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Research Focus

Cornell Researchers Tackle Green Flavors in Red Wines

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Green flavors are undesirable in red wines, and winemakers strive to eliminate them. But these vegetable-like aromas and tastes can't often be removed in the winery. They come in with the fruit, and the traditional way growers minimize them is to delay harvest.

Recently, a team of Cornell researchers found that weather conditions and canopy management early in the season can dramatically influence the vine's production of one group of chemical compounds associated with green flavors, methoxypyrazines (MPs). Their results point to different ways - beyond extending 'hang time' - that growers can reduce MPs in the vineyard.

Gavin Sacks, assistant professor of enology in Cornell's Department of Food Science & Technology at the New York State Agricultural Experiment Station, became aware of the problem in 2004, when he worked at Shalestone Vineyards. There, his experience pulling leaves in the vineyard to increase fruit exposure to sunlight led directly to his research on MPs after he joined Cornell in 2006.

This effort has grown into a collaborative project with Cornell viticulturists Alan Lakso and Justine Vanden Heuvel, and thesis projects for Ph.D. candidates Imelda Ryona and Justin Scheiner. It is the first to examine in detail at what stage in the growing season MPs are produced and degraded, and how vineyard conditions and management practices influence the amount of MPs that persist in wines.

What are methoxypyrazines? Methoxypyrazines, though present in low concentrations (less than 50 parts per trillion), are compounds reported to be primarily responsible for green bell pepper characteristics, particularly in such Bordeaux cultivars as Cabernet Franc, Cabernet Sauvignon, and Merlot. The MPs considered

Gavin Sacks with analytical equipment (GC-MS or Gas Chromatograph-Mass Spectrometer) needed to measure low concentrations MPs.

Key Concepts

- Methoxypyrazines (MPs) are associated with green ' bell pepper' flavors
- MPs are present at low (parts per trillion) concentrations
- MP concentrations in grape clusters peak about one month after fruit set
- Cluster exposure to sunlight reduces MPs
- High shoot vigor is associated with high MPs
- Crop load explained 50% of the vineyard to vineyard variability in MPs in 2008
- Both overcropping and undercropping vines can increase MP concentrations.
- Early leaf removal and balanced cropping are keys to managing MPs

most important to wine flavor chemistry are isobutylmethoxypyrazine (IBMP) and, to a lesser extent, isopropylmethoxypyrazine (IPMP).

In an effort to reduce these unwanted flavors, wineries are increasingly extending their crops' "hang time"—that is, delaying harvest—hoping that MP levels (and vegetal flavors) diminish. But extended hang time has its drawbacks. Growers complain that the grapes dehydrate, and they lose significant tonnage while waiting for the delayed harvest. Sugar levels rise, resulting in higher alcohol levels in wines, along with overripe, cooked, jammy flavors and high pH levels. Furthermore, in our cool northeastern climate extended hang time is not often an option.

First identified in green bell peppers in the 1960s, MPs weren't studied extensively in wine grapes until analytical methods for these low-concentration compounds were developed in Australia in the 1980s. There, researchers found higher concentrations at veraison (start of fruit ripening) than at harvest–and notably higher levels in wines from cool-climate regions than warmer areas of Australia and New Zealand.

Sacks investigated the vineyard processes that influence MP *accumulation,* as well as their *degradation.* He reasoned that it may be possible to reduce MP levels early in the season, rather than extending hang time to wait for them to decrease.

"No one had followed the changes in MP levels throughout the growing season on shaded versus sun-exposed grape clusters," said Sacks. "We thought that we might find some interesting trends by measuring MP concentrations regularly from fruit set through harvest."

Seasonal Patterns of MPs. Sacks and graduate student Imelda Ryona sampled clusters weekly from fruit set to harvest in 2007 and 2008 to determine the seasonal pattern of MP accumulation and degradation in Cabernet franc. The sampling was done on both sunlight-exposed and shaded clusters to determine if sunlight exposure would affect accumulation or degradation.

They found that MP levels peaked about a month and a half after bloom then steadily declined through the rest of the growing season (Figure 1). Furthermore, MP levels were consistently lower in exposed fruit than in shaded fruit.

The effect of sunlight exposure, however, was dwarfed by differences between years. Peak accumulation in 2007 was about half of that observed in 2008, leading to the conclusion that factors other than cluster exposure were having a significant effect.

They suspected that weather differences–in particular, sunlight and moisture during the six weeks following bloom—were associated with the observed differences in MPs. The 2007 season was drier and sunnier during that period, while 2008 had more frequent rainfall and cloudier weather.

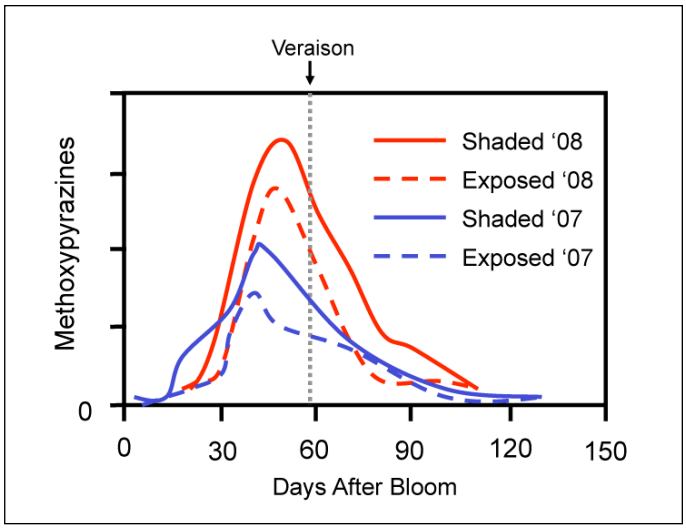

Figure 1. *Seasonal pattern of MP accumulation and degradation in a Cabernet Franc vineyard in 2007 and 2008. Shaded grape clusters had higher MP levels than sunlight-exposed clusters. Peak MPs in the dry 2007 season were about half of those during the wetter 2008 season.*

MPs at Veraison and Harvest. An additional survey of 13 vineyards in 2007 (Figure 2) showed that MP levels at veraison predicted levels of MPs at harvest ($R^2 = 94\%$). Sacks concluded that once the grapes had reached the post-veraison ripening phase, there was little that growers or winemakers could do to influence them beyond waiting long enough to harvest the grapes.

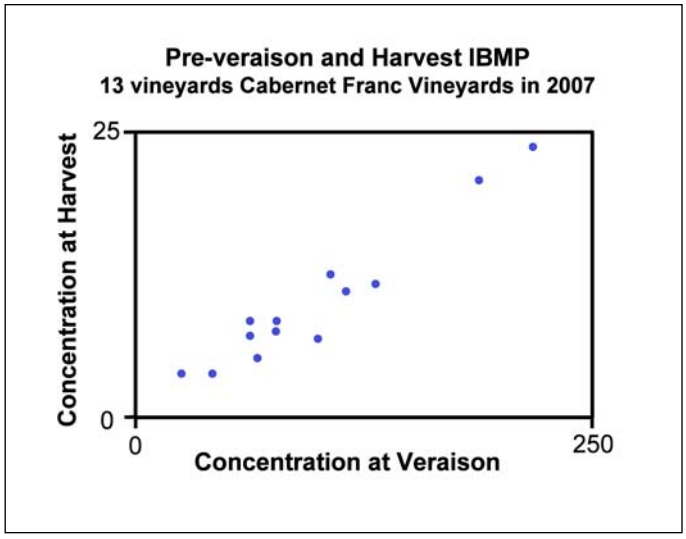

Figure 2. *MP concentrations around veraison and at harvest in 13 Cabernet Franc vineyards in 2007. Note that veraison concentrations (ppt) are 10-fold higher than concentrations at harvest.*

Rainfall and sunlight, of course, affect many different vine processes. More rainfall early in the season spurs more growth, which may lead to more shading in the fruit zone. The Cornell team set out to distinguish these different effects.

Shoot vigor and light exposure. Fruit physiologist Alan Lakso of the Department of Horticultural Sciences in Geneva designed an experiment (Figure 3) to separate the effects of sunlight and shoot vigor on MPs. He differentially pruned Cabernet Franc vines to produce individual shoots with a wide range of vigor. This is possible because leaving fewer buds at pruning results in faster growth of individual shoots (shoot vigor), while leaving more buds will result in slower growth. By maintaining full light exposure to these shoots, he was able to separate out the light effect from the vigor effect.

Figure 3. *Cabernet franc vines with differential pruning to produce shoots with differing amount of vigor, but constant light exposure. Vines pruned and shoot-thinned to six shoots (right side) and variable number of shoots (left side). By varying the number of extra shoots (left side), growth rate of the six count shoots (right side) was changed.*

Lakso found that the most vigorous shoots produced clusters with the highest concentrations of MPs, independent of light exposure. In other words, light and vigor acted independently in influencing MPs. Additionally, it appears excessive moisture during the most rapid MP accumulation period (mid-July to early August) correlates with higher shoot vigor and higher levels of MPs.

This observation matters for eastern growers, who have limited control over early season moisture because of frequent rains and often fight excess vigor. In contrast, managing vine growth by imposing water stress through regulated deficit irrigation is a common practice in dry western regions. Lakso's results suggest that imposing water stress also reduces MPs, which may account for some observed quality differences.

Canopy Management. A major focus of assistant professor of viticulture Justine Vanden Heuvel's program is the relationship between canopy management practices and wine quality. In 2007, she set up experiments to evaluate leaf removal and its impact on fruit characteristics in a commercial Cabernet Franc vineyard. She varied both the timing (early, late) and intensity (0%, 50%, 100% exposure) of leaf removal, and measured MPs and other quality indicators.

She found that leaf removal early in fruit development (within one month of fruit set) had the greatest potential to reduce MPs, and that removing just half of the leaves on the first five shoot nodes was enough to produce this effect.

Relative Importance of Different Variables. These studies set the stage for a different approach by grad student Justin Scheiner, who studies under Vanden Heuvel and Sacks**.**

Scheiner measured vine attributes at 10 different commercial Cabernet Franc vineyards across three regions of New York to determine which of the variables had the greatest influence on MPs. He made no attempt to impose specific standard practices on these vineyards, but sought to capture the variability at each site to determine the relative importance of the attributes in these vineyards.

Scheiner measured more than 100 variables, including assessments of vine growth and cropping level, canopy density, weather, water status, nutrition, and chemical composition of fruit. He then applied a statistical technique called partial least squares regression to determine which of these measurements were most closely associated with MP levels.

His work revealed that three factors—crop load, light exposure before veraison, and growing season temperatures—were most important in determining MPs at harvest.

Justin Scheiner making experimental Cabernet franc wines at Cornell's Vinification and Brewing Laboratory in Geneva, NY.

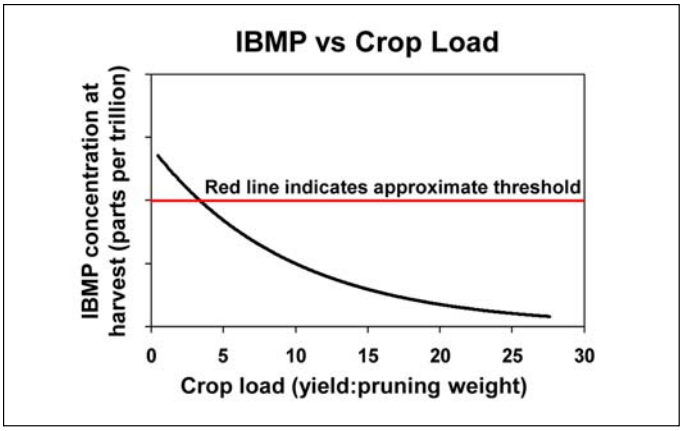

Figure 4. *Relationship of IBMP concentration at harvest to crop load (top) and yield (bottom) in 10 Cabernet Franc vineyards in 2008. Variation in crop load (yield to pruning weight ratio) accounted for more than 50% of the variation in MPs at harvest. There was no relationship between yield (up to 30 lb/vine) and MPs ($R^2 < 2\%$). MPs were individually measured in 8 vines in each of the 10 vineyards.*

By far, the most important was crop load, defined as the ratio of yield to vine pruning weight (Figure 4). This measure, commonly known in the viticulture world as the Ravaz Index, indicates how much leaf area a vine has in relation to the crop it carries. Large vines with more leaf area can ripen more fruit than small vines. Remarkably, this factor accounted for more than 50% of the variability in MPs.

Scheiner found the highest MP levels in vigorous vines carrying a light crop—that is, those with a low crop load. In those vineyards with a Ravaz Index of less than 5 (Figure 4), MPs at harvest exceeded the sensory threshold of 10 ppt. In contrast, yield had no relationship with MPs ($R^2 = 2\%$). High yielding vines with adequate vine size had just as low MP levels as small vines with a small crop.

Sunlight exposure (15%) and temperature (8%) explained additional variation in MPs. As in Ryona's experiment, more sunlight correlated with lower MPs, as did higher heat unit accumulations in the vineyard.

Scheiner plans extensive sensory evaluations of 2008 wines made from these 10 vineyards. They are aging in the Vinification and Brewing Laboratory in Geneva, and will be tasted this winter to confirm whether or not the lower MPs result in less vegetal wines. Scheiner will also analyze the data set from a repeat vineyard study during the 2009 growing season.

Future Directions. Sacks expects green flavors to be a continuing focus of his research in wine chemistry. "Wine is much more than just MPs, water, and ethanol," he said. "The MP concentration alone doesn't entirely predict the 'greenness' of a given wine, especially when MPs are right around the sensory threshold. There are dozens of aroma compounds in wines that could potentially contribute to vegetal aromas. We plan on looking at some of these and how they interact to influence wine characteristics."

The 2008 and 2009 Cabernet franc wines produced from Scheiner's study will provide a starting point for understanding how other aspects of wine composition affect green flavors.

Lakso plans to continue studying vine physiology and its impact on MPs and other flavor components. He wants to learn how variation in vigor and water stress impact fruit composition from vine-to-vine and to the individual shoot level. He believes an electronic water stress microsensor that can continuously monitor stem water potential, which is under development in his lab and others, will allow more precise measurements of this variable.

Management Implications. Minimizing green flavors is a significant goal for both small producers in eastern North America and large premium wineries on the West Coast. These recent studies at Cornell have highlighted the important roles that both weather and vineyard management play in influencing MPs that contribute to them.

"We have a lot of season-to-season variation in weather that strongly influences wine characteristics in our cool-climate region," said Tim Martinson, statewide viticulture extension associate. "These studies have underscored the role of sunlight, rainfall, and heat in influencing MPs, and provide insights that will help growers and winemakers understand this variability."

These studies identified a specific window of time—four to six weeks after bloom—as a particularly critical time for MP accumulation. During this period, weather, shoot vigor, and crop load are important variables that act together and independently to influence MP levels. This knowledge points to measures growers and wineries can take beyond extending hang time to reduce MPs and green flavors.

Leaf removal in the four weeks following fruit set is one practice that can reduce MP accumulations. Growers can't do anything about ambient temperatures, but they can influence sunlight exposure to fruit by thinning shoots or removing leaves that shade the clusters.

Apparently, the most effective practice to reduce MPs is to make sure that vines are carrying the right amount of crop, matched with their inherent vigor level and vine size. In short, balanced cropping may be the most important practice for reducing MPs. Undercropping vines can be as damaging as overcropping them.

These results will benefit many growers in the Finger Lakes as they realize the importance of scheduling leaf

removal right after fruit set, rather than waiting until mid-season. More precise timing will pay off in increased fruit quality and uniformity.

This collaborative research effort will pay dividends to growers particularly in cool-climate regions, where frost or rainfall often ends the growing season and extended hang time is not a viable option. By focusing on balanced cropping and early-season leaf removal to increase sunlight exposure, growers can moderate MPs to the greatest extent possible. The result should be more consistent, higher-quality red wines.

References

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