Yield Estimation

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Frequently wineries set yield targets for growers that need to be adhered to. It is therefore essential that growers develop some basic skills to estimate their potential yields effectively. Sampling a vineyard to estimate yield and fruit composition is a need for all vineyard mangers and winemakers. It may seem like an easy task, and if done improperly, it probably is. To sample properly, it requires time, skill, and knowledge.

It can be difficult to predict the yield of a vineyard for several reasons. In the American northwest, particularly in northwestern Oregon, the period during bloom and cluster initiation is often cool, wet and rainy. This type of weather will make set this season and cluster initiation for the following season unpredictable, especially with sensitive cultivars such as Pinot noir. The result is variable cluster number, variable flower number and variable berry number per cluster, making yield prediction challenging.

There are many other factors that affect the yield in a vineyard. Here in northeast North America, winter injury is a constant threat. Vineyards may have cold spots where vine health is variable, vines may be missing, and yields are difficult to estimate. Uneven drainage patterns and any other factor that will affect the potential for winter injury will adversely affect the consistency of a vineyard.

First, let's consider an average Chardonnay or Riesling vineyard in the Finger Lakes in NY or the Niagara Peninsula in Ontario. Chances are, the vines are spaced about 1.2 m apart and the rows are about 2.5 m wide. That leaves us with about 1200 vines per acre. Now, each vine is likely producing about 3 kg of fruit with about 30 clusters per vine if the crop size is 4 tons per acre.

Now we need to think a bit more critically. How many clusters do these 4 tons represent? That's easy; actually, it's about 36,000. How about cluster weight, number of berries per cluster, and weight per berry? Mean cluster size for Riesling and Chardonnay varies from site to site, and is subject to variation due to vine size, crop load, clone, and other viticultural practices and decisions; however, all said and done, let's assume 110 g is a mean cluster weight. Now, what is the total number of berries per cluster that makes up that 110 g? Data we have collected through the years suggests a range of 70 to 85, so that makes an average berry weight of about 1.4 g.

All this basic math provides us with a figure of about 2.52 million berries on every acre of Riesling or Chardonnay! How can we possibly do a decent job of sampling for yield, fruit composition, or potential wine quality in order to arrive at an estimate in which we might have confidence?

Factors affecting yield components

A basic understanding of yield components of a grapevine is needed in order to understand the appropriate data points required and the timing of calculations for yield estimation.

Planting density and trellis design. The influence of planting density on other yield components is closely related to site and trellis factors. A low vine density with a divided canopy can have the same canopy length per hectare as a simple trellis at twice the vine density.

Cluster initiation. The period of fruit initiation the previous season will determine the number of clusters per shoot, the cluster weight and thus the yield per node. This can be manipulated by pruning and canopy management.

Dormant pruning. This will determine the number of nodes per vine and potentially the number of shoots per vine. The number of shoots may be modified by percentage budburst (also affected by degree of dormant pruning) or winter/spring hazards.

Budburst. Severe pruning will result in 100% or greater than 100% budburst because of the breaking of latent or 'non-count' buds. Minimal pruning will result in lower budburst. The survival of these shoots can be affected by spring frost hazards.

Flowering. The number of flowers per inflorescence is determined just prior to and during budburst.

Fruit set. The proportion of flowers that develop into berries is regulated by both climatic and endogenous factors. The maximum fruit set occurs with the minimum number of clusters per vine. Conversely, minimally-pruned vines will have a low percent set because of the large number of clusters.

Berry development. Berry size is affected by climatic conditions, management practices and genetic characteristics.

Sampling for yield

In order to come up with a yield per acre value you need two basic things: 1. Number of clusters per vine, and; 2. Estimated weight per cluster at harvest. You also need to have as accurate a count as possible of the number of vines per acre or per block, and the number that are missing. Start with counting the number of clusters per vine on as many vines per block as you can. To deal with the spatial variability issue, choose several vines (at least 10 vines per acre equivalent) and sample in an "X" configuration from opposing corners across the block. Record the cluster number for every vine.

Next, it is time to estimate cluster weight. To do a decent job sampling for yield it is also very necessary at this point to have a full understanding of how miniscule your cluster sample really is in the whole scheme of things. Counting clusters on 10 vines per acre provides a 0.8% sample size. Collecting one cluster from each of those vines is equivalent to a 0.03% sample. What size of cluster sample will provide you with reliable data, assuming you are taking a sample from a population of 36,000 per acre? The experts have not agreed, other than the more samples, the better. Amerine and Roessler (1958b) suggested 40 clusters per 1000 vines to get a reasonable sample for estimating fruit composition, but they did not speculate whether this was sufficient for estimating yield.

The decision of how many clusters that are sampled must be done in accordance with some of the aforementioned rules: 1. Sample from normal, healthy vines; 2. Take a modal, stratified sample so that the final composite sample represents clusters from all portions of the canopy.

Moreover, when do you sample? We know (Reynolds and Wardle 1989) that berry weight increases by about another 40 to 50% of final weight from veraison to harvest as a result of cell expansion, provided that no water stress exists. For example, Gewurztraminer berries sampled at veraison weighed 0.7 g each, whereas those at harvest weighed 1.2 g. So, whatever cluster weight value you get from a veraison sampling will need to be adjusted upwards by roughly a factor of 1.7 to 2 to obtain as accurate a cluster weight as possible.

An excellent technical note describes a two-step method for estimating vineyard yields (Wolpert and Vilas 1992). The first step involves determining clusters per vine around bloom when clusters are easily visible. Cluster weights are determined around veraison when their weights have stabilized. The authors provided detailed tables prescribing sample sizes required at varying levels of precision. The general take-home message is that in vineyards with large variations in cluster numbers per vine and/or cluster weights, large sample numbers are required in order to have an error < 5%. The compromise is to accept a higher error rate and as a consequence take smaller samples.

Yield estimation—A summary

Data points for this calculation:

1. The number of bearing vines per block
2. The number of clusters per vine
3. The cluster weight at lag phase of berry growth
4. The cluster weight at harvest

Sampling for yield—a systematic approach

A sampling system must be implemented that will reflect the vineyard. The number of vines in a sample will be dependent on the uniformity of the vine - the more uniform the vineyard, the smaller the sample size required. A general rule is to sample about 4% of the vines in small blocks of 2 to 3 acres, and fewer as the block size increases. However, if the vineyard is more variable in vine size, vine age, vine health, then the sample numbers must be increased.

In a uniform vineyard, sample vines can be selected on a grid pattern, e.g. every 20 vines, every 2nd row. In a non-uniform vineyard, an imposed non-random pattern that is not based on the vineyard geometry may reduce the natural bias for choosing the best healthy vines. An example of this would be following the rows in a serpentine fashion with a continuous count and choosing the 20th vine, then the 35th vine then the 17th vine, then the 20th, 35th and 17th again, etc., regardless of the row length. The chosen vines are never parallel to each other across the rows but the whole vineyard is sampled systematically. Numbers are chosen that are not multiples of the row vine numbers.

The sample vines should remain the same throughout the yield estimating procedure, for whatever phase of the sample they are required. Harvest sample vines should be adjacent to lag phase sample vines, and of similar health and size, to be meaningful.

Block (vine) count

An accurate count of the number of bearing vines in a vineyard is the base value for the estimating. Area is not as significant as vine number, because it is the vine number that will vary over time. An accurate count should be established by walking/driving the rows, counting misses and replants and subtracting this from the total number of vines in the block, previously calculated by using the vine spacing and the number/length of rows in the block. Once this value is established, it need only be verified in following years by subtracting additional misses and replants. This number will be essentially fixed in a mature uniform vineyard unless a catastrophe such as winter cold hits or the vineyard begins to decline with old age. In these cases, vines will have to be re-surveyed.

Clusters per vine

This number is affected by the number of nodes per vine, shoots per nodes and the clusters per shoot. These are affected by the pruning rate, the winter/spring conditions and the conditions for fruit initiation the previous year. The clusters per vine should be counted before bloom, as soon as they have expanded enough to be seen and are not yet obscured by the foliage. This number will not change before harvest unless the cultivar is thinned at some time during the season. These must be counted every season because of the environmental influence of the previous season and the variation of pruning rate.

Cluster weight at lag phase

Final cluster weight is difficult to predict and is subject to many environmental factors between bloom and harvest. However, by lag phase, two components are already fixed - berries per cluster and seeds per berry, both of which have a profound influence on cluster size. Clusters that are large at lag phase tend to be large at harvest, and clusters that are small at lag phase also tend to be small at harvest. As a general rule of thumb, cluster weight at lag phase will be about 50% that at harvest.

Small clustered cultivars (Pinot noir, Riesling) tend to have less variability in weight and sample sizes of 200-to 400 clusters/block (2 to 3 acres) are appropriate. For larger clustered cultivars (Cabernet Sauvignon, Merlot), especially those with large shoulders/wings (De Chaunac, Seyval, Vidal), the sample size will have to be increased because of the increased variability in cluster weight at harvest.

The timing of this sample should be approximately half way between bloom and harvest, roughly at veraison or just before. For Pinot noir in Oregon, this is about 55 days post bloom, but this will vary slightly with cultivar and district, roughly 50 to 60 days post bloom. The seeds should be about 75% hard and too hard to crush with a knife without crushing the berry. Do not delay the sample so that the berries are in the period of rapid size increase just following veraison. This will skew the weight estimate upwards.

Cluster weight at harvest

To estimate the cluster harvest weight of the sample at lag phase, the final weight must be known in this particular vineyard. This value gives the historical basis for the calculation. This is the factor by which the lag phase weight or the prebloom cluster count is multiplied to estimate the harvest weight of that particular year.

Cluster weights at harvest are preferably made from sample vine counts and weights because bin samples cannot distinguish between whole clusters and broken wings or part clusters. Again, a sample of 200 to 400 clusters should be used, more or less being determined by the cluster size. Sampling should include all positions in a vertically stratified pruning system, e.g. the three wires in a 6-cane Kniffin system will have different cluster weights depending on the position of the wire.

Yield prediction

You have an accurate block count, an estimate of cluster numbers per vine in this block, an estimate of lag phase weight per cluster in this block, an historical average of cluster weight at harvest in this block.

Estimate #1:

Vines/block X cluster/vine = clusters/block

Clusters/block X historical harvest weight/cluster = tonnes/block

Estimate #2:

Harvest cluster weight/Lag phase weight = 1.9 - 2.5 (Oregon, Pinot noir)

Check historical harvest cluster weight/lag phase cluster weight to verify ratio

Lag phase cluster weight X ratio X clusters/block = tonnes/block

Keeping track of block history

Detailed records of cluster weight at harvest and the ratio between lag phase weight and final harvest weight, in conjunction with the weather records for that season will give accuracy and confidence to these yield predictions. These values will be cultivar and vineyard specific. This calculation assumes that clusters will always increase in weight the same amount during this period of the growing season. Obviously, they will not and will be subjected to any environmental factor that will affect berry weight.

Adjustments should be made in adversely dry or wet seasons. Dry seasons will result in smaller berries, depending on the timing of the onset of the drought. Wet season may result in heavier cluster weights, but may also result in greater disease problems and less crop actually harvested due to losses from botrytis.

End use of the fruit may also influence cluster weight at harvest. Cultivars that are thinned for various purposes will influence the final cluster weight depending on the timing of the thinning, but will obviously alter the final cluster count as well. Cultivars harvested early for sparkling wines, later for table wine, later still for late harvest, and finally for icewine will all have different final harvest cluster weights because of environmental influences as well as the impact of botrytis rot.

Accurate yield prediction requires good long term records and an understanding of the causes of yield variability.

Sampling for basic fruit composition

Just like yield sampling, one again needs to have an understanding of sample size and what it potentially represents. We have literally taken hundreds of berry samples from vineyard blocks < 5 acres in size and what really amazes me is the variability in berry weights, soluble solids, titratable acidity, pH, and other variables despite a rigorous sampling protocol. But, taking one hundred 100-berry samples is only equivalent to about a 0.4 % sample upon which to base a harvest decision.

Obviously this is an issue that has been studied. In 1950's California, Amerine and Roessler (1958a) published work on comparing berry, cluster, and whole vine sampling. Generally, collecting many berry samples gave composition values higher in soluble solids and pH and lower in titratable acidity than either multi-cluster or whole vine samples. They did not mention which method of sampling came closest to the actual values at harvest. A later report suggested that to be within 1 degree Brix, one would need to take two 100-berry samples, four 10-cluster samples, or 11 whole-vine samples per 1000 vines (Amerine & Roessler 1958b). Some follow-up work from this group (Roessler and Amerine 1962) more or less confirmed their previous conclusions, that 100 to 200 berries collected randomly from 1000 vines would give a value $\pm$ 0.6 ^{o}Brix of the value obtained from the load. They did indicate that both berry and cluster sampling gave slightly higher values than the figures from the harvested loads, but that these were less variable than full vine sampling.

In Australia, Rankine et al. (1962) did a detailed study that compared several sampling methods, and concluded generally that berry sampling provided as precise a result as cluster sampling. They addressed a number of issues of importance that are worth repeating here: 1. Greater variability exists in vineyards with immature fruit than those with mature fruit; 2. Spatial variability exists between and within vines, and both between and within clusters; 3. Use of irrigation can increase variability.

More recently, Kasimatis and Vilas (1985) recommended either two 10-cluster samples or two 50-berry samples per vineyard block, but recommended cluster sampling for greater accuracy.

Many of these authors argued against use of multi-cluster or whole vine samples for estimating fruit composition, mainly because of the time and labor cost factor associated with the removal of these large samples from the vineyard, the subsequent sample preparation notwithstanding. Berry sampling was described as being the most convenient and sufficiently accurate, provided that sampling was carried out properly.

Assuming that berry sampling is the method of choice, what is "proper" sampling. The sampler needs to realize that vines differ in terms of vigor and crop size, and hence crop load (crop size: vine size ratio) will therefore differ amongst vines. This will impact rate of soluble solids accumulation; overcropped vines, for instance, may have lower soluble solids on a given date than normally-cropped or under-cropped vines. Degree of fruit exposure plays a major part in determining fruit composition; exposed berries are usually lower in titratable acidity and pH, and higher in anthocyanins, phenols, and terpenes than partially-shaded and fully shaded fruit (Reynolds et al. 1986; Reynolds and Wardle 1989). Moreover, position on the cluster may also play a part; clusters tend to accumulate soluble solids from basal end to distal end, and therefore berries from close to the distal end of the cluster are normally lower in soluble solids than those adjacent to the basal end of the cluster (Wolpert et al. 1983; Wolpert and Howell 1984). Wolpert and Howell (1984) also pointed out that clusters on non-count shoots can provide estimates of soluble solids that may not accurately reflect the population mean.

The implications of this are significant: it suggests that one must take a modal sample from any vineyard block, and must do so with the assurance that berries from all portions of the clusters are obtained. In other words, the berry samples must reflect the crop load and fruit exposure in each block sampled.

Industry practice. A sampling protocol for determining fruit maturity from one Ontario winery.

The winery that was queried contracts several hundred tons of vinifera grapes throughout the Niagara Peninsula. Their procedure is to randomly sample 10 clusters per vineyard block. Rows are chosen randomly; samplers walk down several rows in the block and sample the clusters. Sampling is done at different heights and different levels of exposure (some exposed, some shaded). Samplers are instructed to try to make cluster selection as random as possible, and to not necessarily avoid selecting a cluster because it has some rot, etc. Samplers also do not collect samples from the two end panels or from outside rows. If the block is very large, two 10-cluster samples are taken – one from each "half" of the block. Other aspects of this company's protocol: 1. Sampling is done in the morning whenever possible; 2. Samples that are wet are not taken because water can alter the results; 3. Sampling is not done on rainy days or when dew is very heavy; 4. Samples, once collected, are placed in a cooler so they don't "bake" in a vehicle; 5. Samples are brought to the winery lab before 1:00 pm each day.

As to color, sampling is done on for blocks of Cabernet Franc, Cabernet Sauvignon, and Merlot at harvest in order to pay growers a "color bonus". Color samples are taken the day before the grapes are to be harvested when possible. In addition to these, color samples may be taken at different times for selected varieties and blocks in order to monitor maturity. Samples for these blocks are taken at different soluble solids stages, in addition to the day before harvest. Sample collection is as follows: The sampler walks through the block in a random pattern (not specified); small portions of whole clusters are clipped off and collected into zip-lock bags; enough partial clusters are sampled so that at least 300 berries are collected (equivalent to about 10 whole clusters). After collecting the samples they are stored in a freezer. Frozen berries are counted into four samples of 50 berries each, plus another sample of 100 berries. These are subsequently analyzed for total anthocyanins, absorbance at 420 nm, and absorbance at 520 nm; the sum of the latter two variables gives intensity of color.

Conclusions

How does one sample a vineyard for yield and fruit composition? It may seem that this article raises more questions than it provides answers. Some points that bear repeating are the following:

1. In sampling clusters at veraison for yield estimation, remember that the cluster weight should be multiplied by 1.7 to 2 to calculate final cluster weight.
2. Take into consideration any missing vines when calculating yields; a mere 5% missing vines will create a significant error.
3. The pattern of sampling for both yield and fruit composition is important. The "X" configuration method of sampling appears to be common. The grid pattern of sampling is also very acceptable. What is most important is the number of samples, and the method by which samples are obtained.
4. Both experience and research have shown that berry sampling can provide accurate data as long as enough berries are collected, and, provided that they are collected in a manner reflective of a particular vineyard block.
5. Sampling needs to be modal. If you have 20% shaded clusters, then make sure your sample reflects that level of cluster exposure. Realize that all clusters are basically conical, that most clusters have an exposed and a shaded "side", and that both sides need to be sampled to obtain accurate data. Note also that grapes tend to accumulate soluble solids from top to bottom, and that all sections of clusters need to be sampled.

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