Crop Estimation of Grapes

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Introduction

Long-term sustainable production of grapes for wine making is increasingly tied to a clear and accurate knowledge of vineyard conditions, which often are variable due to inconsistent weather from season to season, especially in the eastern United States. In addition, climate change (such as increased heat accumulation and rainy events) is predicted to increase this variability. Therefore, future economic survival and success of grape and wine industries are dependent on our ability to understand and take this variability into account and strive to improve fruit quality. This fact sheet assists growers with that endeavor by providing tools to reduce yield and quality variability, which can be achieved through crop estimation (CE). CE is the practice of predicting as accurately as possible the quantity of grapes that will be harvested. Growers need to know the quantity of grapes they produce, as well as whether vines are balanced enough (i.e., not over-cropped or under-cropped) to produce quality fruit and healthy vines. Further, vintners want to know ahead of time how much fermentation tank space is needed.

Physiology of Berry Growth

Grape berry is a fleshy fruit that grows in size and weight during the season following an *S*-shaped or double sigmoid curve pattern that can be divided into three different stages (Figure 1). After bloom (flowering) and fruit set, initial berry growth is associated with a rapid cell division and a subsequent cell expansion. The phase of cell division (Stage I) is followed by a phase of cell expansion (Stage III) with an intermediate phase (Stage II) of a reduced growth called "lag-phase."
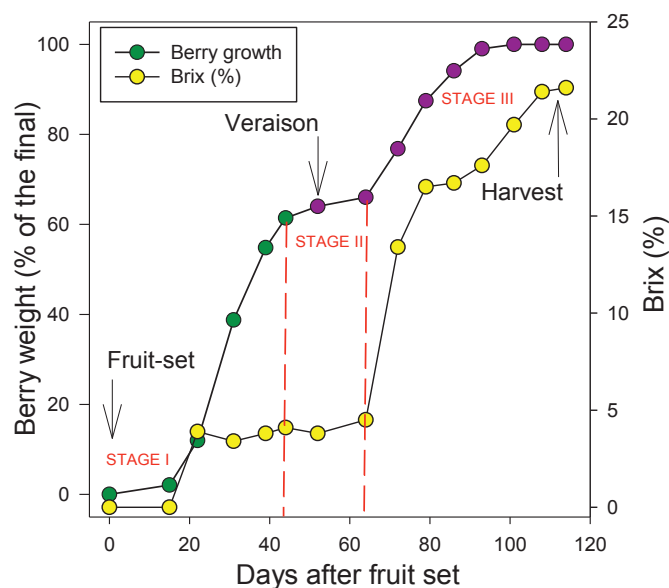
Figure 1. Berry growth (percent of final weight) and sugar accumulation (Brix) in Cabernet franc from fruit set to harvest. Note the three distinctive stages (I, II, and III) of the double sigmoid pattern and the rapid accumulation of sugar at the end of Stage II.

Stage I

Stage I corresponds to a phase of cell division that results in a fast increase in berry size and weight. Seeds are soft and green, and berries are hard, accumulating mainly organic acids (tartrate and malate), but no sugar. The duration of this stage is dependent on the grape variety and lasts between 4 to 10 weeks.

Stage II

Stage II is often described as a "lag-phase," a temporary reduction in berry growth. This is the stage when the seeds are starting to mature (i.e., changing in color and hardness). This stage can be identified when seeds can no longer be cut with a sharp knife and last 1–3 weeks depending on the variety. For example, Pinot gris has a shorter Stage II than does Cabernet franc (Figure 2). The end of Stage II is characterized by skin color change, indicating the initiation of fruit ripening, or veraison.

Stage III

Stage III is the ripening period when sugars rapidly accumulate and berries soften. During this stage, berry volume increases rapidly then slows down until reaching a plateau a few weeks before harvest. Sugars—mainly glucose and fructose—rapidly ac-

cumulate while acids and other pigments (e.g., chlorophyll) degrade. During ripening, tartaric acid does not get metabolized through cellular respiration like malic acid does; therefore, its level remains relatively constant throughout this stage.
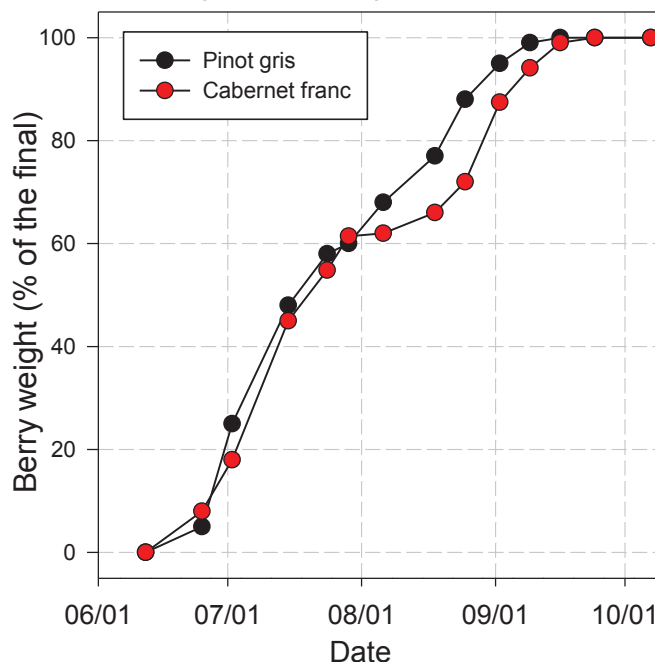

Figure 2. Berry growth in Pinot gris and Cabernet franc during the growing season. Generally, cultivars are characterized by a similar Stage I but a different Stage II. In this case, Pinot gris has a shorter Stage II (7–10 days) than does Cabernet franc (15–25 days).

Methods of Crop Estimation

Viticulturists have developed different systems for estimating yield. Three methods are described in this fact sheet, but growers should choose the method that is accurate and doable for their vineyard operation. The harvest cluster weight method is based on historical records of cluster weights at harvest. The lag-phase method is based on cluster weights during the growing season, when berry growth slows momentarily (around 50–60 days after bloom). The last method discussed in this fact sheet is based on Growing Degree Days (GDD) accumulation and berry growth reaching less than 50% of their final weight. The three methods are based on determining (a) the number of bearing vines, (b) the number of clusters per vine, and (c) the cluster weight. While (a) and (b) are fixed numbers during the season, (c) is variable.

1. Harvest Cluster Weight Method

Components of yield vary each year depending on the weather, site, variety, and cultural practices. The following formula can be used to estimate yield.

$$PY = (ANV \times NC \times CW)/2000$$

Where:
PY = predicted yield (tons per acre)
ANV = actual number of vines per acre
NC = number of clusters per vine
CW = cluster weight (in pounds)

According to the formula, the grower needs to measure three parameters each year: the actual number of vines per acre, the number of clusters per vine, and the cluster weight. These parameters are discussed below with examples.

- *Actual number of bearing vines per acre (ANV):* The maximum number of vines per acre is determined by row and vine spacing. For example, spacing of a 6 × 9 feet vineyard will have 807 vines per acre. Almost always the "actual number" is lower than the "maximum number" of vines per acre due to missing vines for several reasons such as disease (e.g., crown gall), winter injuries, replanting, etc. For these reasons, each year, growers need to count missing vines, then subtract that number from the maximum number to get an accurate count of bearing vines. If 5% of the 807 vines per acre (i.e., about 40 vines) were missing or nonbearing, then the actual number of bearing vines per acre is 767.

- *Number of clusters per vine (NC):* This number will depend on how many nodes (buds) are left after pruning. The number of clusters per vine can be determined as soon as the clusters are visible (before bloom) or as late as pre-veraison. The advantage of an early count is that clusters are readily visible and are not obscured by leaves. The number of vines on which to count clusters depends on vineyard size and uniformity. For example, in a 1- to 3-acre-vineyard with vines of a uniform age, size, and pruned to the same bud number, only 4% of the vines need to be counted. In practice, a minimum of 20 vines is counted. Growers need to bear in mind that the higher the number of vines selected for cluster count, the more accurate the yield estimate will be. In larger, non-uniform vineyards, more vines should be selected. All the clusters on the sample vines should be counted. Also, the vines should be selected methodically. For example, select every tenth vine in every other row.

- *Cluster weight (CW)*: Cluster weight is the component of yield that varies the most from year to year. It is affected by environmental conditions. For example, wet weather during bloom could cause poor set and may lead to low cluster weight. Also, a dry summer tends to reduce berry size and thus may decrease average cluster weight. Other factors that may affect cluster weight include variety, cultural practices (i.e., irrigation and fertilizers), diseases, insects, and wildlife. Cluster weight at harvest is a key part of any yield prediction program. The goal of obtaining cluster weight at harvest is not to predict the yield that year, but to provide records for yield prediction in subsequent years. At harvest, it is best to sample clusters from vines rather than from harvest bins. The same vines used for cluster counts could be used for cluster weights. Average cluster weight is obtained by sampling at least 100 clusters throughout the vineyard; weigh the total and divide by the number of clusters sampled. Growers who do not have these data may use estimates of cluster weights shown in Table 1. Maintain records of cluster weights from year to year in order to improve estimation.

- *Example of Harvest Cluster Weight Method:*
  Variety: Cabernet franc
  Spacing = 6 × 9 feet or 807 vines per acre
  Missing or nonbearing vines = 5% or about 40 vines per acre
  Actual number of bearing vines, ANV = 807 − 40 = 767 vines per acre
  Average cluster count, NC = 40 clusters per vine
  Average cluster weight, CW = 0.23 lbs
  Predicted yield, PY = (ANV × NC × CW)/2000 = (767 × 40 × 0.23)/2000 = 3.5 tons per acre

2. Lag-Phase Method

Pinot noir grape growers in Oregon use the lag-phase method. This method presupposes the prediction of final yield on the basis that at Stage II of berry development (lag-phase), berries are approximately half their final fresh weight. Seed hardness is the pri-

Table 1. Average cluster weight (in pounds) of common grape varieties*					
Variety	**Small (<0.3)**	**Variety**	**Medium (0.3–0.4)**	**Variety**	**Large (>0 .4)**
Cabernet franc	0.23	Concord	0.30	Chambourcin	0.42
Cabernet Sauvignon	0.19	Chardonel	0.36	Marquis	0.50
Chardonnay	0.23	Lemberger	0.30	Neptune	0.53
Gewürztraminer	0.20	Niagara	0.35	Seyval	0.43
Pinot gris	0.22	Vidal blanc	0.34		
Pinot noir	0.18				
Merlot	0.22				
Riesling	0.18				
Traminette	0.24				

*Sources: *The Midwest Grape Production Guide*, Michigan State Viticulture and Enology program (unpublished data).

mary indicator that berries have entered lag-phase. If the grower has an estimate of yield per vine (tons per acre) at lag-phase, this allows enough time before harvest to adjust the final yield by cluster thinning, for example, to reach the desired fruit quality at harvest. The lag-phase estimate requires the measurement of (1) the number of bearing vines in the vineyard, (2) the number of clusters per vine, (3) the cluster weight at lag-phase, and (4) the calculated cluster weight at harvest. At Stage II (Figure 1), grape berries are approximately at 50% of their final weight; therefore, multiplying the cluster weight by 2 gives an approximate prediction of final cluster weight at harvest. The major challenge of this method is to determine when the lag-phase occurs every year. Growers need to split berries and check with a sharp knife the resistance of the blade cutting the seeds. For Pinot noir in Oregon, the lag-phase occurs approximately 55 days after bloom.

3. Growing Degree Days (GDD) Method

Growing Degree Days, or GDD, are calculated from April 1 to October 31, with a base temperature of 50°F (or 10°C). Many juice grape growers use the GDD method developed for Concord in New York. It was demonstrated that berry weight of Concord at 1,100 GDD (about 30 days post-bloom) corresponds to 50% of final berry weight at harvest. Subsequent work in Michigan developed GDD models for several winegrape varieties. Most varieties reach 50% of their berry weight when GDD range between 1,000 and 1,700; this corresponds to the optimum time window for crop estimation (Table 2).

Table 2. Growing Degree Days that correspond to 50% (GDD50) of harvest berry weights of common winegrape varieties*	
Variety	**GDD50**
Chardonnay	1,070
Pinot noir	1,140
Pinot gris	1,150
Cabernet franc	1,170
Marechal Foch	1,180
Frontenac	1,180
Vignoles	1,180
Riesling	1,190
Cabernet Sauvignon	1,200
Concord	1,210
Chardonel	1,470
Pinot blanc	1,470
Traminette	1,470
Seyval	1,500
Merlot	1,700

*GDD computed from April 1, with 50°F base temperature.

Why Are My Crop Estimates Still Off?

Even with thorough sampling, accurate vine counts, and many years of average cluster weight data, the actual crop tonnage at harvest can vary significantly from what is predicted. Consider a good estimate if it is within 15% of the actual yield. Do not get discouraged if first attempts at crop estimation are inaccurate, because the more experience and data acquired, the more accurate the estimates will become. Always remember that no person can have better knowledge about the vineyard or greater incentive to achieve maximal sustainable production of ripe grapes than does the vineyard's manager. That person knows that her/his vineyard is not uniform, and different vineyard blocks could be categorized as "high-," "moderate-," or "low-" producing. We suggest that vineyard managers select a few vines that are characteristic of these categories. Then use them as indicators for that location's production potential for a given season. Selection of one or more panels (3–4 vines between two posts) that accurately represent the block is the first, critical step. These panels and vines can serve effectively over the vineyard's life, and can be the basis for long-term understanding of that location/vine relationship. The utility of the vineyard data grows as the information collected grows over years.

Useful References

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Appendix: Crop Estimation Worksheets

1. Harvest Cluster Weight Method

Variety:_____

Vine spacing (ft) × row spacing (ft) = _____ × _____

Vines per acre = 43,560 ft^2 / vine spacing × row spacing (ft) = _____ vines per acre

Missing or nonbearing vines = _____ vines per acre

Actual number of bearing vines = vines per acre − missing vines per acre = _____ vines per acre

Average cluster count = total cluster counts / number of vines = _____ clusters per vine

Average harvest cluster weight = _____ lbs (published or from previous years' records)

Predicted yield = (ANV × NC × CW) = _____ lbs per acre or _____ / 2,000 = _____ tons per acre

Target yield = _____ tons per acre = _____ × 2,000 (lbs per acre)

Desired cluster number per vine = target yield (lbs) / number bearing vines / cluster weight = _____

Cluster thin = (actual cluster number per vine) − (desired cluster number per vine) = _____

Vine	Cluster number Variety 1:_____	Cluster number Variety 2:_____	Cluster number Variety 3:_____
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
	Total =	Total =	Total =
	Avg. =	Avg. =	Avg. =

Crop Estimate Variety 1 = _____ × _____ × _____ / 2,000 = _____ tons per acre

Crop Estimate Variety 2 = _____ × _____ × _____ / 2,000 = _____ tons per acre

Crop Estimate Variety 3 = _____ × _____ × _____ / 2,000 = _____ tons per acre

2. Lag-Phase and Growing Degree Day (GDD) Methods

1. Get the total berry weight for the representative vines and divide by the total number of berries. The result is the average berry weight. If this has been collected at 1,200 GDD or at lag-phase, the result can be doubled, producing an estimate of final berry weight.

2. We now know the berry weight and the average berry number per cluster. We can now calculate the estimated yield per primary shoot and secondary shoot (in hybrids). Since we used primary shoots for our estimate, we keep the value and multiply by the number of primary shoots on the representative vines. Use the same number for secondary shoots, except multiply the value by 0.33. Add the values for the primary and secondary shoots, divide by the number of vines, and the result is the estimated final yield per vine.

3. If the row × vine spacing is 9 × 8, vines per acre = 605. If 10 × 8, vines per acre = 570. Multiply your single vine estimate by the appropriate number and get lbs per acre. Divide by 2,000 lbs and get tons per acre.

Vineyard Data Collection Worksheet for 3 Representative Vines (See photos below for details.)		
Date:		
I. Pre-bud break		
A. Count nodes/vines after pruning		
Vine 1:	**Vine 2:**	**Vine 3:**
II. Shoots at 3-inch stage		
A. Count number of blind nodes		
Vine 1:	**Vine 2:**	**Vine 3:**
B. Count number of frosted primary buds		
Vine 1:	**Vine 2:**	**Vine 3:**
C. Count number of frosted secondary buds		
Vine 1:	**Vine 2:**	**Vine 3:**
III. At Bloom		
A. Count number of clusters per vine		
Vine 1:	**Vine 2:**	**Vine 3:**

Spring frost may occasionally kill primary buds in their early stages of growth. Consequently a secondary (sometimes also tertiary bud) will develop. Secondary buds are fertile in native and hybrid varieties, but not in vinifera. The photo on the left shows frost injury to the primary bud and the new growth of the secondary bud. On the right, note the angle of insertion of the future shoot in the cane; the primary bud is less than 45 degrees from the cane axis, while the secondary bud is less than 90 degrees from the cane axis.

4. At 1,200 GDD for Concord (see Table 1 for other varieties) or at lag-phase (i.e., seed hardening), select three shoots per vine. Collect the clusters, count, and weigh the berries per shoot on all clusters.

Date:		
Vine 1		
Berry count		
Shoot 1:	**Shoot 2:**	**Shoot 3:**
Berry weight		
Shoot 1:	**Shoot 2:**	**Shoot 3:**
Vine 2		
Berry count		
Shoot 1:	**Shoot 2:**	**Shoot 3:**
Berry weight		
Shoot 1:	**Shoot 2:**	**Shoot 3:**
Vine 3		
Berry count		
Shoot 1:	**Shoot 2:**	**Shoot 3:**
Berry weight		
Shoot 1:	**Shoot 2:**	**Shoot 3:**

Now use the data above to estimate the crop level.

Example of crop estimation for Concord (applicable for other varieties as well):	
Step 1	*We retained 120 buds per vine at pruning = 120 × 3 vines = 360 buds*
Step 2	*At 3-inch stage there were 10 + 12 + 14 = 36 total blind nodes on the three vines*
Step 3	*There had been a slight frost, and the total for the three vines was 30 dead primary buds*
Step 4	*At pre-bloom there were 750 clusters on the three vines*
Step 5	*At 1,200 GDD for Concord (see Table 1 for other varieties), three primary shoots per vine were harvested and the berries on each shoot were counted and weighed*
Step 6	*The average berry weight was 1.4 g and average berries per shoot were 60*

Example of calculating potential yield per vine, based on average per vine:	
Step 1	*120 nodes per vine*
Step 2	*14 blind nodes*
Step 3	*10 dead primary buds by frost*
Step 4	*96 live primary shoots*
Step 5	*10 live secondary shoots*
Step 6	*60 berries per primary shoot (1.4 g berry weight at 1,200 GDD) × (2 = final berry weight at harvest) = 168 g per shoot*
Step 7	*(168 g) × (96 primary shoots) = 16,128 g on primary shoots × vine*
Step 8	*(168 g) × (10 secondary shoots) × (0.33 for reduced productivity of secondary) = 554.4 g on secondary shoots × vine*
Step 9	*16,128 g + 554 g = 16,682.4 g per vine*
Step 10	*16,682.4 g = 16.7 kg per vine = 36.8 lbs per vine*
Step 11	*(36.8 lbs per vine) × (605 vines per acre) = 11.1 tons per acre*

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