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Understanding Vine Balance:

An important concept in vineyard management

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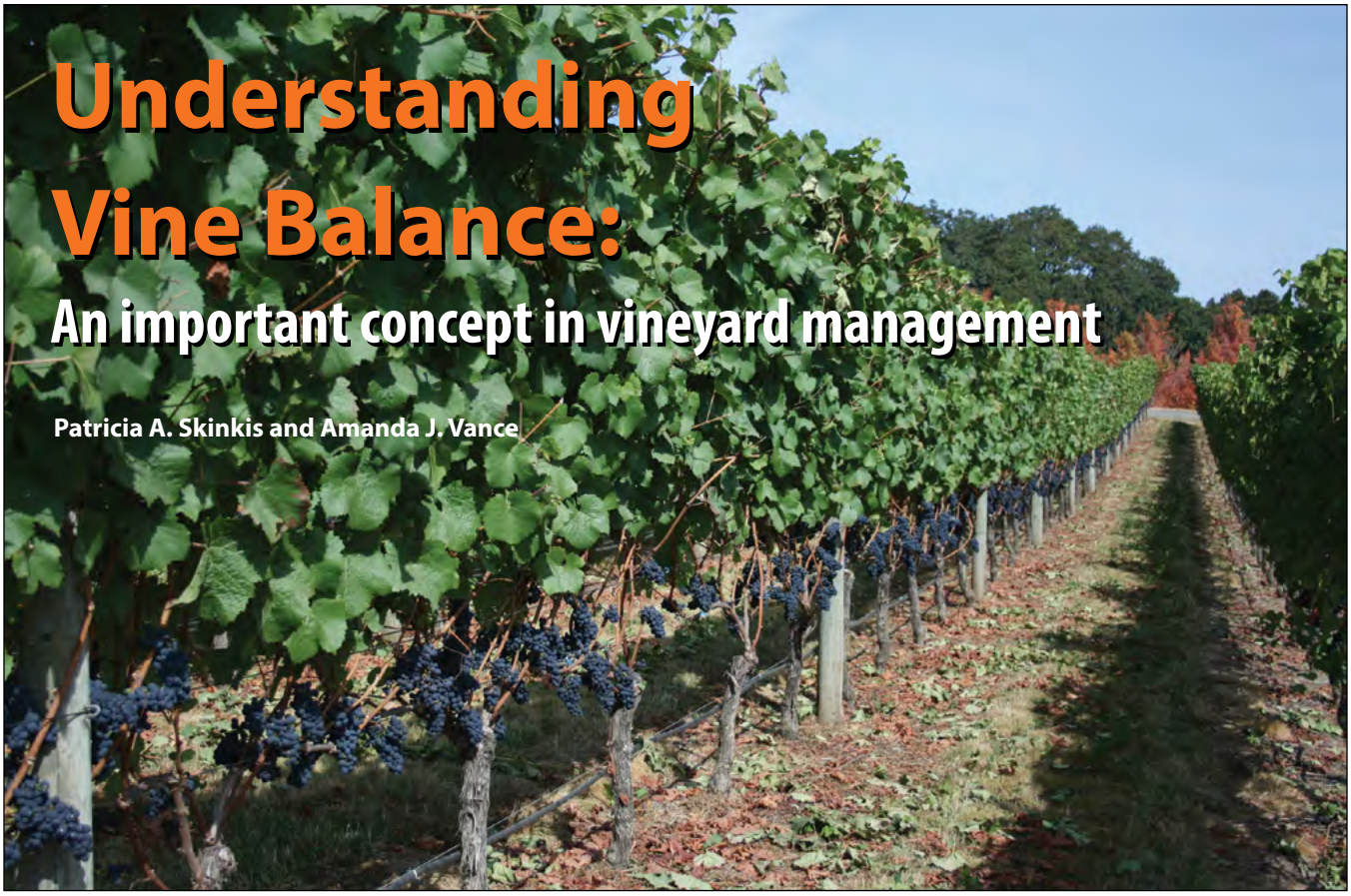

Figure 1. Good canopy management and vineyard design leads to yield that is balanced with an adequate canopy to achieve optimum fruit quality. (Photo: Patricia A. Skinkis, © Oregon State University)

Vine balance is a critical concept to understand in viticulture. Vineyard design and management methods used to obtain vine balance help sustain productive yields, achieve desired fruit quality, and preserve overall vine health (Figure 1). The varied climates of winegrape-producing regions within Oregon present different challenges in managing vine balance; however, the same basic concepts apply across these regions.

Vine balance is defined as the state at which vegetative and reproductive growth can be sustained indefinitely while maintaining healthy canopy growth, adequate fruit production, and desired fruit quality, namely sugar levels, acid balance, and flavor compounds. This concept has been researched by viticulturists throughout the United States and the world during the past century. Canopy management and production practices can impact vine balance directly by changing yield through flowering and fruit set. Management practices can also influence fruit quality, vine nutrition, and cold hardiness. The concept of vine balance is complex due to the many factors that influence vine growth, fruitfulness, and fruit ripening. Vineyard site characteristics, including soils, water availability, and climate, in combination with vineyard design, cultivar, management practices, disease, pests, and production goals are factors in determining appropriate methods to achieve vine balance. Therefore, there are no prescriptive guidelines for achieving balanced vines across all vineyard sites.

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Figure 2. Grafted grapevines can have lower vegetative vigor than own-rooted vines. The vines in the background are Pinot noir grafted to the rootstock Riparia Gloire, while vines in the foreground are on their own roots. Differences in shoot length, density, and leaf color are clearly visible. (Photo: Patricia A. Skinkis, © Oregon State University)

Environmental impacts on vine balance

Environment and plant material (cultivar and rootstock) are the primary factors that influence the growth potential of a vine. Vineyard management methods play a secondary role in vine balance but are important for managing vine size and productivity within a given site. Vineyards growing on deep, fertile soils with good water-holding capacity and high annual precipitation, as is the case in many western Oregon vineyards, will be able to produce larger vines and maintain higher yields than vineyards that have shallow or coarse soils with lower water-holding capacity, such as in the arid regions of eastern Oregon and Washington.

Vines with relatively unlimited resources of soil moisture, mineral nutrition, sunlight, and heat will be able to produce adequate canopy to allow carbon production to sustain canopy growth and fruit production and provide nutrients to storage reserves for post-budbreak growth in the following year. Conversely, vines with limited water and nutrient resources will have less canopy growth and lower carbon levels produced as a result for the current season's fruit production and storage reserves for growth during the following season. To reach vine balance within a given site, environmental factors must be considered along with potential inputs, such as irrigation or fertilizers, to allow the vine to reach a balance of canopy and fruit growth.

Cultivar and rootstock impacts on vine balance

Vine growth and development are influenced by both the rootstock and scion (cultivar) of the grapevine. While rootstocks have primarily been developed for phylloxera resistance, they have other beneficial qualities for grapevines, including increasing or decreasing vine vigor (Figure 2). The

ability of the rootstock to increase or decrease vine growth is not fully understood. However, research indicates that rootstocks can alter vegetative vigor, fruiting potential, pest resistance (nematodes, phylloxera), water-use efficiency, and nutrient uptake and use. All of these factors may impact vine balance. For more information about the characteristics of grapevine rootstocks, see *Grapevine Rootstocks for Oregon Vineyards*.

Different grapevine cultivars have varying levels of vine vigor, but as most commercial vineyards today are grafted to rootstock, it is likely that rootstocks and environmental conditions, especially water and nutrient availability, have more influence on scion growth than the scion genotype itself. Therefore, grape growers can use vineyard design and management practices to enhance or decrease vine growth as needed.

Vineyard management impacts on vine balance

Vineyard management methods and economics of winegrape production are important considerations in managing vine balance. Production practices that do not take into consideration the production capacity of a vineyard will inevitably result in unsustainable vineyard management through decreased yield or fruit quality and increased production costs. For example, adding nitrogen fertilizers to already healthy grapevines on fertile soils may lead to more excessive growth and more canopy management practices, which require more labor and time to conduct. For more information about vineyard management methods used to reach vine balance, see *The Role of Canopy Management in Vine Balance*.

Causes and effects of unbalanced vines

Overly vigorous vines. Vines with large canopies and excessive vegetative growth relative to crop levels can result in poor bud fruitfulness and reduced cold hardiness, fruit set, yield, and quality at harvest. Unless measures are taken to manage vigorous vines, these problems compound over the years and vines can spiral into an overly vegetative state in which canopy vegetative growth far exceeds fruit production. Cutting off excess canopy through hedging and leaf removal can help modify the microclimate, but these methods do not bring a vine back into balance directly. Removing growing shoot tips through hedging causes vigorous vines to continue new growth from lateral shoots, thereby creating increased canopy density and requiring further hedging or removal of leaves or lateral shoots. The cause of high vigor in problem vines must be determined in order to moderate vine growth and bring the vines back into proper balance between shoot growth and fruit development.

Figure 3. Overly vigorous vines have significant canopy growth throughout the growing season. Long lateral shoots develop, creating very dense canopies as early as bloom as observed in these Pinot noir vines in the Willamette Valley (Photo: Amanda J. Vance, © Oregon State University).

Potential causes of high vine vigor include unsuitable vineyard design or training system, high soil fertility and soil moisture, unnecessary fertilization, or under-cropping vines. Planting vines too close together or on training systems designed for low to moderate vine vigor on a site with deep soils and high water-holding capacity can result in excessive shoot growth and very dense canopies (Figure 3). Grapevines have low nutrient demands relative to other perennial crops. When nutrients such as nitrogen are added when not required, they can cause significant increases in vegetative growth, creating overly dense canopies that shade both leaves and fruit. While crop thinning is often used to increase fruit quality in premium winegrape regions, continuously limiting yields in vigorous vines can cause problems for vine growth and wine quality. In this situation, vines have increased vegetative growth and canopy density, reduced bud fruitfulness, and flowering and fruit set issues, which may cause

Figure 4. Weak vines can have stunted shoots early in the season and often do not fill the trellis wire as shown in this photo of a vineyard in the Willamette Valley (Photo: Patricia A. Skinkis, © Oregon State University).

further reduced yields. Fruit quality also suffers in overly vigorous vines, resulting in poor-quality wines. This problem has been observed in some high-vigor vineyards in western Oregon, particularly those sites planted to high vine densities on deep soils.

Weak vines. Weak vines can experience similar maladies as overly vigorous vines, including poor bud fruitfulness, reduced yields, and poor fruit quality. Other symptoms of weak vines include reduced budbreak and stunted shoot development in early spring, due to limited carbon and nutrient reserves stored in roots and trunk tissues. As the season progresses, weak vines can have stunted shoot growth, which can lead to poor bud development for the following year, significantly reducing crop level in the current season and reducing fruit quality as the fruit struggles to ripen. When shoot growth is stunted in early spring and into the growing season, shoots may not develop enough leaves to support all the clusters, requiring fruit thinning to allow the remaining fruit to ripen and replenish carbon reserves for growth next spring.

Many factors can contribute to poor vine growth, including weed or cover crop competition for water and nutrients, improper irrigation, overcropping (high yields), impermeable or shallow soils, pests, and incorrect pruning. Improper vineyard establishment, such as poor weed control and lack of irrigation or nutrition during the first few years of vineyard development, can lead to delayed development and weak vines during the first production years.

If vines are in a state of sustained nutrient or water stress, root systems and canopy growth are restricted and weak, causing poor vine health and low productivity.

Weak vineyards are identified as those that are underproductive for a given site—for example, a vineyard where vines do not completely fill the trellis wire (Figure 4). Efforts must be made to determine why the vines are weak and make changes where

necessary to increase vine productivity both short-term and long-term.

Pruning to manage vine balance

Pruning is critical for maintaining vine size and canopy architecture while optimizing fruit production in grapevines. The number of buds retained at pruning can greatly influence vine growth and productivity over time. While spacing and training system will provide a general idea of how many buds to retain to fill the trellis, it is important to consider the vine health status when fine-tuning the number of buds to retain at pruning:

Vigorous vines. More buds can be retained at pruning (less severe pruning) because they have adequate nutrient reserves to support more buds during early shoot growth stages. Larger vines typically have larger root systems and greater access to more nutrients in the soil to allow sufficient nutrient uptake for support of shoot growth and crop production.

Restricting bud number on vigorous vines can lead to overly vigorous vine growth, excessive adventitious shoot growth, bull canes, and reduced yield. The net result is that vines become farther out of balance. These vines often require more canopy management work or division of the canopy (i.e. with divided canopy training systems such as Scott Henry or Geneva Double Curtain) to keep the canopy open and well exposed to sunlight.

Even though more buds can be left on vigorous vines to obtain balanced growth, it is important to consider that too many buds can lead to crowding and problems with shading within the canopy.

Weak vines. These vines should be pruned more severely, leaving fewer buds remaining compared to larger, healthy vines. This will allow improved shoot growth early in the season and allow the vine to carry a smaller yet manageable crop. Leaving too many buds on weak vines results in those vines struggling to grow adequate canopy to support the fruit with resources available. Therefore, crop thinning will be required to maintain adequate balance between fruit and canopy size.

The **balanced pruning method**, which evaluates pruning decisions based on vine growth the previous season, was developed by Nelson Shaulis to improve sustainability of vine growth (Shaulis 1950). To implement balanced pruning, individual vine pruning weights are measured. Depending on vine vigor level, which is determined by pruning weights, a certain number of buds are retained per vine. For the first pound of pruning wood, either 10, 20, or 30 buds are retained per vine. An additional 10 buds are retained for each pound of pruning wood beyond the first pound depending on the vine vigor level (Table 1). A moderate vigor vine with 2.5 pounds of pruning weight per vine would have 1 lb x 20 buds + 1.5 lb x 10 buds = 35 buds total retained per vine. While it is impractical to measure and calculate this equation for each vine in a vineyard block, it can be used on reference vines within vineyard blocks to determine an adequate bud number at pruning. This method has been used with great success across regions, species, and cultivars to improve vine balance.

Table 1. Balanced Pruning Method

Vigor level	Average cane weight	Number of buds to retain
Low	<0.02 lbs or <10 g	10+10
Moderate	0.04-0.09 lb or 20-40 g	20+10
High	>0.13 lb or >60 g	30+10

Ways to measure vine balance

Vine balance has been defined and calculated as the ratio between fruit yield and vine size, representing reproductive and vegetative production of the vine. The following are ways in which you can measure and interpret vine balance in your vineyard.

Crop load. This term, which is often confused with yield, is the balance of the fruit mass and canopy size of vines. It is calculated by using yield at harvest and comparing it to the dormant pruning weight measured in the winter following harvest (Crop load = Vine yield / dormant pruning weight). This calculation is known as the Ravaz Index (Ravaz, 1903). Because the equation uses yield and dormant pruning weight, many producers question how this metric is relevant to determine vine balance in a vineyard that is cluster-thinned or hedged during the season, as is typical in most of Oregon's production regions. It is important to remember that pruning weights and yields are not meant to be measures of total biomass production of the vine, rather they are meant to reflect the final size of the vine given the management practices. Viticulture research conducted in Oregon shows that despite canopy management, differences in pruning weight are able to be quantified with changes in nutrients, soil moisture, and other factors that affect the vine size and yield. Furthermore, it is important to understand that pruning weights will capture growth differences such as lateral growth and cane diameter, which reflect vine vegetative growth even when hedging is used. If vines are significantly crop-thinned, particularly late in the season, you may wish to rely on pruning weights to determine vine vigor levels (Table 1) instead of using the crop load metric. Alternatively, if crop thinning is conducted at lag phase, you may wish to use data you collect at lag phase to calculate potential total crop when calculating your crop load. This allows you to compare potential crop load to actual crop load calculated with final harvest yields. Ultimately, you want to be able to understand what crop loads are appropriate for your site and cultivar to reach optimum fruit production and wine composition. Furthermore, calculating the Ravaz Index is relatively easy, particularly if you already collect harvest yield data and pruning weights.

Figure 5: After pruning reference vines, the dormant 1-year-old canes are weighed using a hanging scale. Data can then be used for calculating crop load (Ravaz) and interpreting overall vigor (Photo: Patricia A. Skinkis, © Oegon State University)

Pruning weight. The weight of 1-year-old canes collected from vines during the dormant period (Figure 5) is an important measure of vine growth. (See *How to Measure Dormant Pruning Weights of Grapevines* for detailed instructions on collecting pruning weight data.) This measure indicates your vineyard's vegetative vigor level (Table 2). Measurements of dormant pruning wood can be used in various ways to help you determine your vine vigor status. Although vines in Oregon are altered significantly through canopy management such as shoot thinning, hedging, lateral removal, and leaf pulling, the pruning weight measures can help you determine if there are differences in vigor within or between blocks. By using the linear foot and cane weight calculations outlined below rather than the per vine pruning weight, you can better interpret the pruning weight data that you collect, considering that different vineyard blocks may have more or less vine spacing that may alter the total vine pruning weights. It is best to do per vine, per linear foot, and cane weight calculations for your records to make comparisons of vine vigor across vineyards and blocks where different spacing, density, or training systems may be used.

Pruning weight by linear foot. This is determined by dividing total vine or vineyard pruning weight by the number of linear feet of canopy per vine or by vineyard block, depending on how your data is collected.

Examining pruning weights by linear foot of row helps define the amount of vine vigor across space, which can be useful in comparing vigor in different vineyards or blocks within a single vineyard.

Looking at pruning weights without context of space can be misleading. For example, a vine with 2 pounds of pruning wood on a 5-foot vine spacing will be significantly more vigorous than a vine with 2 pounds of pruning wood on a 10-foot spacing.

Determining linear foot of row in a vineyard block:
Linear foot per acre = 43,560 ft^2/acre ÷ row width (ft)

Cane weight. This is calculated by dividing the pruning weight per vine by the number of shoots per vine. Prior to taking your pruning weight measurements, you will need to count shoots for this calculation and subtract the number of canes retained for the next season's growth (cane pruning). The shoot count and pruning weight must be paired per vine. This provides a comparison across vineyard blocks or areas within vineyard blocks, and when considering different blocks, you may find that some areas have heavier canes than others, suggesting higher vigor rather than simply higher number of shoots per vine causing differences in whole vine pruning weight comparisons.

Table 2: Metrics for vine balance

Recommended Ravaz Index Ranges	
Vitis vinifera cultivars	5 to 10
Naturally low-yielding cultivars, cool climate production	<5
Recommended leaf area/yield ratio[a]	
Single canopy training systems	3.9 to 5.9 ft^2/lb fruit
Divided canopy training systems	2.4 to 3.9 ft^2/lb fruit
Recommended pruning weight per linear ft[b]	
All vineyards	0.2 to 0.4 lb/ft
Vigor classification by cane weight[b]	
Low	<0.02 lb
Moderate	0.04 to 0.09 lb
High	>0.13 lb

[a]From Kliewer and Dokoozlian (2005). These values were derived from warm climate cultivars. Research being conducted in Oregon suggests higher leaf area to yield ratios, and these are currently being evaluated.
[b]From Kliewer and Casteel (2003).

Leaf area: Comparing canopy leaf area to vine yield is another way to quantify vine balance. However, the method by which to collect these data is far more time-consuming than collecting yield and pruning weights. Vine leaf area is hard to quantify, particularly in vertically shoot-positioned, Guyot-trained vines (VSP), since they are manipulated by canopy management practices and then experience re-growth, resulting in an ever-changing value for leaf area quantification. Leaf area is most often measured at véraison (onset of ripening) when the canopy typically ceases shoot growth. The current guidelines for leaf area for a full canopy in a productive vineyard are between 2.4 to 5.8 square feet per pound of fruit, depending on the training system (Table 2). However, these guidelines have been based on research conducted in warm climate vineyard production regions using single curtain training systems. Ideal leaf-areas-to-fruit ratios are likely to be slightly different in cool climate regions and for different cultivars and training systems. Recent research in the Willamette Valley shows that more leaf area is likely necessary for reaching optimum ripening in Pinot noir or other cool-climate cultivars. For practical vineyard management and recordkeeping, it is best to record some canopy size information, such as the canopy height, length, and width per vine. When this information is combined with shoots per vine, pruning weights and yield, it provides descriptive information on overall vine size and canopy density in a given vineyard block (See *How to Determine Vine Leaf Area* for detailed instructions on measuring leaf area).

Keeping records of vine balance

Tracking development and productivity changes in your vineyards requires that you keep records for vine balance, including vine yields, pruning weights, and other pertinent vineyard information across seasons. This will help you determine the impact of management practices on production and fruit quality over time. Research on vine balance suggests that Ravaz Indices within 5 to 10 are considered optimum for most viticulture production regions across the world. However, a Ravaz Index value below 5 has been suggested to be suitable for lower-yielding varieties such as Pinot noir in cool climates where season length and growing degree days are limited (Table 2). These recommendations encompass a wide range to account for differences in cultivars, climates, and production goals. The key is to collect data from your vineyards to determine your vine balance status. Here are some general guidelines to help you understand and interpret your vineyard's vine balance:

- Ravaz Index values at the low end of the optimum range are considered under-cropped or highly vigorous—vines have a larger canopy size relative to fruit yields.
- Ravaz Index values at the high end of the range are considered over-cropped or of low vigor—vines have larger fruit yield relative to the canopy size.

Research in the Willamette Valley shows that typical Pinot noir production vines never reach a Ravaz Index of 5. Therefore, values on the low end of the suggested ranges may be normal in order to achieve optimum sugars and anthocyanins (the red or purple color pigments in red grapes), particularly in cool seasons (Vance 2012). Often sugars and anthocyanins are parameters that can be affected by crop load. Being at either end of the crop load spectrum can lead to unsustainable vine growth and fruit quality. Excessively high or low vegetative growth leads to nutrient imbalances, decreased yields, and reduced fruit quality while requiring more management costs, such as fertilization, irrigation, crop thinning, canopy management, and disease control.

Summary

Vine balance can be achieved when viticulturists and vineyard managers understand and manage the many underlying factors that influence vineyard production.

It is important that vineyard records include the basic vine balance metrics, including pruning weights, yields, crop load, and other management details such as vine nutrient inputs, spray records, pest management methods, and irrigation practices. These are all factors that need to be considered in the vineyard production system and play an important role in vine balance. When vines are in balance, fewer inputs, labor, and expenses are required to optimize fruit quality and vine health.

Frequently Asked Questions about Vine Balance

Q. Does cluster zone leaf removal result in delayed ripening of fruit?

A. Most cluster zone leaf removal practices conducted in Oregon reduce the vine's total leaf area by 10% to 14% and adequate canopy remains to ripen fruit. In most VSP-trained canopies of moderate to high vigor, cluster zone leaf removal helps to increase air flow and sunlight exposure of the fruit. Removal of just a few leaves should not greatly affect the total photosynthetic capacity of the vine or the ability of the vine to ripen fruit. Weak vines with sparse canopies may need cluster zone leaves to support the fruit. With already-low canopy density, weak vines likely have sufficient fruit exposure and would not require additional leaf removal. In vineyards with dense canopies where many leaves and laterals cover the fruit, the benefit of increased fruit exposure outweighs the loss of basal leaves. In some cases in warmer climate regions or years, overexposure of fruit can cause delayed or arrested development when the berries are heat-stressed or sunburned. To avoid this, growers often remove leaves well before véraison and selectively to avoid overexposure during the warmest parts of the day. For more information about leaf removal, see *The Role of Canopy Management in Vine Balance*.

Q. How many leaves per shoot are required to ripen a cluster?

The number of leaves required to ripen fruit is highly variable by cultivar, climate, and vineyard. Some estimates have been made from research in warmer climates and indicate that 15 to 18 leaves per shoot are required to adequately ripen fruit on a vine. However, there are many factors that need to be considered, including canopy density, cultivar, and climate, which may increase or decrease this number of leaves required to ripen fruit. Grapevines of moderate to high vigor in the Willamette Valley typically have at least 20 to 40 leaves per shoot. However, this does not mean that all of the leaves on a shoot are functioning at optimum levels due to inner canopy shading and leaf age.

Q. Does hedging reduce vine vigor?

Typical hedging practices used on VSP vines does not reduce a vine's capacity to grow; it can actually stimulate growth of lateral shoots depending on the vine vigor level and growth stage when hedging is conducted.

In more vigorous vines, lateral shoots may form from the main shoot even before hedging begins. Increased lateral growth increases canopy density and perpetuates more vigorous growth. However, hedging is required to reduce the canopy height and to cut laterals to decrease canopy density and avoid shading.

Depending on the vine vigor level, this may require repeated passes. There are other means to better control vigor, as hedging is not the direct method by which to reduce vigor.

Q. How does lateral shoot removal impact the vine and fruit?

A. Lateral shoot removal may be beneficial in decreasing canopy density and increasing light exposure and air flow, particularly in the cluster zone of highly vigorous vines.

However, by removing laterals, younger and potentially more productive leaves are removed, and this could be detrimental to the ripening process if the canopy is limiting on moderate to lower vigor vines. In general, vigorous vines have more and longer laterals than moderate vigor vines, which require more management to control canopy density.

Q. How much does crop yield affect vine vigor?

A. Fruit competes with vegetative growth for carbohydrates and nutrients during the growing season. The impact of yield on canopy growth depends on the site's soil and climate. In vigorous vines, higher crop levels may be sustained without significant reductions in vine vegetative growth compared to weaker vines.

However, in resource-limited sites (i.e., water, nutrients) a high crop level can reduce shoot growth, and crop thinning can be used to balance fruit level relative to canopy size. Overcropping vines year after year may result in weaker vines over time. For this reason, it is important to know the balance between canopy size and fruit yield.

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Further reading

For more information on vine balance and canopy management, please see *eViticulture* (http://eViticulture.org), an online Extension resource in viticulture. For more detailed information on vine balance, please see the following:

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