

## Concord Crop Adjustment: Theory, Research, and Practice

Dr. Terry Bates

Viticulture Research Associate

Cornell University

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. In the past five years, we have conducted several research projects at the Cornell Vineyard Laboratory in Fredonia and in cooperating grower vineyards investigating the physiological and practical aspects of mechanical crop adjustment. Many area growers have tried thinning for themselves with varying degrees of success. The following article covers the theory behind crop adjustment, the information we have learned from our Concord research projects, and the practical method for in-the-field mechanical crop adjustment.

### Theory

Sustainable productivity of both ripe fruit and mature wood depends on the appropriate ratio of exposed leaves to retained fruit, otherwise known as crop load. An undercropped vine (one with a lot of exposed leaf area to retained fruit) will have ripe fruit and excess vegetative growth. An overcropped vine (one with little exposed leaf area relative to retained fruit) will have delayed fruit and wood maturity leading to a decrease in vine size and future fruiting potential. There have been extensive arguments over the definition of vine balance. Most likely because the definition is different depending on the individual grower, processor, winery, grape variety, intended purpose for the fruit, or maturity characteristic being measured. For the purposes of this article, let's assume that a

“balanced” vine reaches a desired Concord fruit maturity of 16°brix by the middle of a typical harvest season while maintaining 2.5 to 3.0 pounds of cane pruning weight.

Since 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 (Figure 1). 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. The vines were harvested during the middle of a normal harvest season and the crop load / °brix curve shows that desired fruit maturity was achieved when there was 15 square centimeters of exposed leaf area per gram of retained fruit. 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.

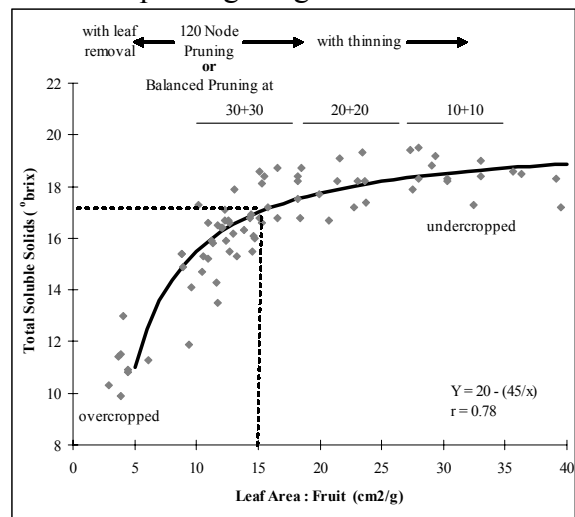


Figure 1. The effect of crop load (exposed leaf area to fruit ratio) on juice soluble solids in Concord.

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°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°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°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 / °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 / °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.

### Research

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.

Surprisingly, 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 which I refer 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 2A).

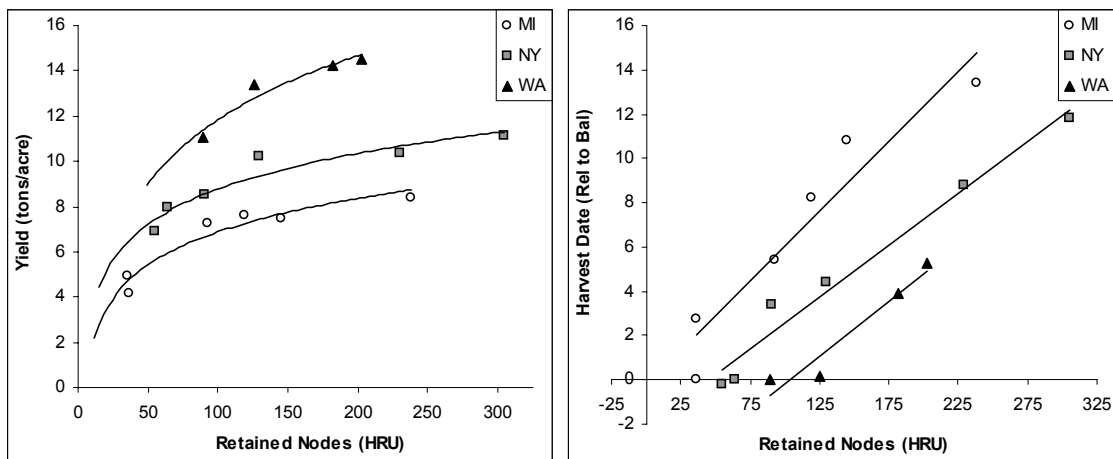


Figure 2A and B. The effect of retained nodes on yield (A) and relative harvest date (B) of small (circles), medium (squares), and large (triangles) vines. Data are from the three-state Concord juice quality project on single wire trained vines. Harvest date in (B) is the number of days it took a treatment to reach 16° 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 2B). 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.

At the Vineyard Laboratory, 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 °brix (figure 3A). 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° brix at harvest and you thin the crop down to 7-8 tons/acre, the crop will reach 16° brix at harvest.

In addition to and probably more important than the increase 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 3B). Periderm counts are a mature bud measurement that is proportional to pruning weight. In our 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).

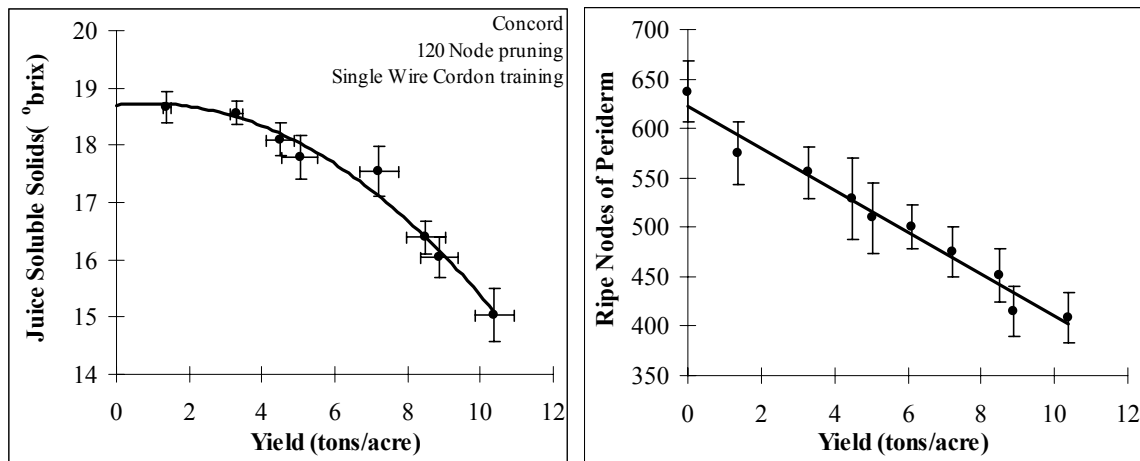


Figure 3A and B. The effect of yield on juice soluble solids (A) and ripe nodes of periderm (B) on 120 node pruned vines at the Cornell Vineyard Laboratory in Fredonia. Each point is the mean of 10 vines, bars=standard error.

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.

In the specific example in figure 3A and B, our goal was to harvest between 16 and 17°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°brix and periderm counts were around 400. Fruit thinning down to 7-8 tons/acre increased the fruit to 16.5°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.

I am always drilling home the importance of vine size on Concord productivity. It is no surprise that vine size also influences the thinning response in Concord. In 2002, we repeated the 120 node thinning experiment on small, medium, and large vines.

The yield/brix regression lines in figure 4A 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 / °brix curve is the same for all vine size categories; however, at a given yield level the vines will be at a different points on the crop load / °brix curve. Or, the vines will reach similar leaf area to fruit ratios at different crop levels.

What about timing? Typically, commercial Concord vineyards are mechanically crop adjust at 30 days after bloom; however, other thinning times have been tested or considered. Dr. Shaulis used manual flower cluster thinning in the West Tier back in the 1960's. 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 that small.

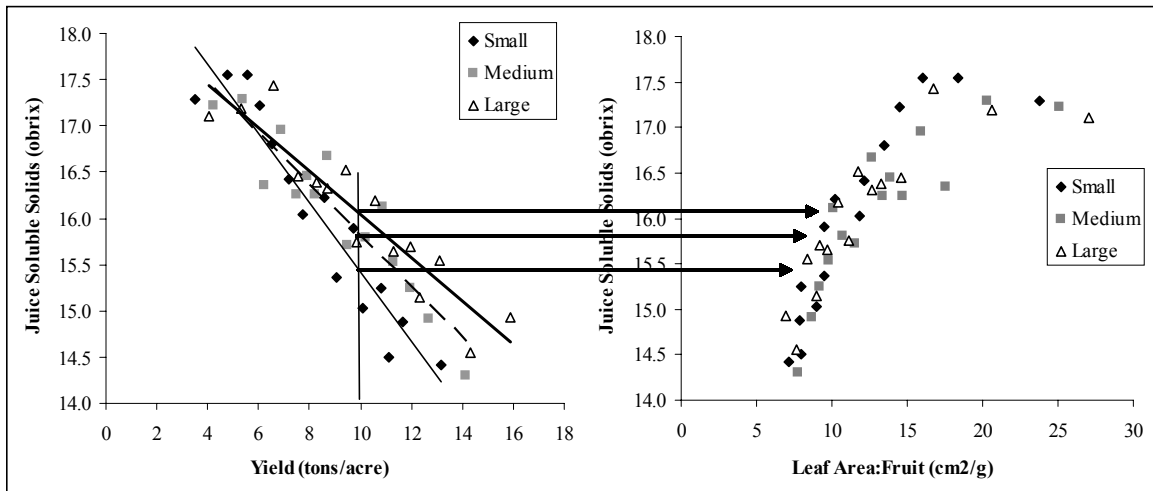


Figure 4 A and B. The effect of crop level (yield-A) and crop load (exposed leaf area to fruit ratio-B) on juice soluble solids of small, medium, and large Concord vines pruned to 120 nodes.

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. 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.

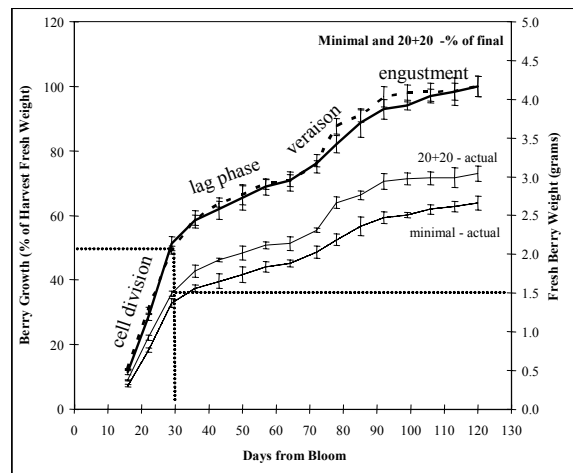


Figure 5. Typical Concord berry growth curve showing both actual and % of final berry weight for balanced (20+20) and minimal pruned vines.

In 2002, 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.

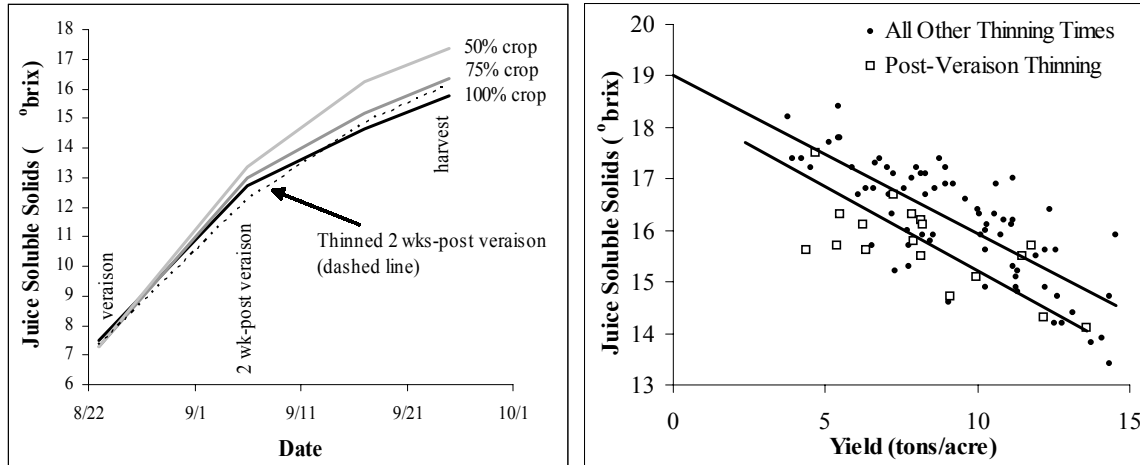


Figure 6A and B. Juice soluble solids accumulation from veraison to harvest on vines with different crop levels prior to veraison and on vines thinned 2 weeks post-veraison (A). The effect of yield on final harvest juice soluble solids of vines thinned at various times pre-veraison and 2 weeks post-veraison.

In terms of juice soluble solids accumulation, all of the pre-veraison thinning times led to a similar increase in °brix at a given crop level. Fruit from all treatments in the experiment started at approximately 7°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 6B). In theory, all data curves in figure 6A 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.

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.

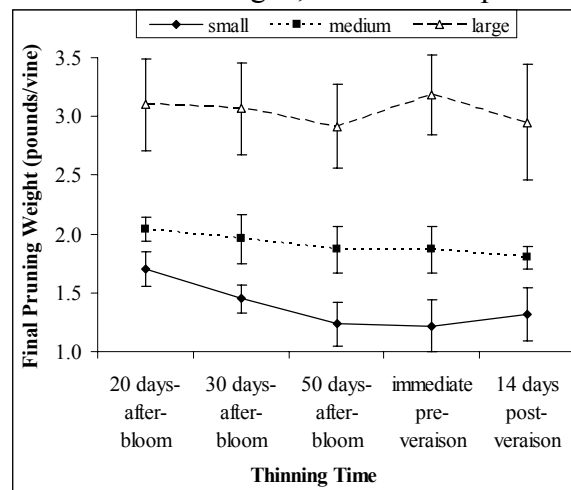


Figure 7. The effect of thinning time on final vine pruning weight of small, medium, and large vines.

Pruning weight data from different sized vines thinned to 75% crop level at five different timings during the growing season brings our whole discussion of crop adjustment together. On already large vines, thinning time did not have an effect on final vine size (figure 7). 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.

#### 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 higher crop load 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 (although I question if this statement remains true if the same vines are pushed and thinned late for several years in a row).

#### Practice

Everyone is always asking me how our research translates to commercial vineyards. In-the-field mechanical thinning research has been going on in the Lake Erie region since the early 1990's. I have been involved with several growers, especially Bob and Dawn Betts, Joel Rammelt, and Dave Vercant, for the past five years evaluating on-farm mechanical thinning. Our research shows that mechanical crop adjustment, if done correctly, gives the same results as thinning at the Fredonia Lab (figure 8). We have used different harvesters and thinning heads with straight rods and bow rods and at different thinning speeds.

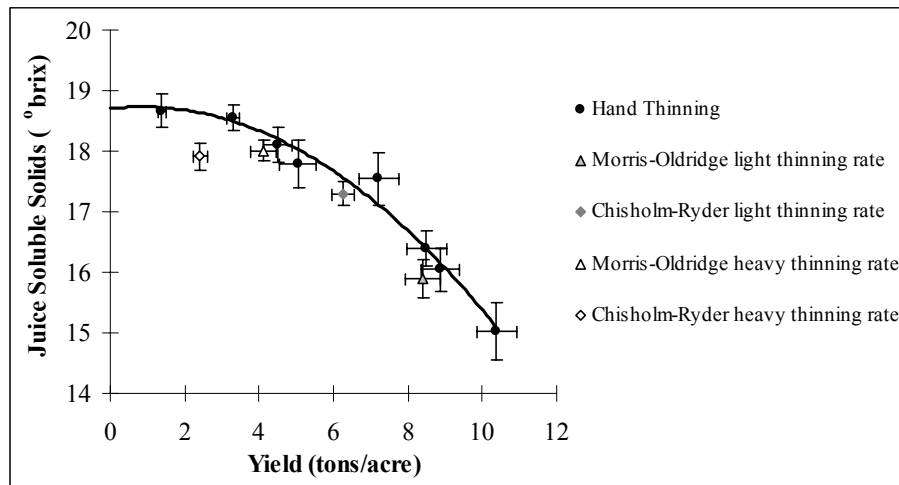


Figure 8. The effect of yield on juice soluble solids of hand thinned 120 node vines (same as figure 3A) compared with two thinning machines at two thinning rates. Canopy damage only impacted fruit maturity when we tried to thin approximately 8 tons/acre.

Many growers have reported that they have beat up their vines with mechanical thinning and it is certainly possible to cause significant canopy damage when thinning. However, we have found that with some common sense and a little machine operation experience that this damage can be avoided. Some useful tips are. . .

1) Bring your common sense. If it looks like you are taking off more leaves than fruit or causing significant canopy damage, you probably are. Adjust your thinning machine.

2) Avoid having to thin off more than 3-4 tons. If you have a vineyard that can yield 8 tons/acre in an average year, use dormant pruning to target 10 tons/acre in the prospect of a good growing season. Then thin off a few tons if the year is less than perfect. Avoid hanging 15 tons/acre and then having to thin off 7 tons/acre – it always leads to poor results.

3) Shake - don't slap! Machines that grip and shake the canopy tend to cause less canopy damage than those that slap the foliage and break shoots. Floating picking

heads and bow rods are nice features to some new machines but they are not mandatory. We have had excellent results with the correct set up of old machines and straight harvester rods.

4) Some like it Hot! We have found much less shoot breakage on Concord when thinning is done during a warm afternoon. First thing in the morning, the shoots are pumped up with water and tend to break during thinning. At 30 days after bloom in mid-July, the warm afternoon temperatures cause the shoots to relax and become more flexible later in the day resulting in less shoot breakage.

5) Talk to your fellow growers that have thinned successfully. They are a wealth of practical information.

#### How to Mechanically Crop Adjust: The Easy Method

The following method considers mechanically crop adjusting at 30 days after bloom with “playing all the averages.” The easy method takes less thought but can also

be less accurate because it takes into account several assumptions.

To successfully crop adjust; a grower needs to know what the balanced cropping potential is for a particular vineyard block in an average growing season. For example, a grower knows that Block A is in a poor spot and can only handle 5 tons/acre and that Block B is in a good spot and can run 8 tons/acre in an average growing season without losing significant pruning weight. Next, all the grower needs to do is measure what crop is hanging in the vineyard and adjust the harvester to take off the excess crop to reach the target crop level.

To crop estimate using the easy method, 1% of an acre is clean picked and weighed at 30 days after bloom. At 9 foot row and 8 foot vine spacing, there are 605 vines in one acre. A row of 605 vines at 8 foot spacing would be 4840 feet long. 1/100<sup>th</sup> or 1% of that row would be 48.4 feet. An easy way to pick 1/100<sup>th</sup> of an acre is to measure and cut a piece of rope 48 feet long, lay it down on the vineyard floor, and clean pick the vines in that rope length with a harvester. The picked green berries are then sent across the harvester shoot to a barrel on a scale (many growers use a milk scale on a trailer). Weight the picked fruit. In the easy method, simply read the weight of the fruit picked off of 1/100<sup>th</sup> of an acre (in pounds) and move the decimal point over one place to the left to get the harvest estimate in tons/acre.

For example, in Block X, Bob lays out his 48 foot crop estimation rope (roughly two post lengths) and clean picks it. Dawn, on a trailer in an adjacent row, places a barrel on a milk scale, tares (or zero's) the scale, collects the berries from the harvester shoot into the barrel, and weighs the green fruit. The scale reads 100 pounds. Dawn moves the decimal point one place to the left and

estimates that the block will have 10 tons/acre at harvest. Bob and Dawn repeat the procedure in a Block Y and the scale reads 50 pounds. They estimate that they will harvest 5 tons/acre from Block Y.

Bob and Dawn decide that Block Y with the 5 tons/acre estimate does not need thinning and they leave it alone. Block X, on the other hand, has a 10 tons/acre estimate and they want to thin it down to 8 tons/acre by taking off a harvest equivalent of 2 tons/acre. Working backwards and moving the decimal point one place to the right, Bob and Dawn must set up their harvester to remove 20 pounds of fruit in the same 1/100<sup>th</sup> of an acre (48 feet). After a couple trial runs at different beater speeds, they are comfortable that they are taking an average of 20 pounds of fruit off of a 48 foot section. Bob then runs over the rest of the block with the determined machine set-up.

#### How to Mechanically Crop Adjust: The Advanced Method

The easy crop adjustment method assumes that thinning is done at 30 days after bloom, that the berries are at 50% of final berry weight at 30 days after bloom, and that there is an average growing season. The actual physical activity in the vineyard between the easy and advanced methods is the same – pick 1/100<sup>th</sup> of an acre and make some decisions about thinning. However, the advanced method takes into account actual berry weight and growing season conditions to make more educated decisions in the vineyard and to decrease error in the thinning process.

The way I like to calculate % final berry weight in crop estimation is to weigh a berry sample at the time I am thinning and make a prediction on what the final berry weight is going to be. I do this for three reasons: 1)

the berry weight at 30 days after bloom and at the end of the season is different every year (is there such a thing as an average year?); 2) the berry weight is changing very fast in the 30 day after bloom / 1200 GDD period (see figure 5); 3) I am not always crop adjusting at exactly 50% of final berry weight in any one vineyard or any one area in the Lake Erie Belt.

1. Clean pick 1/100<sup>th</sup> of an acre (as in the easy method) and weight it.

Example: 142 pounds of green fruit is picked from 48 feet.

2. Measure average fresh berry weight at thinning time. Typically I weigh a couple different 100 berry samples to get a reliable average berry weight at thinning time.

Example: Average berry weight measured at 1.8g.

3. Predict what you think the final berry weight will be at the end of the season. This can be tricky but I feel that it is more accurate than automatically assuming that the berries are at 50% final berry weight.

Rules of thumb: Final berry weight changes with crop level, pruning method, and growing season. Balanced pruned vines with relatively light crops average 3.0g berries at harvest. 120 node vines average 2.75 g berries and Minimal pruned vines average 2.5 g berries at harvest (see figure 5). Excellent growing conditions with adequate water during the cell division phase of berry growth lead to larger than average berries. Lack of water post-veraison can lower final predicted berry weight. Predicting final berry weight is a guess at best and will always add error to the crop estimation (however, cluster and berry counts are old crop estimation

errors that are now removed from the procedure).

4. Calculate % final berry weight.

Example: If average berry weight is 1.8g when I am going to thin and I predict that the final berry weight is going to be 2.75g then I calculate that I am at 65.4% of final berry weight ( $1.8/2.75 = 0.654$  or 65.4%).

5. Calculate the multiplication factor for crop estimation.

Example: If I am at 65.4% of final berry weight then I should multiply my 1/100<sup>th</sup> of an acre sample by 1.53 ( $100/65.4 = 1.53$ ) to get what the sample will weigh at harvest.

6. Calculate the per acre crop estimate.

Example: 142 pounds of green fruit multiplied by 1.53 = 217.3 pounds of fruit in 1/100<sup>th</sup> of an acre at harvest. This is equal to 21730 pounds of fruit per acre at harvest ( $217.3 \times 100 = 21730$ ) or 10.87 tons/acre ( $21730 / 2000$  pounds per ton).

7. Determine the desired crop level for the vineyard block. As in the easy method, if the grower knows a vineyard block is balanced at 8 tons/acre then that yield can be targeted each year. However, at the vineyard lab we look at the growing degree days at thinning time and make a judgment on how much crop to leave based on how many days we are ahead or behind average. The rule of thumb: For every three days ahead of average we are at thinning time we can ripen one ton/acre more than average. This “3 day per ton” rule comes from a Concord pruning experiment where vines with a range of crop levels were harvested based on juice soluble solids and not on a single date.

Example: If a vineyard can ripen 8 tons/acre on an average year and we are a week ahead of average at 30 days after bloom then we would predict that the same block can potentially ripen 10 tons/acre. In contrast, if we are a week behind average at 30 days after bloom then we would predict that the same vineyard block may be better balanced at 6 tons/acre. The only downfall to this rule of thumb is if the weather drastically changes between thinning time and harvest. However, I am more comfortable making weather related crop load decisions one month after bloom than I am in the middle of January when crop load is being decided with pruning alone.

8. Work backwards to determine the machine set up for thinning.

Example: To shake off 2 tons/acre harvest equivalent when the berries at 65.4% of final berry weight. ( $2 \text{ tons/acre} \times 2000 \text{ pounds/ton} = 4000 \text{ pounds/acre} = 40 \text{ pounds in } 1/100^{\text{th}}$  of an acre at harvest.  $40 \text{ pounds} / 1.53 \text{ berry weight multiplication factor} = 26.14 \text{ pounds of green fruit to remove from } 1/100^{\text{th}}$  of an acre at thinning time).

9. Set-up machine to take off desired amount of fruit. Unfortunately, with all the different machines and harvester configurations out there, this is still a trial and error process. The set-up with a Chisholm-Ryder with straight rods is different than a Morris-Oldridge thinning head or a Korvan with bow rods.