and harvested at a pre-determined fruit maturity level. Interestingly, the plot in MI tended to have small vine size, the one in NY had medium vine size, and the one in WA had large vines (1.5, 2.5, and 3.5 pounds/vine, respectively). In each state, yield increased with increasing retained nodes to a point, often refered to as the yield plateau. The small vines reached a yield plateau at approximately 90 buds, medium vines at 120 buds, and large vines at 150 buds (Figure 2).

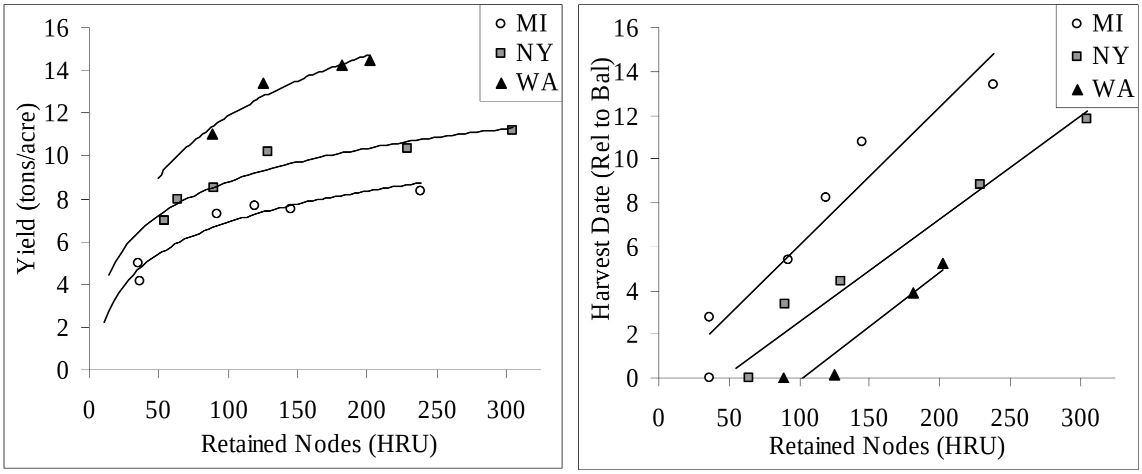

Figure 2. The effect of retained nodes on yield and relative harvest date of small (circles), medium (squares), and large (triangle) vines. Data are from the three-state Concord juice quality project on single wire trained vines. Harvest date is the number of days it took a treatment to reach 16^{o}brix relative to balanced (20+20) pruned vines

Pruning to a lower bud number decreased yield and increased the rate of fruit maturity – this simply follows our crop load discussion. Leaving more buds with hedge pruning or minimal pruning did not increase yield further because of yield compensating factors such as lower cluster and berry weights; however, excess buds further delayed fruit maturity presumably because of canopy inefficiency (Figure 2). Therefore, when pruning for maximum crop it is important to prune to a bud number that gives maximum crop potential for a given vine size level but not to prune beyond that number.

Does this apply to wine grape production? Certainly – Spur pruned Riesling on VSP training are typically shoot thinned to 4-5 shoots per foot of row. Doubling the shoot number would not only increase the crop level but would also cause excessive canopy crowding, both leading to a decrease in the exposed leaf area : fresh fruit weight and delayed fruit maturation.

Crop Adjusting for the Actual Season

At the Cornell Vineyard Laboratory in Fredonia, we have been researching the physiological effect of crop adjustment on 120 node pruned vines at 30 days after bloom. We prune to 120 nodes because we target 2.5-3.0 pound vines and our node number experiment (from figure 2) indicates that the yield plateau is reached at approximately 120 nodes. Each year we have recorded an inverse relationship between yield and ^{o}brix (figure 3).

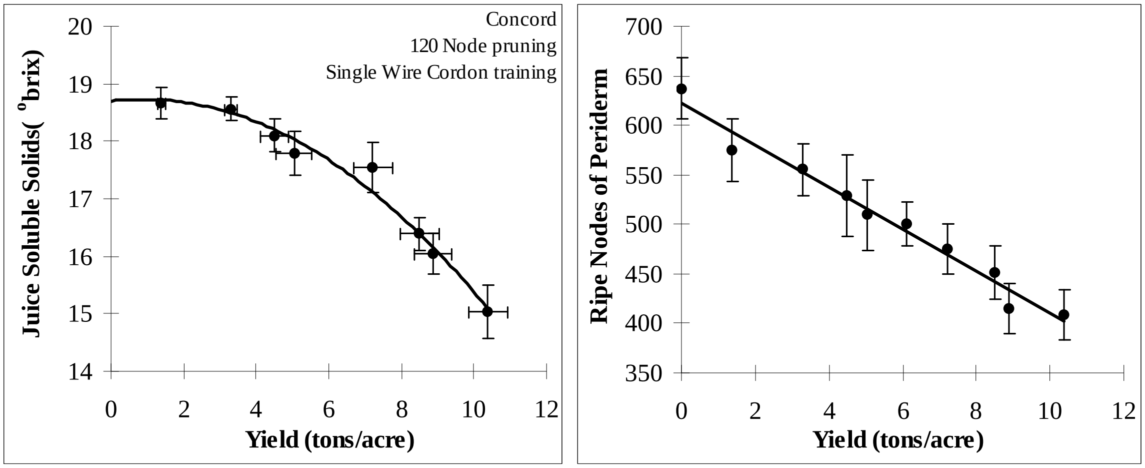

Figure 3. The effect of yield on juice soluble solids and ripe nodes of periderm on 120 node pruned vines at the Cornell Vineyard Laboratory in Fredonia. Each point is the mean of 10 vines, bars=standard error.

Below 5 tons/acre, the vines are undercropped and there is no further increase in juice soluble solids with further fruit thinning (i.e. the vines are on the top of the crop load / brix curve in figure 1). From 5 to 11 tons/acre, juice soluble solids decrease as yield increases. Although growing season conditions will influence the slope of this curve from year to year, the general trend is that for every 2 to 3 ton/acre increase in yield there is a decrease in one degree brix. In practical terms, if you have a 10 ton/acre crop that is going to be 15^{o}brix at harvest and you thin the crop down to 7-8 tons/acre, the crop will reach 16^{o}brix at harvest.

In addition to the increase in juice soluble solids with thinning is the response of wood maturity to thinning. There is a direct inverse relationship between yield and ripe nodes of periderm (figure 3). Periderm counts are a mature bud measurement that is proportional to pruning weight. In our Concord experiment, as the crop decreased from 11 tons/acre down to 0 tons/acre the number of mature buds increased (and the pruning weight increased).

Other studies have shown that increasing vine size increases crop potential; therefore, thinning in year one not only influences fruit maturity in year one but also influences crop potential in year two by increasing vine pruning weight. Currently, Martin Goffinet of Cornell is investigating the effect of Concord crop adjustment on individual bud development for the subsequent season.

In the specific example in figure 3, our goal was to harvest between 16 and 17^{o}brix and maintain the vines between 450 and 500 ripe nodes of periderm (roughly 2.5 pounds of pruning weight) – our own specific vineyard balance definition. At 11 tons/acre, the fruit was harvested at 15^{o}brix and periderm counts were around 400. Fruit thinning down to 7-8 tons/acre increased the fruit to 16.5^{o}brix and 475 ripe nodes of periderm, thus achieving our goal for vineyard balance. Thinning below 7 tons/acre turned out to be excessive thinning in that particular vineyard and growing season.

Does this apply to wine grape production? Certainly – Take our spur pruned and VSP trained Riesling. Shoot thinning to 4-5 shoots per foot of row should provide a well exposed canopy depending on the vine size (exposed leaf area) and cluster thinning to one or two clusters per shoot will manipulate crop size (fresh fruit weight). What we currently lack is hard crop load data for NY Riesling (and other varieties) for desired fruit maturity not just in terms of brix but for other flavor compounds as well. Is the optimum crop load more or less than 15 square centimeters of exposed leaf area per gram of fresh fruit weight for quality Riesling juice?

Vine Size and Crop Load

I am always referring to the importance of vine size on Concord productivity because vine size influences both vine leaf area and bud fruitfulness. It is no surprise that vine size also influences the thinning response in Concord. In 2002 and 2003, we repeated the 120 node thinning experiment on small, medium, and large vines.

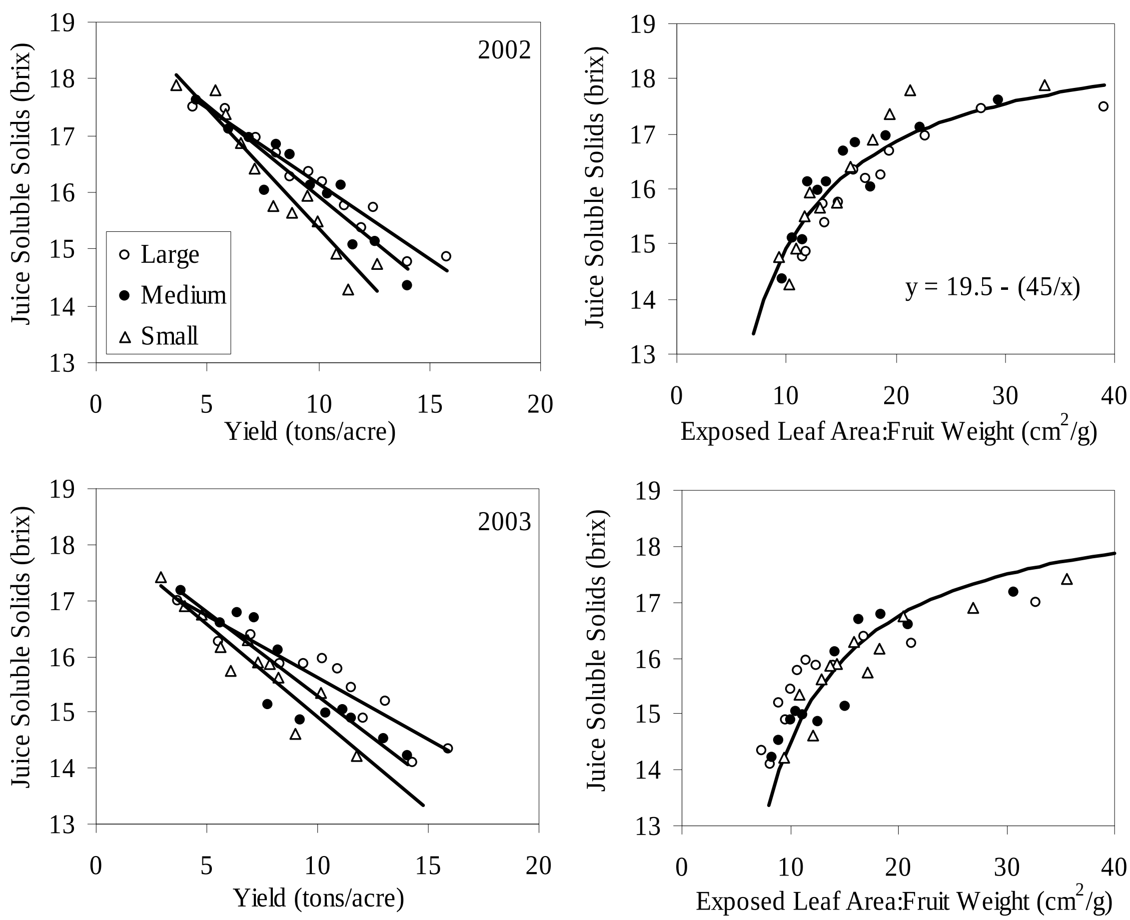

Figure 4. The effect of crop level (yield) and crop load (exposed leaf area to fruit ratio) on juice soluble solids of small, medium, and large Concord vines pruned to 120 nodes in 2002 and 2003.

The yield/brix regression lines in figure 4 show that small vines were more responsive to thinning than medium or large vines. Calculated exposed leaf area to fruit ratios (Figure 4B) also show that the crop load / ^{o}brix curve is the same for all vine size categories; however, at a given yield level the vines will be at different points on the crop load / ^{o}brix curve. Or, the vines will reach similar leaf area to fruit ratios at different crop levels.

Does this apply to wine grape production? Certainly – The rate of fruit maturation in the VSP Riesling (or any other variety) will be dictated by the crop load which is partially a function of vine size. What we don't know is what the crop load vs. brix (or vs. terpene concentration or vs. some other quality attribute) looks like compared to our Concord data. The concept will be the same but the numbers will change.

Timing for Crop Adjustment

Typically, commercial Concord vineyards are mechanically crop adjust at 30 days after bloom; however, other thinning times have been tested or considered. Partridge used flower cluster thinning in 1931 and Shaulis used manual flower cluster thinning in the West Tier back in the 1960's (Partridge 1931; Shaulis and Steel 1969). Unfortunately, thinning prior to fruit set can increase the percent of florets that set fruit leading to some degree of yield compensation. In theory, the earliest that the crop can be adjusted after fruit set, the more efficient the vine response will be because the vines have invested few resources into the crop. In practice, the berries have little mass right after fruit set and it is difficult to accurately fruit thin with a machine when the berries are too small.

Dr. Pool investigated Concord berry growth in relationship to both calendar days after bloom and growing degree days. His research showed that Concord berries reached 50% of final fresh berry weight approximately 30 days after bloom and more specifically at 1200 growing degree days (base 50^{o}F). The "50% final berry weight/30 day after bloom" timing has been adopted by several growers as a convenient time to both estimate the crop and mechanically crop adjust.

Growers have also asked about thinning later in the season (50 days after bloom) when berry growth slows down during the lag growth phase (Figure 5). At 30 days after bloom, fresh berry weight is rapidly changing and a few days in either direction can cause large errors crop estimation. At 50 days after bloom, the rate of fresh berry weight change is smaller when compared to the rate of change at 30 days after bloom, potentially providing added flexibility and accuracy to crop estimation. However, there should also be a resource cost associated with leaving an excessively large crop on the vine for an extended time period.

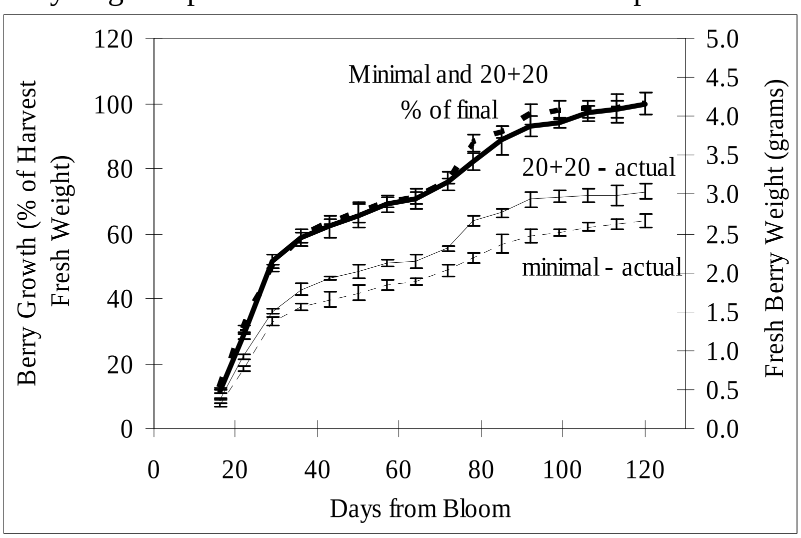

Figure 5. Typical Concord berry growth curve showing both actual and % of final berry weight for balanced (20+20) and minimal pruned vines.

In 2002 and 2003, we conducted another thinning experiment in 120 node vines at the Fredonia Lab where we manually crop adjusted at 20, 30, 50 days after bloom, immediate pre-veraison, and 2 weeks post-veraison. In terms of juice soluble solids accumulation, all of the pre-veraison thinning times led to a similar increase in ^{o}brix at a given crop level. Fruit from all treatments in the experiment started at approximately 7^{o}brix at veraison (figure 6). The rate of soluble solids accumulation in vines with 50% crop was greater after veraison than on vines with 75% or 100% crop. Vines thinned two weeks after veraison had a slow initial rate of soluble solids accumulation (similar to vines with 100% crop). After thinning 2 weeks post-veraison, the rate of soluble solids accumulation increased until harvest (similar to vines with 50% or 75% crop). The post-veraison thinned vines were unable to catch up to the earlier thinned vines by the selected harvest date (figure 6). In theory, all data curves in figure 6 would eventually merge into one line if the growing season were long enough. The practical problem is that an extended harvest season is a rare luxury in the Lake Erie grape belt.

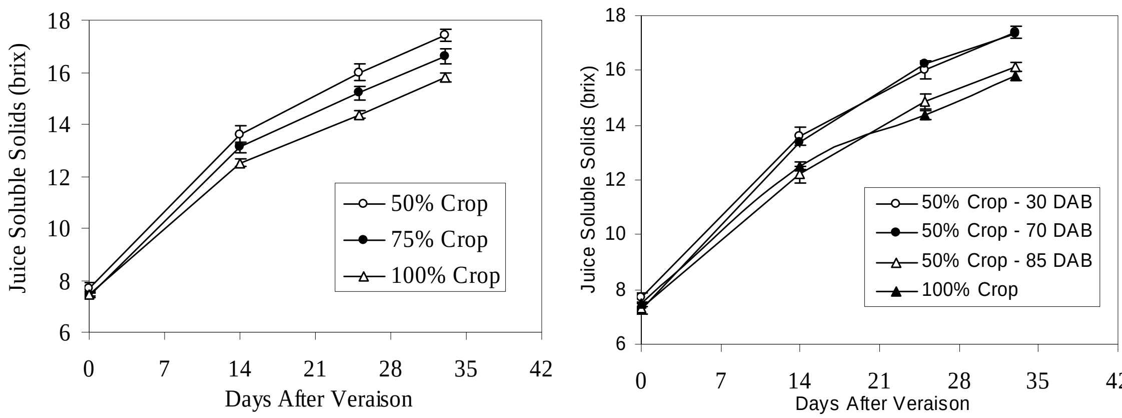

Figure 6. Concord juice soluble solids accumulation from veraison to harvest on vines with 50, 75, or 100% crop established at 30 days after bloom (left) or on vines with 50% crop established at 30, 70, or 85 days after bloom (right).

As discussed earlier, crop adjustment is important for both fruit maturation and wood development. Concord growth analysis research that we have done shows that perennial grapevine tissues accumulate starch approximately one month after bloom until the end of the growing season. It could be argued that delaying crop adjustment later than 30 days after bloom would infringe upon early wood development through the partitioning of resources, such as carbon and nitrogen, into the crop.

Pruning weight data from different sized vines thinned to 50% and 75% crop level at five different timings during the growing season shows some effect of thinning time on vine growth. On already large vines, thinning time did not have an effect on final vine size (figure 7).

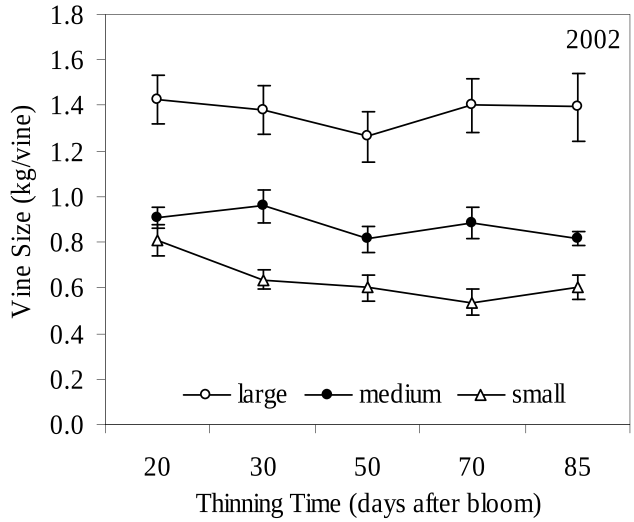

Figure 7. The effect of thinning time on final vine pruning weight of small, medium, and large Concord vines.

The large vines had a relatively high leaf area to fruit ratio at a given crop level when compared to medium or small vines (as seen in figure 4); therefore, the large vines in our experiment could mature both the fruit and wood well within the limit of the growing season. In contrast, small vines with relatively low leaf area to fruit ratios (higher crop load) at a given crop level had lower juice soluble solids accumulation rates (figure 4) and were affected by thinning time (figure 7). In general, delaying crop adjustment decreased vine pruning weight and this response was measured as early as 30 days after bloom.

Does this apply to wine grape production? Certainly – Cluster thinning is common in cool climates for many wine grape varieties and the cluster thinning can be done anytime before veraison without a delay in sugar accumulation (again, I am unsure about other flavor components). In young or small vines, the data suggests reducing the crop as early as possible to remove crop stress. In moderate sized vines, late (immediate pre-veraison) thinning can be used in an attempt to control canopy growth during the middle of the season. However, in over-vigor situations, I think it is important to note that big vines are usually big for a reason such as from excess water and nutrients from deep and fertile soils or from the inappropriate use of aggressive rootstocks. Trying to use mid-season crop stress to control excessively large vines will probably be met with disappointing results.

Conclusions:

1) Vine response to crop load is the same whether crop load is manipulated by pruning, thinning, or a combination of the two.

2) In an average growing season with average vine size, Concord vines require 15 square centimeters of exposed leaf area per gram of fruit fresh weight for balanced production. Vines with a lower leaf area to fruit ratio need crop adjustment or an extended growing season to maintain a balance between vegetative and reproductive growth.

3) In overcropped vines, thinning increases both juice soluble solids and vine pruning weight. The response is more pronounced on small vines than on large vines because small vines have a lower LA:Fr than large vines at a given crop level. On small vines, thinning

approximately 2 tons/acre leads to an increase in one degree brix. On large vines, thinning approximately 3 tons/acre leads to an increase in one degree brix. On undercropped vines (below 5 tons/acre), there is no effect of thinning on juice soluble solids.

4) In terms of thinning time, thinning can be done any time before veraison to increase the juice soluble solids accumulation rate in the remaining fruit. In terms of wood maturation, thinning time impacts small vines more so than large vines. In commercial vineyards with lower than optimum vine size and/or with a variety of biotic and abiotic stresses, crop adjustment should be done as early as practically possible so that the crop load change can have a larger increase on wood development. On large healthy vines, thinning time did not impact the resultant vine size.

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