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VINEYARD YIELD ESTIMATION

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Vineyard Yield Estimation

Key Definitions in Yield Estimation

Yield: Typically, the amount (weight) of fruit over a given spatial area, such as tons of grapes per acre. In some cases, *yield* refers to the amount of fruit on an individual vine (see *Crop load*). Usually a generalized target number; it may or may not be related to the vineyard's ability to produce fruit. As a generalized number, it is often related to contract specifications, not vine physiology.

Crop load: The ratio of reproductive (clusters) to vegetative (exposed, photosynthetically active leaves) development. Understanding *crop load* ratios allows the grower to determine the optimal amount of fruit that a given vine can ripen. Vegetative growth can either be directly measured by using the leaf area of a vine during the growing season, or indirectly measured using dormant pruning weights. Measuring dormant pruning weights is the most practical means of determining vegetative growth in commercial production. A common name for the ratio of fruit yield per vine to subsequent dormant pruning weight per vine is the Ravaz index (see Dry et al. 2004). *Crop load* is independent of contract specifications.

Vine balance: The point where *crop load* is ideally matched with vine growth. Achieving the correct *crop load* ratio for a balanced vine can optimize the quality of the fruit and lead to consistent production (Skinkis and Vance 2013). Commonly measured as the ratio of fruit weight to pruning weight, the exact number can vary between cultivar, location, training system, management practices, and overall climatic conditions. If using a Ravaz index comparison, every 5–10 lb. of fruit weight (per vine) should have approximately 1 lb. of pruning weight (per vine).

Under-cropped: Used to describe a vine that is carrying less fruit than what it can theoretically ripen. A Ravaz index less than 3 indicates *under-cropping* in warm environments such as eastern Washington, but might be appropriate in cooler climates such as western Washington.

Over-cropped: Used to describe a vine that is carrying more fruit than what it can theoretically ripen. A Ravaz index greater than 10 typically indicates *over-cropping*. The standard "appropriate" range falls between an index score of 5 and 10.

Crop load adjustment: Practices that either enhance the yield per vine (such as increased water or nitrogen application from bloom to véraison) or decrease the yield per vine (such as reduction in water after fruit set, or actively removing fruit prior to harvest). *Crop load adjustments* are done to either help balance vine growth by leaving the appropriate amount of fruit relative to the canopy size, or meet contract specifications from the winery.

Introduction

Estimating yield is a vital component of commercial grape production. Necessary for many vineyard and winery operational decisions, yield estimation can be a challenging process. There are multiple ways and times to estimate yield. This guide will highlight why yield estimation is important and provide an overview of the various estimation methods (Table 1) currently being used in commercial grape production for both juice and wine.

Yield Estimation Purpose

Yield estimation helps vineyard managers balance their vines and winery managers improve harvest scheduling and space utilization.

Crop Management

Vital to decisions relating to crop load adjustments, yield predictions serve as a base for decisions relat-ing to yield management. The amount of fruit in a vineyard, which is the most common form of yield presentation (that is, tons per acre) is often dictated by contract specifications. However, the amount of fruit that a vine can ripen is dictated by vine health, site capability, weather, and cropping history. Taking both business and viticultural factors into consideration, the appropriate crop load for the same site can vary from year to year. Typically, areas with soils that have high water-holding capac-ity (such as clay or silt) and organic matter content (>2%, which is associated with nitrogen), along with optimal growing season length (more than 180 frost-free days) and warm average tempera-tures (daytime highs between 75° and 95°F; 24° and 35°C), result in a greater potential for a large crop load. Vines grown in areas under conditions such as water

Table 1. The most common vineyard yield estimation methods, primarily distinguished by timing.

Vine Phenological Stage	Estimation Method
Growing Season*	*Traditional* and *Lag Phase*: Cluster counting or berry counting can be done at multiple times during the growing season.
Dormant Season	*Bud Dissection*: Dormant buds can be dissected during the winter months to count developing clusters (*inflorescence primordia*). This method is particularly useful after a damaging cold event to provide a rough estimate of crop loss.

*Cluster emergence to harvest.

stress, low nutritional status (sandy soils, low organic matter), and cool temperatures (average daytime highs during the growing season are less than 75°F) have a reduced ability to ripen a crop, and therefore have a lower optimal crop load.

The long-term mismanagement of crop load can have negative consequences. Over-cropping a vine can lead to a decrease in the vine's carbohydrate reserves (which are necessary for overwintering and spring growth) and a reduction in potential bud fruitfulness. If vines are continuously over-cropped, premature death can result. Under-cropping the vine can result in management challenges but will not lead to as severe of consequences (premature death of the vine) as over-cropping a vine. By under-cropping a vine, energy will be diverted and used for vegetative growth instead of reproductive growth. The end result of this will be an excessively large canopy. Such canopies can ultimately shade the fruit and reduce ripening potential. This can also cre-ate the perfect microclimate for various fungi such as *Erysiphe necator,* causal agent of grape powdery mildew, and *Botrytis cinerea*, causal agent of Botrytis bunch rot.

In most cases, if yield (tons per acre) does not align with crop load, the long-term sustainability of the vineyard can be threatened. In those cases, man-agement practices should be adjusted to meet the capacity of the individual vines. For example, if the individual crop load is low due to lack of vine vigor, which would ultimately translate into low yield, then management strategies would suggest an intervention such as increased water between bloom and véraison, or additional nitrogen application during the standard pre- and post-bloom nitrogen fertilization programs if soil and tissue tests indi-cate nitrogen is low (Hoheisel and Moyer 2014). If the vineyard manager simply leaves more buds and clusters to increase the yield in the vineyard, the crop load might be too high for the individual vines, and they will not be able to adequately ripen the fruit (over-cropped situation relative to what the vine can handle). In an alternative example, if crop load is high due to high vine vigor but contracts specify a low yield (under-cropped situation), management strategies such as reduced water application (implementation of regulated deficit irrigation, or RDI, just after fruit set) or multiple vineyard passes to remove excess fruit may be necessary. In this latter case, how-ever, inappropriate timing of crop adjustment can

Yield and Crop Load Example

Cougar Vineyards has a contract with Crimson Winery, which specifies a yield of 5 tons on their one-acre Chardonnay block. After years of farming, they have realized that this yield results in ideal vine balance under "average" conditions; but, not all years are average. The vineyard manager knows that if it is a hot year, and they keep watering all season, 6 tons will be produced. In other words, given higher than average water and heat, vine balance is achieved at 6 tons per acre. What does the vineyard manager do to maintain his contract in this situation? They can either thin the crop between bloom and bunch closure to reduce yield, or they can limit the amount of water available to the plant, especially just at and after fruit set, to reduce the vine's capacity to produce fruit. In the first scenario, the vineyard manager is not addressing vine balance, and as such, is artificially reducing crop load relative to the vine's capacity. This might result in increased canopy growth. In the water-restriction scenario, the vineyard manager is directly altering vine balance by specifically limiting both reproductive (clusters) and vegetative (canopy) growth. In cooler vintages (years where the growing degree day accumulations are less than the region's average), the vine's capacity to ripen a crop is limited. In order to balance the amount of fruit on the vine to what its capacity is, clusters must be removed. In this scenario, less than 5 tons per acre is likely the appropriate crop level to maintain vine balance.

also send a high vigor vineyard into uncontrollable growth, thus perpetuating the out-of-balance cycle.

Winery and Juice Facilities Preparation

Vineyard yield estimates are also critical for wine-makers who prepare their winery for a rapid influx of fruit (Figure 1). Scheduling and coordinating storage and processing space is critical in keeping the work-flow of a winery under control. Yeast, fining agents, barrels, and tanks all need to be ordered

and ready by the time harvest begins. In juice processing facilities, yield estimates help to determine whether additional juice or juice concentrate (necessary to meet market demand) will have to be sourced from elsewhere, or if price adjustments will be made to encourage sales to a particular company.

Yield Estimation Factors

The factors common to all yield estimation calcula-tions include:

- Planting density (PD; number of vines per acre)
- Number of producing vines per acre (PV)
- Average number of clusters per vine (CV)
- Average cluster weight (CW)

Planting Density (PD)

To aid in yield estimation calculations, Table 2 gives examples of various planting densities and the result-ing vines per acre.

Number of Producing Vines per Acre (PV)

In most cases, not every vine in the vineyard will be productive; some may be missing entirely. To deter-mine the number of producing vines per acre, do an annual count. If the number of producing vines per acre cannot be counted, total vines per acre is an appropriate substitute with the understanding that your estimated yield may be higher than the actual yield.

Average Cluster Number (CV)

Counting clusters is another necessary activity in yield estimation. Remember, the more vines you sample, the more accurate your estimation will be. Sampling, however, takes time and effort, so a strat-egy should be devised that allows you to collect a sufficient sample size in a short period of time.

Figure 1. Grape processing for wine and juice production. Crush facilities and wineries need advanced notice of expected yield to ensure adequate supplies are available prior to the start of harvest. Photo by Brittany Komm.

When collecting cluster counts, all the clusters on the selected vines need to be counted. Select these vines in a methodical fashion, such as every 25th vine in even-numbered rows (Dami and Sabbatini 2011). When counting clusters on vines, it is important to select vines that are representative of the average vine in the block. Counting vines that are "abnor-mal" can significantly skew final yield estimation. If the vineyard is not uniform, doing multiple counting passes and then taking the average may significantly improve yield estimates. A general description of sampling vineyards that are not uniform is discussed in *Assessing and Managing Cold Damage in Washington Vineyards* (Moyer et al. 2011). For a more detailed explanation of determining the exact sample size for the number of vines to count in a vineyard, includ-ing calculations and tables, see Wolpert and Vilas (1992).

Table 2. Vines per acre based on distance between rows and between vines.

Spacing (Feet)		Between Rows									
		3	4	5	6	7	8	9	10	11	12
Between Vines	3	4840	3630	2904	2420	2074	1815	1613	1452	1320	1210
	4	3630	2723	2718	1815	1556	1361	1210	1089	990	908
	5	2904	2178	1742	1452	1245	1089	968	871	792	726
	6	2420	1815	1452	1210	1037	908	807	726	660	605
	7	2074	1556	1245	1037	889	778	691	622	566	519
	8	1815	1361	1089	908	778	681	605	545	495	454
	9	1613	1210	968	807	691	605	538	484	440	403

Clusters per vine can be determined by i) physi-cally counting the number of clusters per vine dur-ing the growing season (either a single or multiple times) or ii) multiplying the number of buds you left during pruning (that is, the number of in-tended shoots per vine) by the typical number of clusters per shoot you see for that variety or block. The second method may present a problem if latent buds develop and produce fruit, or if cooler temperatures from the previous growing season reduced bud fruitfulness, but it does allow for es-timation during the dormant season. In addition, buds can be dissected during the dormant season, and the number of developing clusters (inflores-cence primordia) can be used as an estimate of the number of clusters per shoot.

Average Cluster Weight (CW)

Unlike the task of counting clusters, to obtain cluster weights, clusters must be removed (generally by hand) from the vine. Only remove clusters from the fruit zone; avoid any clusters that are develop-ing on summer lateral shoots (also termed "Christ-mas clusters" or "second crop" clusters). Arbitrary sampling from multiple vines and weighing ap-proximately 100 clusters per acre is sufficient if the vineyard is uniform across 1–3 acres (Dami 2006).

For larger blocks (5+ acres), typical protocols suggest sampling and weighing 200–400 clusters (Hellman and Casteel 2003).Cluster weights can be measured during the lag phase of cluster development(see *Understanding Lag Phase* for more information) or as close to commercial harvest as time allows.

An alternative method to determine average cluster weight is to remove and weigh all of the clusters from a single vine, and then divide that weight by the number of clusters sampled (Figure 2). This method is only recommended in uniform vineyard blocks.

The annual variation seen in yield estimation is most often attributed to using different methods to calculate cluster numbers (70%) and weights (30%) (Dami 2006). If yield estimates fluctuate more than an acceptable level (5–15% according to industry standard) every year, a reevaluation of techniques might be warranted to determine where the biggest source of error is. In many cases, large fluctuations are associated with a sample size that is too small, and collecting more clusters may be necessary for a more accurate estimate.

Yield Estimation Methods

There are several methods to predict vineyard yield that can be conducted during different times of the year, but long-term accuracy requires using the same method(s) consistently.

Figure 2. A) Vitis vinifera 'Sauvignon blanc' vine prior to destructive cluster collection. B) The same vine after removal of all clusters. This whole-vine cluster collection can be used to determine average cluster weight, but is not recommended in non-uniform vineyard blocks. Photos by Brittany Komm.

The two most com-mon methods (Table 1) for crop estimation are i) in-season cluster counting (traditional, historical) or weighing (lag phase) or both, and ii) dormant winter bud dissection. In-season methods can be di-vided into traditional, which uses in-season cluster counts coupled with knowledge of historical cluster weights, and lag phase, which incorporates in-season cluster counts with in-season cluster weights measured during stalled berry growth. Viticultur-ists may use a combination of methods to improve estimation accuracy.

To illustrate how the different yield estimation meth-ods work, fictitious vineyards will be used. Tables 3 and 4 depict conditions seen in wine and juice grapes, respectively.

Traditional, Historical Harvest Weight

The traditional method of yield estimation relies on data from previous years.

$$\text{Yield (tons per acre)} = \frac{(PV \times CV \times CW_{Harvest})}{\frac{2000 \text{ lb}}{\text{ton}}}$$

Equation 1: Traditional Yield Estimation (where $CW_{Harvest}$ is historical cluster weight at harvest).

Using the data from Cougar Vineyards in Table 3, total yield is calculated using the traditional, histori-cal cluster harvest weight method:

$$\text{Yield (tons per acre)} = \frac{(PV \times CV \times CW_{Harvest})}{\frac{2000 \text{ lb}}{\text{ton}}}$$

Equation 1: Traditional Yield Estimation (where $CW_{Harvest}$ is historical cluster weight at harvest).

If good historical data was gathered and the corre-sponding records were kept, this method can reveal trends and facilitate comparisons with the current year's data. If the current year's numbers come in significantly higher or lower than in previous year's records, estimations should be redone. Another sig-nificant benefit of using this method is that it can be done at any time during the growing season because it relies on historical data.

Lag Phase

During lag phase (stalled berry growth), berries of many cultivars are at around 50% of their final weight. Because of this relationship, cluster weights taken at this time can be multiplied by a factor (typi-cally 2.0) to determine approximate harvest weight (see Equation 3); this factor is often referred to as the harvest multiplier.

Table 3. Data for the fictional Cougar Vineyards, provided to calculate yield estimates based on cluster weights.

Cougar Vineyards: *Vitis vinifera* 'Chardonnay' 6 feet x 9 feet, vine x row spacing	Planting density (PD): 807 vines per acre
	Actual number of producing vines per acre (PV): 726 vines per acre
	Average number of clusters per vine (CV): 44
	Average weight of single cluster: 0.15 lb at lag phase (CW_{Lag}), historical final harvest weight of 0.30 lb ($CW_{Harvest}$)*

*Historical weights are needed for some calculations. However, where historical numbers are not available, such as in new vineyards, collect and weigh several random clusters 1–2 weeks before harvest.

Table 4. Data for the fictional Crimson Vineyards, provided to calculate yield estimates based on berry weights.

Cougar Vineyards: *Vitis labruscana* 'Concord' 6 feet x 9 feet, vine x row spacing	Planting density (PD): 807 vines per acre
	Actual number of producing vines per acre (PV): 726 vines per acre
	Average number of clusters per vine (CV): 177
	Average number of berries per cluster (BC): 30
	Average weight of single berry: 1.36 grams at lag phase (BW_{Lag}), historical final harvest weight 2.72 grams ($BW_{Harvest}$)*

*Historical weights are needed for some calculations. However, where historical numbers are not available, such as in new vineyards, collect and weigh several random clusters 1–2 weeks before harvest.

Using Berry Weight to Estimate Cluster Weight

Another type of in-season estimation is to use the average berry weight and the average berries per cluster to determine total cluster weight. This method, common in juice grape production, allows tracking of annual changes in berry size and can provide more accurate yield predictions if a vineyard is mechanically harvested. In comparison, handpicking introduces 2–5% yield estimation error because the cluster rachis is included in the berry weight (Dokoozlian 2000). This component of yield is not a factor in mechanically-harvested vineyards because the cluster rachis is left behind (Figure 3).

In many cases, it is necessary to sample 100–200 berries to get an accurate estimate. Berries should be selected from different vines, as there is typically more between-vine variation in a vineyard than between-cluster variation (Rankine et al. 1962).

Berry weights can be incorporated into both the traditional and lag phase estimation methods. (The 0.0022 multiplier converts berry weights in grams to pounds.)

Yield (tons per acre)=

$$\frac{\left(PV \times CV \times \frac{berries}{cluster} \times BW_{Harvest} \times \frac{0.0022\,g}{lb} \right) \frac{2000\,lb}{ton}}{}$$

Equation 2a: Traditional Yield Estimation with Berry Weights

Yield (tons per acre)=

$$\frac{\left(PV \times CV \times \frac{berries}{cluster} \times BW_{Lag} \times \frac{0.0022\,g}{lb} \times HM \right)}{\frac{2000\,lb}{ton}}$$

Equation 2b: Lag Phase Yield Estimation with Berry Weights

Based on the data in Table 4, yield estimation for Crimson Vineyards using berry weights is calculated in Example Equations 2a and 2b with traditional and lag phase estimation elements, respectively.

Yield Potential (tons per acre)=

$$\frac{\left(\frac{726\,vines}{acre} \times \frac{177\,clusters}{vine} \times \frac{30\,berries}{cluster} \times \frac{2.72\,g}{berry\,(harvest)} \times \frac{0.0022\,lb}{g} \right)}{\frac{2000\,lb}{ton}} =$$

$$\frac{\left(\frac{23130.36\,lb}{acre} \right)}{\frac{2000\,lb}{ton}} = 11.57\,\frac{tons}{acre}$$

Example Equation 2a: Harvest Yield Estimation with Berry Weights for Crimson Vineyards.

Yield Potential (tons per acre)=

$$\frac{\left(\frac{726\,vines}{acre} \times \frac{177\,clusters}{vine} \times \frac{30\,berries}{cluster} \times \frac{1.36\,g}{berry\,(lag)} \times \frac{0.0022\,lb}{g} \times 2 \right)}{\frac{2000\,lb}{ton}} =$$

$$\frac{\left(\frac{23130.36\,lb}{acre} \right)}{\frac{2000\,lb}{ton}} = 11.57\,\frac{tons}{acre}$$

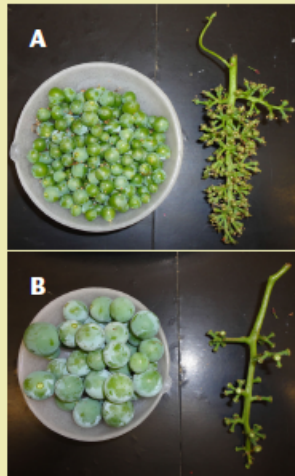*Example Equation 2b: Lag Phase Yield Estimation with Berry Weights for Crimson Vineyards.*

Figure 3. A) A comparison of contributing cluster weight factors from the rachis and berries in a Vitis vinifera 'Chardonnay' cluster; B) A comparison of contributing cluster weight factors from the rachis and berries in a Vitis labruscana 'Concord' cluster. Photos by Brittany Komm.

Understanding Lag Phase

Lag phase is a period of little or no growth in berries that occurs between the two rapid periods of growth. The lag phase directly precedes véraison, approximately 50–60 days after bloom (Dami and Sabbatini 2011). The length of this phase can vary anywhere from a few days up to a couple of weeks depending on the climate and cultivar. Some cultivars have a longer lag phase than others (Dami 2011). If berry or cluster weights or both are tracked throughout the season, the start of lag phase (that is, when size change slows or stops) is simple to capture. This tracking method is recommended if lag phase yield estimation is going to be routinely used.

Each cultivar can have a slightly different harvest multiplier depending on the ratio of their lag phase cluster weight relative to their harvest weight. For example, if a cluster weighs 0.15 lb. at lag phase, as it does in Cougar Vineyards, and the final harvest weight is 0.30 lb., then the harvest multiplier is 2.0. However, if we compare that to a theoretical Riesling vineyard where lag phase cluster weights are 0.10 lb. and final cluster weights are 0.25 lb., the Ries-ling vineyard would have a harvest multiplier of 2.5.

Yield (tons per acre)=

$$\frac{(PV \times CV \times CW_{lag} \times HM)}{\frac{2000\,lb}{ton}}$$

Equation 3: Lag Phase Yield Estimation (where HM is the harvest multiplier used to adjust lag phase cluster weights to an estimated cluster weight).

The yield for Cougar Vineyards is calculated in Example Equation 3 using the lag phase estimation method with a harvest multiplier.

Yield (tons per acre)=

$$\frac{\left(\frac{726\,vines}{acre} \times \frac{44\,clusters}{vine} \times \frac{0.15\,lb}{cluster\,(lag\,phase)} \times 2 \right)}{\frac{2000\,lb}{ton}} = \frac{\left(\frac{9583\,lb}{acre} \right)}{\frac{2000\,lb}{ton}} = 4.79\,\frac{tons}{acre}$$

Example Equation 3: Lag Phase Yield Estimation for Cougar Vineyards

The challenge of using this method is in estimating lag phase. Using the standard calculation for grow-ing degree days (see the appendix) can simplify the process. Moisture during the growing season can also impact final cluster weights at harvest. If large amounts of precipitation occur during cluster develop-ment, clusters may be larger than expected at harvest. Contrary to popular belief, however, addition of drip-applied irrigation near harvest will not increase cluster weights beyond what was already developed; it will simply reduce the likelihood of excess berry dehydra-tion. Loss of water from the cluster during periods of high evaporative potential is also common in vine-yards that have a significant delay between when the fruit is ripe and actually harvested (termed *extended hang time*).

Because the relationship between lag phase and har-vest weights can vary depending on weather patterns and vineyard management strategies (such as irriga-tion regimes), lag phase estimations tend to not be as accurate as estimations made directly before harvest.

Bud Dissection

Clusters are formed over two seasons. In the first season, they develop in the buds formed at the base of leaves on green shoots. These buds overwinter, and shoots bearing those pre-formed clusters emerge to comprise the fruit of that second growing season. Because of this, dissecting buds in the winter can provide information on the potential number of clusters per shoot for the following growing season. To estimate clusters, a selected number of overwintering buds (called "compound buds" as they are actually comprised of three buds; Figure 4) are collected. These are typically collected from canes that would nor-mally be removed in the pruning process. The larger, primary bud in the compound bud is then carefully dissected, by slowly removing the outer bud scales and wooly contents. Using a strong hand lens (30X or greater) or a dissecting microscope, the developing cluster primordia are counted. The number of clus-ters per bud corresponds to the number of potential clusters per shoot. These cluster counts can then be substituted into the previously mentioned equations.

Conclusion

1. Yield estimations are important to a) help managers maintain vine health, productiv-ity, and longevity; and b) inform processors of fruit volume so they can be adequately prepared for harvest.
2. Yield estimations can be used in crop level adjustments, which are critical in years wherevines do not have the capacity to adequately ripen a developing crop.
3. Yield estimation improves with time; keep track of historical cluster and berry weights and yield to improve estimation accuracy.
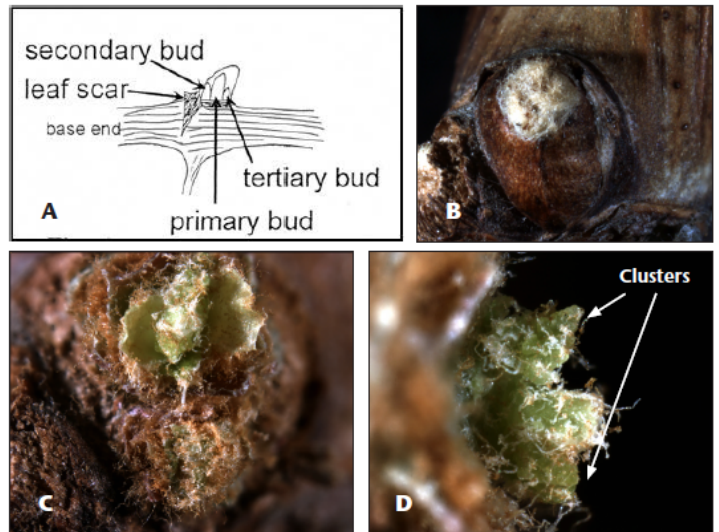

Figure 4. A) An overwintering compound bud, which is comprised of three internal buds. The primary bud is the largest, most visible, and dominant producer of fruit. B) The outer bud scales are carefully removed with tweezers to expose the protective wooly bud hairs that insulate the small shoots and clusters. C) Additional hair is removed to expose a small shoot, complete with tiny leaves. D) The cluster will be very small, conical shaped, and on either side of the shoot. In this image, the bud was turned on its side from a birds-eye view to highlight the cluster primordia. Drawing by Lynn Mills, WSU-IAREC. Photos by Michelle Moyer.

References

Dami, I. 2006. Methods of Crop Estimation in Grapes. The Ohio State University.

Dami, I. and P. Sabbatini. 2011. Crop Estimation of Grapes. *The Ohio State University Fact Sheet* HYG-1434-11.

Davenport, J. and D. Horneck. 2011. Sampling Guide for Nutrient Assessment of Irrigated Vineyards in the Inland Pacific Northwest. *Pacific Northwest Extension Publication* PNW622. Washington State University.

Dokoozlian, N.K. 2000. Grape Berry Growth and Development. In *Raisin Production Manual*, edited by L.P. Christensen, 30-37. University of California Publication 3393.

Dry, P.R., R.G. Iland, and R. Ristic. 2004. What is Vine Balance? In *Proceedings from the 12th Australian Wine Industry Technical Conference*, 68-74, edited by R.J. Blair, P.J. Williams, and I.S. Pretorius. 24-29 July 2004. Melbourne, Victoria.

Fendiger, A.G., R.M. Pool, R.M. Dunst, and R. Smith. 1996. Effects of Mechanical Thinning Minimally-Pruned 'Concord' Grapevines on Fruit Composition. In *Proceedings of the 4th*

International Symposium on Cool Climate Enology and Viticulture, 13-17, edited by T. Henick-Kling, T.E. Wolf, and E.M. Harkness. New York State Agricultural Experiment Station.

Hellman, E. and T. Casteel. 2003. Crop Estimation and Thinning. In *Oregon Viticulture,* 231-234, edited by E. Hellman. Oregon State University Press.

Hoheisel, G.A. and M.M. Moyer, eds. 2015 Pest Management Guide for Grapes in Washington. *Washington State University Extension Publication* EB0762.

Keller, M., L.J. Mills, R.L. Wample, and S.E. Spayd. 2004. Crop Load Management in Concord Grapes Using Different Pruning Techniques. *American Journal of Enology and Viticulture* 55: 35-50.

Kurtural, K.S. and B. O'Daniel. 2007. Crop Estimation in Vineyards. *University of Kentucky Extension Publication* HO-86.

Moyer, M.M, L. Mills, G.A. Hoheisel, and M. Keller. 2011. Assessing and Managing Cold Damage in Washington Vineyards. *Washington State University Extension Manual* EM042E.

Moyer, M.M., R.T. Peters, and R. Hamman. 2013. Irrigation Basics for Eastern Washington Vineyards. *Washington State University Extension Manual* EM061E. Washington State University.

Rankine, B.C., K.M. Cellier, and E.W. Boehm. 1962. Studies on Grape Variability and Field Sampling. *American Journal of Enology and Viticulture* 13: 58-72.

Skinkis, P. and A. Vance. 2013. Understanding Vine Balance: An Important Concept in Vineyard Management. *Oregon State University Extension Manual* EM9068.

Wolpert, J.A. and E.P. Vilas. 1992. Estimating Vineyard Yields: Introduction to a Simple, Two-Step Method. *American Journal of Enology and Viticulture* 43: 384-388.

WSU AgWeatherNet (AWN). Growing Degree Day Overview. Washington State University Irrigated Agriculture Research & Extension Center.

Appendix

Estimating Lag Phase Using Growing Degree Days

Determining the lag phase of cluster development can be simplified by using accumulated growing degree days (GDD). As a standard practice, GDD units are calculated from April 1 to October 31; grapevines use a base temperature of 50°F. AgWeatherNet (AWN) of Washington State University has an automatic GDD calculator for each of its associated weather stations. This information can be accessed by visiting the AWN website.

Equation 4 shows how to calculate GDD; if the result is a negative number, the GDD unit for that day is set to "0" instead.

$$DD \text{ (Heat Units in °F)} = \frac{(T_{max} + T_{min})}{2} - 50°F \text{ (base temp)}$$

Equation 4: GDD Unit Calculation

If the high temperature was 72°F and the low temperature was 50°F, the daily GDD unit value would be calculated as in Example Equation 4.

$$DD \text{ (Heat Units in °F)} = \frac{(72°F + 50°F)}{2} - 50°F \text{ (base temp)} = 11 \text{ DD Units}$$

Example Equation 4: GDD Unit Calculation for a temperature high of 72°F and low of 50°F

Vitis labruscana 'Concord' berries typically reach 50% of their harvest weight at 1170 GDD (°F; 650°C) in New York State (Fendiger et al. 1996). However, studies conducted in Washington State demonstrated that by the time 1170 GDD had accumulated, Concord berries were at 60% of their harvest weight (Keller et al. 2004).

If this GDD method for determining lag phase is not working for a particular site or variety, return to the monitoring outlined in *Understanding Lag Phase*.