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Summer Bunch Rot Diseases and their Management

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Late-season bunch rots can cause significant losses in some seasons. Although they are often referred to collectively as "sour rot", late-season bunch rot is a complex which includes sour rot and diseases caused by several distinct fungi. Late-season bunch rots tend to be most severe in the southeastern US and other warm and wet grape growing regions of the world.

Late-season bunch rot is caused by *Phomopsis viticola* (Phomopsis rot), *Greeneria uvicola* (bitter rot), *Colletotrichum* spp. (ripe rot), *Botryosphaeria dothidea* (macrophoma rot), *Botrytis cinerea* (botrytis rot), and a complex of fungi, yeast and bacteria (sour rot). Often one or the other will predominate, but all can be found at harvest in many vineyards. Black rot, caused by *Guignardia bidwelli*, is not part of this complex because infected fruit shrivel and mummify by mid-summer in most years. This article is going to focus on bitter rot, ripe rot, macrophoma rot, and sour rot. Phomopsis rot is not going to be discussed since most infections occur early in the season.

Bitter rot. Infections by *G. uvicola* can occur as early as bloom but are more typical later in the season. Initial infections occur in the pedicles, the stem that attaches the berry to the cluster, and as fruit ripen the fungus grows from the pedicles into the fruit. Fruit increase in susceptibility from bloom until veraison and decrease thereafter. Six to 12 hours of wetting at temperatures in the mid-70s are most conducive to infection. Infections are first noticeable a few weeks before harvest and appear on fruit as a slightly discolored area around the pedicle. The rot then progresses throughout the fruit. Fruiting structures of *G. uvicola* (acervuli) begin forming on the fruit near the pedicle and eventually cover the entire fruit surface. Fruit often shrivel and mummify before harvest. Spores produced in the acervuli can cause secondary infections during favorable periods until harvest. The fungus survives year to year in dead wood on the cordons, old pedicles, and mummied fruit. There is a wide range in the susceptibility of varieties to bitter rot. Norton, Merlot, Traminette and Chardonnel are among the most resistant; Cabernet Franc, Cabernet Sauvignon and Chardonnay are moderately susceptible.

Photo 1. Bitter rot on Vignoles.

Ripe rot. Ripe rot is caused by *Colletotrichum acutatum* (Ca), *C. gloeosporioides* (Cg) and the sexual stage of *C. gloeosporioides*, *Glomerella cingulata* (Gc). All three fungi are often found in the same vineyard. Their life cycles are similar and all three cause the same symptoms on fruit. The likelihood of infections by Ca, Cg, and Gc during the period from bloom to closing is somewhat greater than with the bitter rot fungus, *G. uvicola*. But, like *G. uvicola*, fruit increase in susceptibility to veraison and decline thereafter. Infections can occur anywhere on the surface of the fruit. Infections remain quiescent (latent) until a few weeks before harvest. They are first visible as slightly sunken, somewhat discolored lesions that expand to infect the entire fruit. Fruiting structures (acervuli) are produced

on the surface of infected fruit. Ripe rot can be hard to distinguish from bitter rot. However, following rain or dew, masses of salmon-colored spores exude from the acervuli. Ca and Cg produce copious quantities of spores that can be washed onto fruit by rain initiating secondary infections until harvest. Ca, Cg, and Gc overwinter in dead wood on the cordons, old pedicles and mummied fruit on the vine. Varieties vary in their susceptibility to ripe rot. Norton, Chardonnay, Merlot, and Traminette are relatively resistant; Cabernet Sauvignon, Cabernet Franc, and Chambourcin are relatively susceptible. The susceptibility of fruit increases as harvest is delayed.

Photo 2. Ripe rot on Vignoles.

Photo 3. Macrophoma rot.

Macrophoma rot. Not as much is known about macrophoma rot. Infections are presumed to occur throughout the summer growing season though symptoms don't appear until a few weeks before harvest. Macrophoma rot is relatively easy to distinguish from bitter rot and ripe rot. Fruiting structures (pycnidia) are less numerous on the fruit surface. However the most distinguishing factor is that the fruit are soft and the skin of infected fruit easily slips off the flesh below. Secondary infections are not as common as those of the fungi causing bitter rot and ripe rot. *B. dothidea* overwinters in dead wood, pedicles, and mummied grapes just as the pathogens that cause ripe rot and bitter rot. Little is known about the susceptibility of varieties to *B. dothidea*. Differences in the susceptibility of muscadine varieties to *B. dothidea* have been reported so it is likely there are differences in the susceptibility of vinifera and French-American hybrid varieties.

Photo 4. Sour rot on Vidal blanc.

Sour rot. Sour rot is a term used for soft rots that have a distinct vinegar smell. Affected fruit are lighter in color than surrounding healthy ones. Sour rot is caused by a mix of fungi, yeasts, acetic acid-producing bacteria, fruit fly larvae and other organisms. Some of the fungi that have been associated with sour rot include species of *Alternaria*, *Penicillium*, *Aspergillus*, and *Rhizopus*. The organisms that cause sour rot enter grape berries through cracks and wounds caused by various injuries, wasps, grape berry moth damage, hail, russet from powdery mildew infections, botrytis infections, splits in the berries as a result of rains just before harvest, and wounds created by expanding fruit in tight-clustered varieties. Sour rot tends to be more of a problem on tight-clustered varieties than those with loose clusters. Among the most susceptible varieties are Viognier, Vignoles, Pinot Noir, and some clones of Chardonnay.

Management of bunch rot diseases. The management of summer bunch rot diseases is based on cultural practices to reduce the inoculum of the rot fungi and create conditions less favorable for infection. It's very important to remove old rachis tissues, mummied grapes, and

dead spurs and cordons while pruning. In older vineyards, the amount of inoculum can be significantly reduced by removing the old cordons and establishing new ones. Shoot thinning, shoot positioning, and leaf pulling can all reduce the drying time within the canopy and fruit clusters and create conditions less favorable for disease development. Most varieties are susceptible to most of the bunch rot diseases and require a 10- to 14-day spray program through the growing season. Norton is somewhat more resistant and the spray interval can often be extended, especially in dry years. The relative effectiveness of some fungicides can be found in Table 1. Botrytis is included for comparison. Generally, a captan-based program during the summer period provides the best bunch rot control. None of the fungicides are very effective on sour rot. Sour rot can be minimized by preventing injuries and timing harvest with anticipated rain to avoid fruit splitting and cracking.

Photo credits: Andy Allen

Table 1. Relative effectiveness of fungicides on bitter rot, ripe rot, macrophoma rot, and botrytis.
The greater the number of plusses (+) the more active the compound. QoI = Abound, Sovran, Flint and Pristine. DMI=Rally (Nova), Elite, Rubigan, Vintage.

Fungicide	Bitter rot	Ripe rot	Macrophoma	Botrytis
QoI	+++	+++	++++	+++
Topsin	+++	**0**	++	++
Captan	+++	++++	++++	+
Vangard/Rovral Elevate/Endura/ Scala	**0**	**0**	**0**	++++
DMI	++	**0**	++	**0**
Copper	**+?**	**+ ?**	**+?**	**0**
Mancozeb	++++	++++	++	**0**

Cluster Thinning: A Review

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Cluster thinning is a cultural practice that may be employed throughout the growing season with the timing dependant on the desired result. According to Winkler et al. (1974) there are three main types of cluster thinning; flower cluster thinning, cluster thinning at berry set, and berry thinning (partial cluster). More recent research has expanded the timing and reasons for thinning from pre-bloom to post-veraison. While flower cluster thinning and berry set are still the most common thinning methods, thinning may also be performed at pea size stage and veraison (green drop).

There are several potential reasons for cluster thinning, many of which are concerned with vine balance. Cluster thinning is performed to improve leaf area to crop and yield to pruning weight ratios (Kliewer and Dokoozlian 2005), improve vine capacity, strengthen weaker vines, encourage earlier fruit maturation and even fruit development, improve fruit and wine quality, and to maintain consistent yields (Bravdo et al. 1984, 1985, Dokoozlian and Hirschfelt 1995, Reynolds 2001, Winkler et al. 1974, Zabadal N.d.). Minimum leaf area to crop ratio is traditionally considered to be 7-14 cm^2/g (0.7-1.4 m^2/kg) where climactic factors in large part determine which values are most relevant (Howell 2001). Zabadal (N.d) suggests that cool climates require 10-14 cm^2/g of fruit (1.0-1.4m^2/kg) while Kliewer and Dokoozlian (2005) suggest that leaf area to crop ratio for a single canopy system requires 0.8-1.2 m^2/kg and a divided canopy 0.5-0.8 m^2/kg in warm climate conditions. Cooler climates require greater amounts of leaf area to crop to compensate for the lower light intensity and shorter growing season (Howell 2001). Values below these levels may not have enough leaves to ripen a full crop which may result in reduced fruit quality (Bravdo et al. 1984, 1985, Dokoozlian and Hirschfelt 1995), lower pruning weight, unripe fruit (Howell 2001), and may potentially weaken the vine (Bates 2003). Conversely levels greatly exceeding this amount may have late ripening or unripe fruit with excessive growth and greater pruning weight (Bates 2003).

Another method to determine vine balance is by utilizing the crop weight to pruning weight ratio. Again, the recommended values vary dependant on training system and climactic conditions. In warm climates ratios of 4-10 in single canopy systems are recommended and 5-10 in divided systems while in cool climates for small cluster varieties a range of 3-6 is suggested (Kliewer and Dokoozlian 2005). Bravdo et al. (1984, 1985) found that

fruit quality within the 4-10 range was acceptable and only when the ratio exceeded 10 was the quality reduced. This range in crop load was reaffirmed in a cool climate by Dami et al. (2006). Levels above 10 were believed to be overcropped and resulted in reduced vegetative growth, amino acids, wine quality, color, tartaric:malic acid ratio, and delayed maturation (Bravdo et al. 1984, 1985). In the same studies they determined that moderate levels of thinning (30-40 clusters/vine) had the most consistent quality parameters from year to year and produced fruit not inferior to severely thinned vines (20 clusters/vine). Conversely, Dami et al. (2006) determined that optimal fruit level in a cooler climate was only 10 clusters per vine. Higher cropped vines (20-30 clusters/vine) were consistently overcropped leading to reduced vine size and delayed maturation, which can be a problem in areas with shorter growing seasons (Dami et al. 2006).

In highly fruitful varieties like many French hybrids, balanced pruning on its own is not sufficient to control crop and prevent overcropping (Ferree et al. 2004, Howell et al. 1987, Kurtural et al. 2006, Morris et al. 2004, Reynolds 2001) so crop thinning is necessary. The benefits of cluster thinning may further be enhanced by shoot thinning in addition to balanced pruning to improve the vine and fruit quality (Morris et al. 2004, Naor et al. 2002, Reynolds et al. 1994).Research by Naor et al. (2002) has shown that with high shoot density soluble solids increased, but ripening was delayed, pH was increased and TA decreased in Sauvignon blanc. In other studies done with Pinot noir, higher shoot densities produced wines with more vegetal characters and less fruit, color, and finish when compared to wine of lower shoot density (Reynolds et al. 1996).

It is well know that increasing crop load will reduce vegetative growth, but to what extent? Edson et al. (1993, 1995) studied the effect of crop load on shoot growth, leaf size, leaf area, cane maturation, fruit quality, and dry weight partitioning. The results of these studies were that as crop load increased, nodes per shoot, shoot length, internode length, leaf area per vine, leaf size, and vine size decreased. When a comparison of the dry weight of different plant tissues was performed, it was determined that as crop load increased the amount of dry weight allocated to the fruit increased at the expense of vegetative growth including root growth and storage tissues. Additionally, cane maturation and fruit ripening were delayed in the high cropped vines.

Flower cluster thinning has traditionally been used on varieties that produce uneven or straggly set with the belief that by removing flower clusters, potential crop is removed earlier which may benefit both the potential fruit and vine (Winkler 1974) Benefits may include: increasing the leaf area to crop ratio, encouraging more uniform cluster development and berry set, increasing cluster weight (Ferree et al. 2003, Naor et al. 2002, Wolpert et al. 1983), berries per cluster, berry weight (Bravdo et al. 1984, 1985, Edson et al. 1993, Morris et al. 1987, 2004, Reynolds 2001, Reynolds and Wardle 1989, Reynolds et al. 1994), and cluster length (Winkler 1974). In addition, flower cluster removal has the potential to increase soluble solids (Ferree et al. 2003), winter hardiness, vine size, fruit quality (Dami et al. 2005, Edson et al. 1993, Howell et al. 1987), color, anthocyanins, (Brasher et al. 2002, Dokoozlian and Hirschfelt 1995, Ferree et al. 2004, Reynolds et al. 1994), flavor compounds (Reynolds 2001), and advance maturation (Bravdo et al 1984, 1985).

Parameters of wine composition, much like fruit composition varied among studies and sites. In a study on Pinot noir in two cool climate regions, reduced crop load by flower cluster thinning increased ethanol, anthocyanins, and pH as well as producing improvements in wine sensory characters (Reynolds et al. 1994, 1996). In these studies higher cropped vines tended to have more vegetative and chocolate characters with aromas described as grassy, plum, berry, and clove. Lower cropped vines were on the other side of the spectrum with aromas of cherry, pepper, currant, licorice, and higher astringency. Bravdo et al. (1984, 1985) noted that vines that remained unthinned produced fruit with lower amino acids, fixed acids, extracts, alcohol, tannins, color, potassium, and inferior wine quality in Carignane grapevines and lower malic acid and potassium in Cabernet Sauvignon when compared to the thinned treatments.

The main disadvantage with flower cluster thinning is tight clusters (Dami et al. 2005, Reynolds 2001, Zabadal N.d.). By reducing competing clusters, berry set is improved and berry weight is increased (Bravdo et al. 1984, 1985, Morris et al. 1987, Morris et al. 2004, Reynolds 2001, Reynolds et al. 1994, Winkler et al. 1974). The result is tighter clusters which can create greater potential for bunch rot and decreased skin to juice ratio thus reducing color, tannin, and flavor (Reynolds 2001). Flower cluster thinning may increase vine vigor which could create larger canopies, shading issues, and higher levels of titratable acidity (TA) (Reynolds 2001). Several studies additionally found that pH was slightly elevated in certain cultivars due in part to flower cluster thinning (Edson et al. 1993, Ferree et al. 2004, Howell et al. 1987, Morris et al. 1987, Morris et al. 2004, Naor et al. 2002, Reynolds et al. 1994, 1996, Wolpert et al. 1983) However, increased pH from flower cluster thinning resulted in unacceptable fruit quality in only one study with Gewurztraminer when excessive potassium

fertilizer was added. Consideration must be given to marketable yield versus total yield. In many instances achieving the highest possible yield is not desirable because the fruit will not be marketable as it won't reach specific quality standards. (Morris et al. 1987). Therefore, yield loss due to cluster thinning is often not damaging to the bottom line and in many instances allows the grower to have fruit with value. As would be expected flower cluster thinning does reduce yield, however, it has greater potential to compensate for the yield loss than thinning later in the season. Bravdo et al. (1984, 1985) only noted yield loss when greater than two thirds of the crop was removed.

Flower cluster thinning can be performed pre-bloom and throughout the bloom period. Winkler et al. (1974) suggested that earlier thinning would benefit the remaining inflorescences and result in more even set. Removing flower clusters is relatively quick and inexpensive when compared to cluster thinning and can be done concurrently with shoot thinning (Dami et al. 2005). The optimal time to cluster thin is pre-bloom when the inflorescence can be seen above the leaves and easily removed by pinching off (Dami et al. 2005, Dokoozlian and Hirschfelt 1995, Winkler et al. 1974). At the same time, thinning pre-bloom can be risky because berry set has not been determined (Dokoozlian and Hirschfelt, 1995).

Reynolds (2001) suggested a formula for determining how many clusters to remove by using the previous season's pruning weight. This assumes healthy vines to be about 1 kg of pruning weight with 13-20 shoots/meter row and 37 clusters/kg of pruning weight.
While determining thinning levels, keep in mind that heavy or complete flower cluster thinning may be beneficial to help weak vines recover (Winkler et al.1974). The authors recommend that for weaker vines thin to one cluster per shoot, healthy vines retain 1.5 clusters per shoot, and on highly vigorous vines retain two clusters per shoot.

Cluster (crop) thinning covers a broad range of fruit removal times from berry set to just prior to harvest. The reason for and result of thinning varies depending on which stage the fruit is removed. Overall, cluster thinning is used to reduce uneven cluster development, reduce crop load to improve fruit quality, encourage earlier ripening, and improve vine hardiness. (Reynolds 2001, Zabadal N.d.) Unlike flower cluster thinning, crop thinning is beneficial for varieties with tight clusters (Dami et al. 2005, Reynolds 2001) and allows the removal of clusters with imperfect set, damaged, or shaded clusters (Winkler et al. 1974, Zabadal N.d.). Furthermore, thinning after berry set allows the grower to use crop prediction to determine the amount of thinning required specific to their vineyard (Zabadal N.d.).

The main disadvantage to crop thinning is the cost and the reduction in yield (Reynolds 2001). The loss in yield has been observed in several studies (Chapman et al. 2004, Dami et al. 2006, Dokoozlian and Hirschfelt 1995, Ferree et al. 2002, Guidoni et al. 2002, Keller et al. 2005, Kurtural et al. 2006, Ough and Nagaoka 1984). By removing half of the crop at pea size stage, Guidoni et al. (2002) recorded a 43% loss in yield. An earlier study found that by removing two thirds of the crop two weeks after flowering, only one third of the yield was lost and when one third of the crop was removed, only a fifth of the yield was lost (Ough and Nagaoka 1984). Winker et al. (1974), has noted that by delaying the timing of thinning there is greater loss in yield which is related to the stage of berry growth and active cell division. The cost associated with cluster thinning is significantly higher than flower cluster thinning because the fruit is hidden within the canopy and it is much more time consuming to remove the clusters (Dami et al. 2005, Winkler et al. 1974).

Berry set to pea-size stage

Berry set is a common time used to remove clusters because at this stage the number of berries per cluster has been determined so less is left to chance (Dokoozlian and Hirschfelt 1995). Removing crop at this stage increases cluster weight, berry weight, soluble solids (Kurtural et al. 2006), and pH (Dami et al. 2006, Ferree et al. 2003, Pallioti and Cartechini 2000, Prajitna et al. 2007). In addition to the increase in soluble solids, Reynolds and Wardle (1989) determined that juice color intensity and free volatile terpenes increased with thinning four weeks after bloom on Gewurztraminer vines. Ferree et al. (2003) studied the effects of different cluster thinning times on Vidal blanc and found that as thinning time was delayed soluble solids and pH increased while berry weight peaked at thinning two weeks after bloom and then declined. An interesting trend that they observed was that as thinning time was delayed, yield decreased over the following three years. Conversely, work done by Dokoozlian and Hirschfelt (1995) found that berry weight, composition, and color accumulation was similar from thinning pre-bloom though four weeks following berry set.

In a recent study by Prajitna et al. (2007) the greater the severity of thinning at pea size stage, the greater the increase in pH, anthocyanins, total phenolics, and antioxidant activity, including resveratrol, in Chambourcin wine. Guidoni et al. (2000) observed that vines thinned at pea size had significantly increased soluble solids, berry skin weight, and anthocyanins concentration as

well as altered anthocyanin composition. Improved color, vine size, and winter hardiness have also been recorded with thinning at this stage (Dami et al. 2005, 2006, Reynolds 2001).

As a general rule or guide, the length of shoots at berry set can be used to determine the amount of crop to remove or retain (Striegler 2007). This is known as the two, one, or none rule. When the shoot length is 8 inches or less remove all the clusters. For shoot lengths of 8-20 inches thin to one cluster per shoot and if the shoot length is greater than 20 inches two clusters per shoot may be retained. This general guide is specific to medium-large clustered varieties. For varieties with small clusters, the number of clusters to retain can be adjusted upwards to two for medium length shoots and three for long shoots. Do not retain clusters on short shoots regardless of cluster size. Young or weak vines should be thinned more heavily to help improve the health of the vine. Overcropping young vines in particular can weaken the vine and reduce its fruiting potential (Bates 2003).

Green drop

Green drop refers to cluster thinning at veraison. At this stage thinning is performed to remove clusters that are ripening unevenly or are delayed in ripening. Wine quality is increased simply due to less unripe fruit being harvested. Keller et al. (2005) suggested that by removing specific clusters observed with green drop thinning in this study, thinning at this time may be beneficial to improve fruit quality as opposed to random thinning. The only difference observed with green drop thinning in this study was an increase in pH and a decrease in acid as crop level was reduced. However if thinning is done just prior to veraison it may be possible to increase pH, soluble solids (Ferree et al. 2003), anthocyanins and polyphenols while decreasing TA (Palliotti and Cartechini 2000). Green drop does not always influence fruit composition and wine quality. According to Dokoozlian and Hirschfelt (1995), thinning six weeks after fruit set was similar to unthinned treatments which produced fruit of variable quality and less color than earlier thinned vines. Chapman et al. (2004), found that thinning at veraison reduced yield, but had little affect on wine quality. In addition, berry size, cluster weight, vine size (Brasher et al. 2002), and winter hardiness are not normally increased by thinning at this stage (Reynolds 2001).

When determining what fruit to remove there are a few guidelines to help evaluate the clusters. In white cultivars at veraison the fruit skins should be clearing and the seeds can be seen starting to harden off. Remove fruit that has not started to clear and are still a dull solid green color or are uneven in ripeness. In red cultivars remove fruit that has not started to color. This includes clusters that have uneven ripening.

Thinning just prior to or at veraison may be essential in areas with shorter or variable growing seasons and high disease pressure (Howell 2001, Pallioti and Cartechini 2000). By thinning at veraison, ripening of the remaining crop is advanced (Reynolds 2001) which is one of the main advantages and reasons to green drop. It is a costly and labor intensive method which reduces yield, but may be beneficial in certain climates or situations.

In summary, cluster thinning is an important cultural practice which can be used to regulate crop level and improve fruit composition. Due to concerns about cluster compactness and bunch rot from flower cluster thinning and the high cost of green drop thinning along with associated yield reduction, post fruit set cluster thinning is the preferred method under Missouri and regional growing conditions.

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Temperature Control during Winemaking

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Viticulture and Enology

Introduction
Temperature control is one of the most important quality control aspects of winemaking and is critical during all stages of wine processing. Temperature has a significant influence on many areas that influence wine quality including fermentation rate and duration, phenolic extraction, wine aroma formation and rate of oxidation. Methods of temperature control in the winery include the use of harvest timing, insulation, brine cooling and air conditioning systems.

Prior to fermentation

White wine production
Hot grapes are susceptible to oxidation and even more so if they have disease and/or a high pH. Temperature control of white wine grapes and must is critical for high quality wine production. All attempts should be made to cool grapes to less than 60°F prior to processing. If this is not possible then must chilling is essential for high quality white wine production. Must is often chilled to below 60°F prior to pressing, once pressed it is left to settle between 40°F to 50°F prior to inoculation.

Red wine production
Cold maceration involves a pre-fermentation maceration for about 3-4 days and results in a slow extraction of anthocyanins (Jackson 2000). Must temperatures during cold maceration are often between 39°-59°F. Maceration temperature has been found to have a significant influence on wine flavor and aroma characteristics with cold temperatures enhancing berry fruit and cool temperatures developing peppery and bitter characters (Heatherbell et al. 1996).

Temperature control and fermentation
Long fermentations at cool to moderate temperatures favor complete fermentations. The four stages of fermentation are the lag, log, stationery and decline (Jackson 2000; Ribereau-Gayon et al. 2000). During the lag phase the number of yeast cells that die during acclimatization is similar to the number that are produced (Jackson 2000). The duration of the lag phase is extended at cool temperatures. To shorten the lag phase winemakers often increase white juice temperature to approximately 68°F before inoculating juice then once fermentation has begun the juice is then cooled to around 50-59°F.

During the log phase yeast cell count increases dramatically until reaching the stationery phase where the number of cells created is similar to the rate of cell death. With every increase of 18°F (10°C) fermentation intensity doubles (Ribereau-Gayon et al. 1975; Ribereau-Gayon et al. 2000). However, yeast viability decreases significantly at warmer temperatures (>68°F) during the decline stage of fermentation. Musts with high sugar concentrations are particularly vulnerable to stuck fermentations. Fermentation in high sugar must becomes more limited as the temperature increases. Even in wines without high sugar, initial fermentation temperatures that are too high (>86°F) can result in struggling or stuck fermentation in the final fermentation stages (Ribereau-Gayon et al. 2000).

Cool fermentation temperatures increase the viability of some beneficial indigenous yeast populations. Cool temperatures have been found to reduce the toxic effects of alcohol and slow the growth rate of species such as *Kloeckera apiculata* (Heard and Fleet 1988) and *Saccharomyces uvarum*. The use of *S. uvarum* has been described as biological acidification, used to avoid the production of flat wines as these yeast have the ability to synthesize malic acid and increase acid content in wine (Massoutier et al. 1998). The aromatic profile of Riesling wines have been known to benefit from the fruitflora aromatic development by indigenous yeasts used during fermentation (Henick-Kling et al. 1998).

During red wine fermentation temperatures between 75-81°F are thought to be optimal (Jackson 2000). Others believe that red wine fermentation should be initiated at around 64-68°F and allowed to gently increase to approximately 89°F (Ribereau-Gayon et al. 2000).

Phenolic extraction
High final fermentation temperatures are known to increase the maceration process (Ribereau-Gayon et al. 2000). Good color and fruity aromas can be obtained at moderate maceration temperatures (77°F) whereas deeper-colored wines with greater longevity can be achieved when maceration is warmer (86°F). However, higher temperatures can also increase the risk of yeast mortality and stuck fermentations especially when made from musts with high sugar concentrations. In white wine production color and tannin extraction are for the most part avoided.

Wine aroma formation
It is generally accepted that cool fermentation and aging temperatures help retain fruity aromas. Esters are a group of compounds responsible for fruity nuances in

wine. Low fermentation temperatures (50°F approx.) promote the creation of fruit esters. High fermentation temperatures (59-68°F approx.) increase ester hydrolysis which decreases ester accumulation in wines. White wines (Semillon) fermented at higher temperatures (>59°F) have a more intense yellow color and herbaceous aromas compared with wines fermented at cooler temperatures (Reynolds et al. 2001).

Higher fermentation temperatures are known to increase the synthesis of negative aroma compounds such as acetic acid and acetaldehyde. The intense aromas of red wines make these off aromas less noticeable (Jackson 2000). However, in white wines it can result in a wine with an aroma profile that is cooked or prematurely aged.

Oxidation and wine aging

Oxidation is one of the most important problems for Midwest winemakers. It is caused by the exposure of wine to oxygen (air) in warm conditions (Rankine 2004). Oxidation results in browning, loss of varietal and vinous character and off flavors in wine.

As previously mentioned grapes should be crushed cool or at a minimum must should be cooled prior to pressing during white wine processing.

Cellar and bottle storage temperatures should be cool (50-59°F). Temperature limits the rate of oxidation: for every increase in temperature of 18°F the rate of oxidation doubles. For a rise in temperature of 36°F, the rate of oxidation is increased 4 fold!

However, one needs to be aware that oxygen is significantly more soluble in cold wine.

Controlling temperature in the winery

The first step to controlling winery temperature is to invest in adequate insulation and make use of passive methods of temperature control. Passive methods of temperature control include earth contact, winery aspect and winery design. A winery built into north-facing hillside with large trees or trellises to shade the east and west external cladding is likely to be more energy efficient than an exposed winery constructed on a slab.

Due to the climate in Missouri utilizing passive methods of temperature control are not enough to consistently produce high quality wine. The astute commercial winery owner must also invest in active methods of temperature control. Commonly used methods of winery temperature control include chillers, air conditioning and brine systems. Temperature control equipment needed in a winery producing high quality wine includes:

- Must cooling
- Temperature controlled fermentation and storage tanks
- Cool storage for barrels and bottled wine

Heat exchanger for warming wine

Conclusion

Temperature control in a Missouri winery is critical for the production of high quality wine. The winemaker needs to pay careful attention to fruit, must, juice and wine temperature through all stages of production.

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Removing Volatile Sulfur Compound Off–Odors in Wine with Copper Sulfate

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Volatile sulfur compounds are commonly responsible for wine off aromas of rotten egg, onion and garlic. The compounds responsible are H_2S, two mercaptans (methanthiol and sometimes ethanethiol) and DMDS (dimethyl disulfide). The first three volatile sulfides are commonly removed during winemaking using a copper sulfate solution or by exposing wine to brass fittings. DMDS involves an extra step during removal involving the addition of ascorbic acid. As with any wine addition, the winemaker must determine the least amount of additives necessary to bring the desired odor removal to the wine. To do this a bench trial is necessary.

Undertaking a bench trial to determine how much copper sulfate to add to wine

1. Prepare a 1% copper sulfate solution =1g CuSO4 ·5H2O (copper sulfate)/100 ml distilled water. Label this as 1% copper sulfate solution.
2. Prepare a 0.004% copper sulfate solution. Pipette 1.0 ml of 1% copper sulfate solution into a 250 ml volumetric flask and bring the volume up to 250 ml with distilled water. Label this as 0.004% copper sulfate solution.
3. Label five 100 ml volumetric flasks with numbers 1 through 5.
4. Leave flask number one aside and pipette 0.5 ml, 1.0 ml, 1.5 ml, and 2.0 ml of 0.004% copper sulfate solution into flasks numbered 2, 3, 4, and 5, respectively.
5. Bring the volume to 100 ml with wine. Mix the contents well.
6. Close the flasks and leave overnight.
7. Check the aroma of trial wines to determine the correct concentration of copper sulfate addition.

Making a copper addition to wine

Prior to making any copper addition, wine should have completed fermentation, be racked and filtered. Any yeast remaining in the wine will bind up the copper making it unavailable for sulfide removal. If the wine has been exposed to oxygen forming DMDS then an addition of ascorbic acid (commonly >50mg/L) or sulfur dioxide prior to copper addition is recommended. DMDS cannot be removed by copper alone and needs to be reduced back to methyl mercaptan via the addition of ascorbic acid or SO_2. **Remember** that wines that have been treated with ascorbic acid cannot have SO_2 assessed accurately using the ripper method. Once the rate of copper addition has been determined through a bench trial the copper addition should be made using a 1% copper sulfate solution.

Important things to remember about making copper additions to wine

US government regulations stipulate that up to 6 ppm (6mg/L) copper can be added to wine. However the residual limit for copper is 0.5 ppm (0.5mg/L) in finished wine. In addition, residual copper levels in wine greater that 0.3 ppm can induce a copper haze.

If copper additions have been made to wine the winemaker must send samples for independent analysis to determine residual copper levels.

The link below goes to the TTB website that gives regulations for: Materials Authorized for the Treatment of Must and Wines:

Table 1. Concentration of copper. Note that 1 ml of 0.004% copper sulfate solution in 100 ml of wine equals approx. 0.1 ppm of copper

Flask	mL of 0.004% Copper Sulfate solution	Concentration of Copper ppm
1	0	0
2	0.5	0.05
3	1	0.1
4	1.5	0.15
5	2	0.2

http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=506cf0c03546efff958847134c5527d3&rgn=div5&view=text&node=27:1.0.1.1.19&idno=27#27:1.0.1.1.19.12.313.7

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(A method for screening for H_2S, DMDS and mercaptans will follow in the next issue of the Midwest Winegrower.)

Table 2. Milliliters of 1% copper sulfate solution to attain 0.2 ppm of copper in wine

Wine Volume	10L	100L	1000L
mL of 1% copper sulfate solution	1.1	10.6	105.6

Wine Volume	10 Gal	100 Gal	1000Gal
mL of 1% copper sulfate solution	4	40	400

Grapevine Petiole Analysis: A Tool for Fine-Tuning Your Vineyard Nutrition Program

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As we move into the veraison stage of grape berry development, it is time to perform one of the most important tasks in the vineyard nutrition program - taking petiole samples for grapevine nutrient analysis. Many growers periodically take soil samples to determine fertilization needs. While soil sampling is also a valuable part of the vineyard nutrition program, soil samples only determine the nutrient content of the soil, not the nutrient content of the grapevines. The level of a particular nutrient in the soil may be adequate but the vines may not be taking it up in sufficient quantity to meet the vines' needs. There are several reasons why this may be so. There may be an imbalance of nutrients that compete with each other for uptake by the grapevines' roots. This is a common occurrence in the case of magnesium and potassium. In low-magnesium soils, particularly with heavy potassium fertilization, potassium may outcompete magnesium for uptake, potentially resulting in magnesium-deficiency. Conversely, in high-magnesium, low-potassium soils, which are common in many areas of Missouri, magnesium may get taken up preferentially to potassium, resulting in potassium deficiency.
Soil water status may affect nutrient uptake. Poorly-drained or wet soils can cause anaerobic soil conditions, resulting in poor root function, including the roots' ability to absorb nutrients from the soil. At the other extreme, drought conditions may result in inadequate levels of nutrients being available in the soil solution, thus limiting the vines' ability to take up nutrients in the quantities needed to meet their needs. This is very common with potassium in very dry summer conditions.
Soil pH level may affect nutrient availability in the soil. Every nutrient has a pH range in which its availability is optimized. Outside of this range, the nutrient's availability is limited due to insolubility or by being tied up in compounds with other elements. For most nutrients a pH range of 6.0 to 7.0 results in adequate or optimum availability.
Additionally, grapevine health may affect nutrient uptake. Root injury by pests such as grape root borer, phylloxera or nematodes can result in reduced root activity and reduced nutrient uptake.
So while periodic soil sampling is important to monitor nutrient availability in the soil, it does not indicate the amounts of various nutrients actually being taken up by the vine. Grapevine petiole analysis however, integrates all of these various influences on nutrient uptake. Utilized on an annual basis, petiole sampling can help fine tune the vineyard fertilization program, assuring that nutrients are being added in sufficient quantities to meet vine needs without applying more than is necessary.
Petiole samples are typically taken at one of two critical stages in grape development each season: bloom or veraison. In states where the grape and wine industry is based mainly on *Vitis vinifera* cultivars such as Chardonnay or Cabernet Sauvignon, bloom-time petiole samples taken from leaves opposite the basal cluster are typically used. This is because the petiole nutrient sufficiency values for *Vitis vinifera* cultivars were developed

using petiole samples taken at this time from these leaves, mainly with the cultivar 'Thompson Seedless'. In the Midwest, petiole samples are typically taken at veraison from the youngest mature leaf, oftentimes referred to as the Most Recently Matured Leaf (MRML). Here, where the industry is based more heavily on native and hybrid cultivars, the sufficiency ranges utilized for petiole samples were developed using veraison-based sampling, primarily with Concord grapevines.

Petiole samples should be collected from uniform blocks of vines no greater than 10 acres in size. Blocks greater than 10 acres in size should be subdivided into smaller units and sampled separately. If the block is not uniform due to changes in soil type or topography which may affect soil fertility or soil water status or due to other factors that can influence vine growth and productivity, the block should be subdivided based on these factors and separate samples should be collected and submitted for each.

Different cultivars should be sampled separately. Research has shown that different cultivars grown under the same fertilization regimes have differing abilities to take up and utilize fertilizer nutrients. Additionally, in a grafted vineyard if a cultivar is grown on two different rootstocks or on its own roots in one block and on a rootstock in a second block, these should be sampled separately rather than combined into a single sample. Rootstocks also have differing abilities to take up nutrients. The rootstock 44-53M is known to preferentially take up potassium over magnesium. In a grapevine rootstock trial in Arkansas, vines grafted to 44-53M were observed to have serious magnesium deficiency symptoms, although they were fertilized at the same rate as vines grafted on other rootstocks in the same trial. Petiole analysis confirmed that these vines had deficient magnesium levels.

Samples should consist of 100 petioles. They can be collected from a group of vines that are representative of the entire block or can be collected according to a pattern such as every 10^{th} vine in every 5^{th} or 10^{th} row, if the block is uniform. As previously stated, where the block is not uniform, it should be subdivided into more uniform parcels and these should be sampled separately. Flag or otherwise map the vines used for sampling and sample the same vines each year. Utilizing the same vines every year will help to reveal trends in vine nutrition that could be masked by utilizing different vines every time due to vine-to-vine variability in nutrient levels.

Collect only 2-3 petioles per vine from the youngest mature leaf near the shoot tip (Fig. 1) and only from leaves fully exposed to the sun, not from leaves on the interior of the canopy. Avoid leaves that are diseased, damaged, or have been fed on by insects. Immediately remove the leaf blade from the petiole and discard it. Waiting until several leaves have been collected to remove the leaf blade can alter the nutrient content in the petioles. The petioles should be placed in a clean, dry paper bag and the bag should be labeled with the cultivar name, rootstock (if used), block identification, and date. Do not store petiole samples in a plastic sandwich bag. Doing so can cause the petioles to grow moldy or to rot. Keep a copy of all of the information for each sample to help with identification and interpretation of analysis results.

Fig. 1.

If foliar nutrient sprays or fungicides containing copper, sulfur, or other nutrients have recently been sprayed, the residue can lead to erroneous results. Collecting the samples after a rain event or rinsing the petioles after collection with distilled water can reduce the residue, but some nutrient values may still be artificially high. After collection and rinsing store the samples in a dry location and send them to the laboratory as soon as possible. Growers in Missouri can send petiole samples to the University of Missouri Soil and Plant Testing Lab in Columbia. Their contact information is:

University of Missouri
Soil and Plant Testing Laboratory
23 Mumford Hall
Columbia, MO 65211
Phone: 573-882-0623
Fax: 573-884-4288
http://soilplantlab.missouri.edu/soil/

Or contact the local University of Missouri Cooperative Extension Office in your county for assistance. In other states, growers should contact their local county cooperative extension office and inquire as to where and how to submit samples. Additionally, there are several commercial labs that perform petiole sample analysis. Critical nutrient concentrations for grapevine petioles sampled at veraison are given in Table 1. The utilization of a well-planned and consistent petiole sampling

program will yield important information on vine nutritional status. This information along with proper timing of application can maximize fertilizer use efficiency, vine performance, environmental protection, and vineyard profitability.

Table. 1. Specific Element Recommendations for Grapes from Petioles

Element[a]	Deficient	Below Normal	Normal	Above Normal	Excessive
N (%)	0.3 - 0.7	0.7 - 0.9	0.9 – 1.3	1.4 – 2.0	2.1+
P (%)	0.12	0.13 - 0.15	0.16 – 0.29	0.30 – 0.50	0.51+
K (%)	0.5 - 1.0	1.1 - 1.4	1.5 – 2.5	2.6 – 4.5	4.6+
Ca (%)	0.5 - 0.8	0.8 - 1.1	1.2 – 1.8	1.9 – 3.0	3.1+
Mg (%)	0.14	0.15 - 0.25	0.26 – 0.45	0.46 – 0.80	0.81+
Mn (ppm)	10 - 24	25 - 30	31 – 150	150 – 700	700+
Fe (ppm)	10 - 20	21 - 30	31 – 50	51 – 200	200+
Cu (ppm)	0 - 2	3 - 4	5 – 15	15 – 30	31+
B (ppm)	14 - 19	20 - 25	25 – 50	51 – 100	100+
Zn (ppm)	0 - 15	16 - 29	30 - 50	51 – 80	80+

[a] Values may differ among species for optimal growth. Values from leaves will vary significantly. For petioles taken between July 15 to August 15.

Source: Midwest Small Fruit Pest Management Handbook. Ohio State Bul. 861.

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ICCVE Activites

Missouri Viticultural Field Day

The ICCVE and the MGGA (Missouri Grape Growers Association) held the annual Missouri Viticultural Field Day at Crown Valley Winery in Ste Genevieve on June 3rd. Speakers included Dr Keith Striegler of the ICCVE, Dr. Wayne Wilcox, plant pathologist with Cornell University, Dr. Turner Sutton, plant pathologist North Carolina State University, and Mr. Jim Anderson of the Missouri Grape and Wine Board. Dr. Wilcox's presentation was on the biology and control of powdery and downy mildews. Dr. Sutton spoke on the control of summer bunch rot diseases. About 100 people turned out for the event which also included vendor exhibits and tours of the winery and the ICCVE's research plots at Crown Valley's vineyards.

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Multi-state Viticulture Field Day

The Multi-state Viticultural Field Day was held on Monday, July 28. Morning sessions were at Fahrmeier Brothers Farms near Lexington, MO and the afternoon sessions were held at Baltimore Bend Winery in Waverly, MO. Over 150 attendees from five states were on hand to hear presentations on vineyard establishment and management practices from viticulture extension personnel from Iowa State University, the University of Nebraska, and the ICCVE

Andy Allen

Upcoming Events

Southwest Center Field Day—September 12

The Southwest Research and Extension Center at Mount Vernon, MO will hold its annual Field Day on Friday, September 12. Along with the regular activities there will be a Special Field Day Tour focusing on viticulture and the new vineyard research plots at the Center. More information on the program and registration will be posted on the ICCVE website as it becomes available.

Midwest Grape and Wine Conference—February 7-9, 2009

The Midwest Grape and Wine Conference will again be held at the Tan-Tar-A Resort at Osage Beach, MO. The theme for next year's conference will be vineyard and winery sustainability. There will be advanced and introductory sessions in both viticulture and enology. Check http://www.missouriwine.org/ for details.