Northern Grapes News

September 2, 2014 Vol 3, Issue 3

Northern Grape-omics:
The Fruit Composition Team is Unraveling Grape Flavors

Jim Luby, University of Minnesota

A tantalizing glimpse of the future for grape breeding was provided for me at a February 2014 meeting of the *Northern Grapes Project* Fruit Composition team. We are rapidly approaching a time when a grape breeder will send a bit of leaf tissue from a seedling to a DNA testing lab and, based on its DNA profile, predict whether it is likely to produce fruit that makes wine with good flavor and aroma character – or something far worse!

Grape breeders have long sought to select for chemical compounds that contribute to desirable flavor and aroma in the grape and against chemicals that can produce undesirable flavors. Selection based on DNA markers for these chemicals would be even better. We could then cull the less desirable seedlings from our crosses without having to invest the time and resources to grow them to fruiting.

Some of these flavor compounds are known from previous research on *Vitis vinifera* and V. *labrusca* cultivars. Many compounds have been associated with fruit for floral flavors: methyl anthranilate, a major component of "foxy" flavor from Concord and other *V. labrusca* cultivars; benzaldehyde, which gives cherry or almond flavor; and gamma decalactone for peachy flavor. Other compounds are responsible for vegetative flavors such as hexenal for fresh cut grass or leaf flavor, and methoxypyrazines for the green flavors of Sauvignon blanc and bell pepper flavors of Cabernet Sauvignon. The flavors of cold climate grapes and wines, however, have not been comprehensively studied.

Several recent advances in chemistry, biology and information technology available to the *NGP* Fruit Composition team are getting us closer:

1. Genomics - We know the grape genome or genetic code, which is the sequence of DNA on the 19 chromosome pairs of grape and partial knowledge of the 30,000+ genes it encodes;
2. Transcriptomics - We can know when and where during berry ripening that specific genes in metabolic pathways related to flavor and color are turned on and off by looking at the levels their message, or transcript, that is present in the plant;
3. Metabolomics - We can quantify and identify flavor- or color-related chemical compounds (metabolites) made by grape berry metabolism;
4. Bioinformatics - We can manage, analyze and make sense of all this information thanks to fast, powerful computing and inexpensive data storage.

The Fruit Composition Team is employing these technologies to answer several questions in popular cold climate cultivars, which should get us to the point of using DNA markers for selection in cold hardy grape breeding.

The process starts in a research vineyard at South Dakota State University (Fig. 1) where Dr. Anne Fennell collects berries at six different ripening stages from the green pre-veraison stage up to the very ripe stage of 26° Brix (Fig. 2). She splits each sample, saving some berries for her own analyses and sending subsets to labs at Iowa State University and the University of Minnesota for chemical and sensory analyses.

Fig. 1. Research vineyard at South Dakota State University

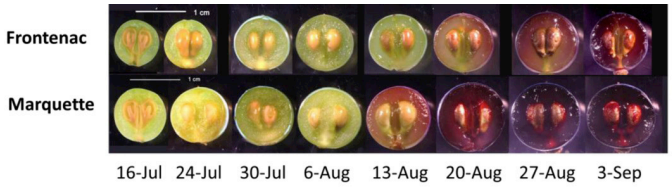


Fig. 2. Frontenac and Marquette grape berries at different stages of ripeness.

What genes are expressed at different stages in the developing and ripening berry?

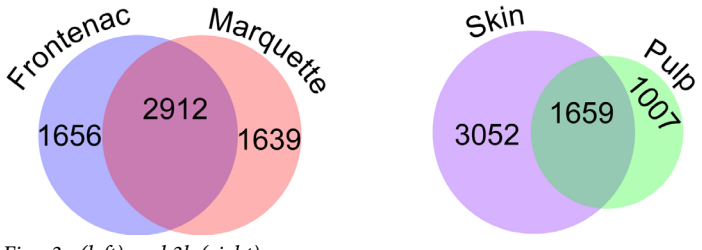
Each cell of a grapevine contains DNA with some 30,000 genes that coordinate all its processes such as growth, flowering, fruit ripening, senescence, cane ripening, dormancy and many others. The first step in the process of making enzymes for grape metabolism is to make an RNA message, or transcript, from a gene. Techniques developed in the last decade allow us to collect and differentiate among the thousands of RNA types found in a plant tissue at the time of sampling.

Of the 30,000 genes in grape, some are expressed, or turned on, all the time and in every part of the plant to perform basic life functions, while others are specific to certain functions and/or tissues. For example, genes involved in photosynthesis will only be turned on in leaves and other green tissue of the plant. Of greatest interest in flavor development are RNA messages from genes that are turned on or off, or expressed at higher or lower levels, during the final few weeks of berry ripening when most of the flavor chemicals are produced.

Dr. Fennell can determine if a gene is turned on or off in the fruit by looking for the RNA transcript produced from that gene. Since previous research has shown that many of the interesting flavor compounds are found in the skin, her team separates skin from pulp at each harvest date and extracts RNA from each. She then identifies and quantifies each type of RNA representing each gene that is turned on at that time.

Figure 3a shows an example of how cultivars can express genes differently. Dr. Fennell found that Marquette and Frontenac both expressed the same 2912 genes in skin or pulp but each expressed over 1600 unique genes that might give us a clue to the flavor and color differences between them.

Figure 3b shows how gene expression differs between skin and pulp. Although the skin and pulp had 1659 genes in common, they differed for over 4000 other genes. As expected, the skin, which contains many more compounds, also has many more active genes.



Figs. 3a (left) and 3b (right).

Thanks to previous research showing how genes work with one another in key flavor, color and tannin pathways, Dr. Fennell and her colleagues can sort among these many RNAs to find the few that are candidates to be associated with differences in flavor, color and tannin levels in the berry.

What flavor compounds are produced in the berries – when and where?

Berry samples from the harvests at 22, 24 and 26° Brix are sent to Dr. Zata Vickers and graduate researcher Emily Del Bel at the University of Minnesota Sensory Center, where trained sensory panelists describe flavors they detect in the berry pulp and flesh at each harvest date. Figure 4 shows how panelists detected differing flavors as the berries ripened.

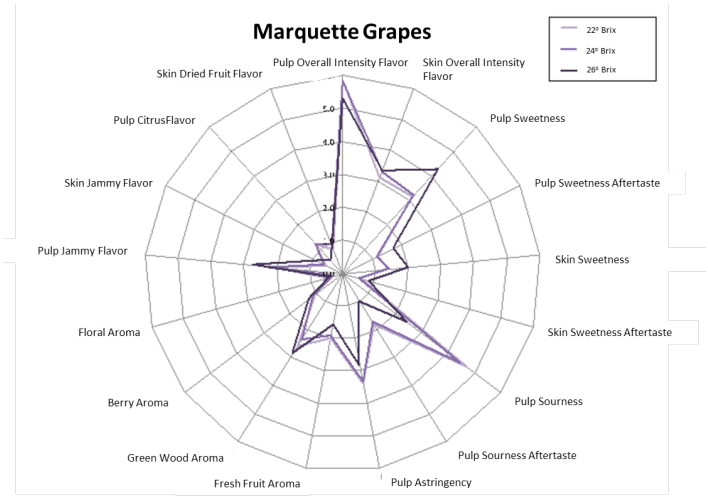


Fig. 4.

What sensory descriptors develop in concert with the flavor compounds?

At Iowa State University, Dr. Jacek Koziel and graduate researcher Somchai Rice also receive a sample from each harvest to identify and quantify volatile, or aromatic, compounds present. They use an analysis called gas chromatography-olfactometry. A sample of the aroma is captured and injected into the gas chromatograph machine, which separates each chemical component of the aroma and identifies them in concert with another machine, a mass spectrometer. As each component passes through the machine, a portion is shunted to a port where a trained panelist indicates whenever he or she smells a compound and describes what it smells like (Fig. 5).

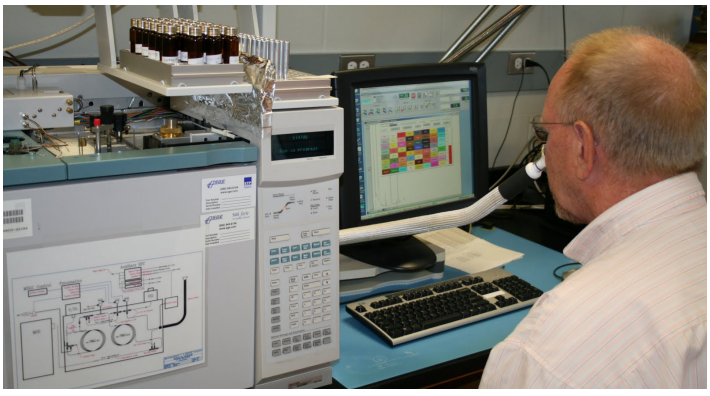


Fig. 5.

The results of gas chromatography-olfactometry are shown in Figure 6. The peaks of the red line indicate the relative amounts of each compound detected by the chromatograph while the peaks of the black line indicate when the human panelist detected an odor and the relative strength of the odor. Some compounds are present in very small amounts (short red peaks) but may give very strong odors (tall black peaks), while other compounds may be present in large amounts but have little or no odor impact.

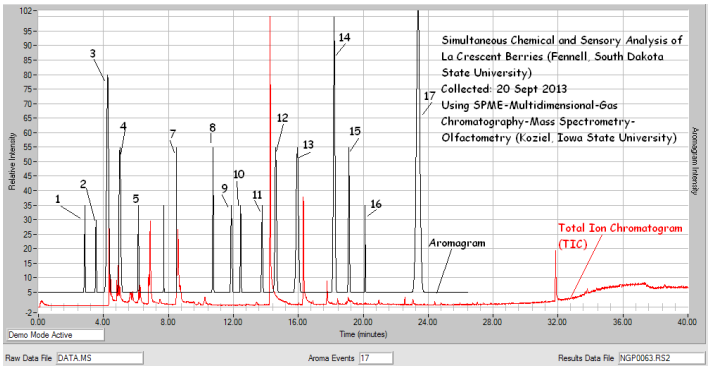


Fig. 6.

How do flavor compounds and sensory descriptors correlate with grape gene expression?

Knowing *where* in the berry and *when* during ripening that flavor compounds are detected by our sensory panelists or the chromatograph, we can then go to our RNA transcriptome data. Our goal is to identify genes associated with the production of those flavor compounds in the appropriate berry tissue that were turned on or off at the right time. We are greatly enabled by previous research by Dr. Fennell and other grape genomics researchers that described the identity and putative function of many of the genes in the grape genome. This information is available in a database that can be queried using Dr. Fennell's RNA transcriptome data. Matching our RNA sequences to the DNA sequence in the grape genome should identify what we call "candidate genes" - candidates for explaining the varying levels of flavor compounds.

Is variation for these genes associated with differences in flavor in segregating populations?

For a breeder, having candidate genes is a key step to being able to do DNA marker informed breeding. At this point, we have only studied the flavor compounds in a few cultivars. Next, we need to confirm the association of candidate genes with differences in flavor compounds in our breeding populations. This is where we rely on resources being developed by another USDA-SCRI initiative – the VitisGen project (see *Northern Grapes News* Vol. 2 Issue 1) which is developing DNA markers across the entire grape genome. We will screen our breeding populations for markers next to our candidate genes and also for the selected flavor compound. If one or more candidate genes are associated with variation for the flavor compound, these markers can be used to inform breeders in future crosses. We can be smarter in our choice of parents and culling of seedlings based on sampling the DNA from a little bit of leaf tissue. The result should be better flavor profiles, resulting in better tasting wine, in future cold hardy grape cultivars.

Understanding the Travel Behaviors of Wine Tourists in Michigan's Leelanau Peninsula

Dan McCole, Don Holecek, and Leanna Popp, Michigan State University

In recent years, many rural areas have embraced wine tourism as a way of generating economic activity, and, in some cases, reviving their communities. Emerging wine areas throughout the northern U.S. have proven successful at attracting new tourists, and their dollars, to rural areas. Despite the positive economic activity that wine tourism brings, some community members in wine regions have concerns about the demands on existing infrastructure. Moreover, wineries and other tourism leaders in emerging wine regions usually don't know the full extent of their visitors' travel patterns, and might benefit from a more thorough understanding of the travel behaviors of visitors to the region. What routes are they taking to get to the wineries? How many stops do they typically make? What other attractions besides wineries are people visiting? Such information about tourists' itineraries can help wine tourism stakeholders better understand the extent to which visitors view a region as offering an appealing menu of compatible attractions. A more thorough knowledge of tourists' behaviors can help the tourism industry to better collaborate, craft marketing and promotional plans, and, ultimately, provide better experiences to visitors. Moreover, knowledge of how tourists move throughout a region can help tourism planners and local policymakers make informed decisions about infrastructure development.

Study design. As part of the studies conducted to learn more about tasting room visitors, one of the objectives of the *Northern Grapes Project*, researchers at Michigan State University intercepted tasting room visitors in Michigan's Leelanau Peninsula and provided them with map of the region (on which they were asked to indicate their routes taken and

stops made), a survey, and a return envelope. In addition to demographic questions, the survey complemented the data from the maps by asking questions about topics such as trip planning resources, planned and unplanned stops, reasons for travel and group composition.

Although the Leelanau Peninsula has long produced wines, the past decade has brought tremendous change to the region, which went from just a handful of wineries in 2000 to over 25 today (with more expected in the coming years). The increase in the number of wineries has resulted in a growing number of wine tourists traveling through the area, and has seen an increase in the impact of these tourists on its infrastructure.

A total of 227 participants were intercepted and 218 of those agreed to participate. Completed questionnaires were received from 110 participants – a response rate of 50.5%. The itineraries from each map were aggregated using GIS to create itinerary maps that reflect a variety of variables including travel routes, total number of stops, visits to wineries, visits to towns, and visits to other attractions.

Results. These results will act as a baseline for any future studies in this region and as a comparison point for other regions. The average number of total stops for the participants was 6.68 (Table 1). Winery visits accounted for 3.91 of these, towns accounted for 2.09 visits, and other attractions accounted for less than one per each trip (0.58). This data confirms that visitors go to the Leelanau Peninsula for multi-destination travel, rather than just stopping at one winery and leaving the area, and that although attracted by the wineries, most visitors stop at other places besides wineries, generating economic activity to other businesses in the area. Tourist itinerary routes were compiled from the map-diaries.

Table 1. Average number of stops in itineraries.

Location	Minimum	Maximum	Mean
Wineries	1	15	3.91
Towns	0	10	2.09
Other attractions	0	4	0.58
Total stops	1	17	6.68

Frequency of road travel and stops were tabulated in order to produce a graduated symbols road map of the county. The roads travelled on by participants are illustrated in Figure 1, where the thickness of the line increases with number of uses. This map also shows the proportional symbols of stops at wineries, towns and other attractions.

The data indicated that 78% of visitors spent at least some time researching their destination prior to traveling and 45% reported spending "a lot" of time planning their trip.

Despite this high level of pre-trip planning, however, 61% of respondents visited wineries they had not planned to visit before traveling for the day. These unplanned stops at wineries were primarily triggered by being in close proximity to another stop on the trip, seeing a sign or passing the winery during travel (Table 2).

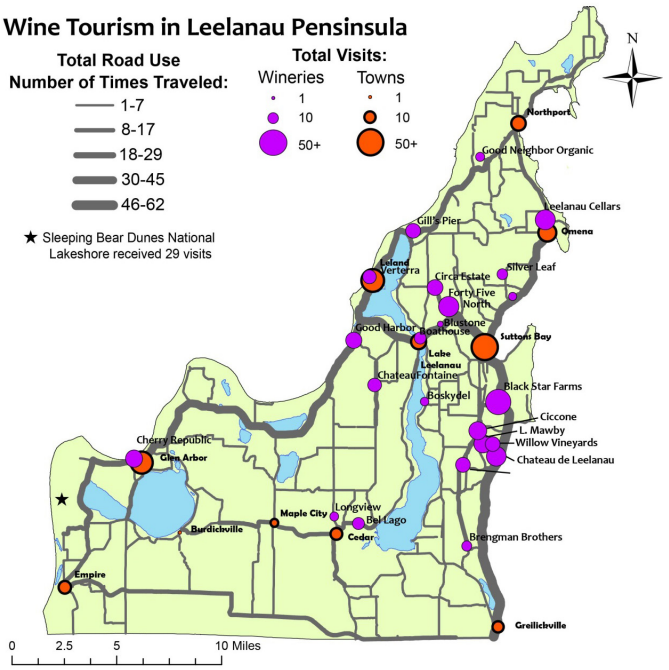


Fig. 1.

Table 2. Reasons for unplanned stops at wineries.

Item	Mean*
Close proximity to another stop	4.07
Signs (road, other)	3.56
Passed during travel	3.47
Read about it	2.50
Recognized the name	2.43
Recommendation from someone else	2.04
Recommendation from another winery	1.42

**Means are basedon a 5-point Likert scale. 1 = No impact, 5 = A great deal of impact*

Another interesting finding from the survey involves how tourists find information about wineries while traveling. Tourism brochures (56.4%), wine trail information (45.5%), and roadside signage (44.5%) were the information sources that were used most often by wine tourists to plan their trips during their travels (Table 3). Results showed that wine trail information was the primary information source for those who made the highest average number of winery visits, suggesting that wine trail guides can help increase the number of stops wine tourists make when touring a region.

The data suggests the majority of participants (52%) indicated they spent only one day visiting wineries, while another 43% visited wineries on two or three separate days during their trip to the area. The remaining 5% visited wineries on more than three days. When not at wineries, participants indicated they participated in activities including sightseeing (80%), visiting the beach (56%), fine dining (52%), retail shopping (66%) or visiting a national/state/local park or

Table 3. Information sources used during the trip and the number of wineries visited.

Information source	Percent*	Mean winery visits
Brochures/Maps	56.4%	4.3
Wine trail information	45.5%	5.2
Roadside sinage	44.5%	4.4
GPS	26.4%	3.9
Mobile application/Smartphone	14.5%	4.1
Recommendation from others	13.6%	3.7
Internet	11.8%	3.8
Guidebook	9.1%	4.3
None	7.3%	2.3
Other	4.5%	4.2

**Percentages total more than 100% because respondents were able to select "all that apply."*

lakeshore (55%). Less than half of the respondents reported visiting friends/relatives (35%), visiting a gallery/art studio (30%), hiking (26%), visiting a site of historical or cultural significance (28%), visiting specialty food shops (41%) or going to a casino (9%).

Conclusions. For decades, tourism researchers have referred to the "gravity effect" in tourism, in which a large attraction draws more people than a small attraction in the same way a large planet has a stronger gravitational pull than a smaller planet. However, there is growing evidence that regions that offer a number of smaller attractions can be just as appealing to tourists as ones with few large attractions, in the same way as a group of stars can have greater gravitational pull than a single large star. Multi-destination trips are becoming more popular, and wine tourism is well suited to take advantage of this trend. Tourists typically seek to satisfy a number of desires, and multi-destination travel is able to satisfy many of them especially when the travel involves groups of people with varying interests. To the traveller, a multi-destination trip reduces the risk of disappointment by offering choices. Additionally, tourists have an economic incentive to choose multi-destination trips as they can save time and money compared to making several different trips. Wine tourism is particularly appealing form of multi-destination travel as it tends to offer both similar attractions (a number of different wineries) and complementary attractions (fine dining, cheese shops, shopping, art galleries, etc.). This research shows that people indeed tend to make multiple stops when traveling in a wine region. Moreover, the findings indicate that although most people spend time planning their trips in advance, unplanned stops are common and can be influenced by promotional materials and signage.

Finally, when we presented the results of this study to the area wineries, many were surprised to learn that visitors tended to take different (and less direct) routes than local residents. This was a reminder that people traveling for leisure are often more interested in sightseeing and exploration than they are in taking the quickest route. This finding has important implications for decisions about signage, and can serve as a useful reminder to winery employees given directions and recommendations. Previous research, (see previous issues of *Northern Grapes News*) has shown that leisure reasons (e.g., spending time with friends and family or doing something unique) are greater motivators for visiting wineries than wine reasons (e.g., learning more about wine or purchasing wine). Moreover, other research has shown that a person's environment and mood can impact their enjoyment of wine. For these reasons, it is in the best interest of leaders in wine tourism regions to use the findings from this study to improve the overall trip experience for visitors.

Northern Grapes & NE1020 Cultivar Tasting

Anna Katharine Mansfield, Cornell University

One of the most popular enology segments of the Northern Grapes Project is the cross-regional yeast trial, which tests the impact of selected yeast strains on wines produced from key cold-hardy wine grapes grown in Minnesota, Vermont, and New York. In addition to extensive instrumental analyses, these wines are intended for sensory use, allowing wine producers to experience the sensory differences arising from yeast strain. On July 17, 26 growers and winemakers from across the northeast gathered in Burlington, Vermont to taste through nine flights of Prairie Star, La Crescent, Frontenac gris, Frontenac, Marquette, and St. Croix produced using three different yeast strains. For most cultivars, there was no clear favorite yeast across regions, suggesting that winemakers in cold climates, like those in any other, need to adapt their wine production methods to compliment their local microclimate and clientele. Detailed analyses of the wines, both sensory and chemical, will be presented in future publications.

NGP Team Profile: Tim Martinson

Tim is a Senior Extension Associate at Cornell University and leads the statewide viticulture extension program. He is the Project Director of the Northern Grapes Project and therefore has oversight of the entire project. He also conducts research on training systems and crop load, and leads the effort to understand performance of cultivars in varying climates.

1. Tell us how the idea for the Northern Grapes Project was generated.
I went to the Unified Symposium in Sacramento in January 2009 and had lunch with Murli Dharmadhikari. We started talking about how the Iowa winery industry had grown so much since 2000, with the same story in other Midwestern and Northeastern states. I mentioned that this represented a terrific return on investment for the money allocated to Jim Luby's breeding program at the University of Minnesota. From there, it was easy to come up with the basic concept: New grape cultivars have created a new industry in cold-climate areas. To maximize these cultivars' potential, coordinated research and extension in growing, vinification, and marketing grapes is needed. Successful wineries will foster rural economic development.

In 2009, we put this into a planning grant that the SCRI funded, and through two sessions in Vermont and Minnesota, brought researchers and industry representatives together to assess needs and interests. The Northern Grapes Project came directly out of those meetings.

2. You grew up in Northeast Iowa – how did you find your way to New York and your career in viticulture extension?
It was a long and winding path. I left Iowa for the University of Idaho, where I completed my B. S. in Plant Protection. After a year back in Iowa working with the Natural Resources Conservation Service, I joined the Peace Corps and ended up teaching Entomology at an agricultural school in Honduras. I then came to Cornell, and started an MS/PhD program in Entomology. After receiving my degree, I spent five years as a research associate working with grape insect pest management, starting in the early 90s. In late 1996, Cooperative Extension had an opening with the Finger Lakes Grape Program, and I started my extension career in what is perhaps the best extension job in New York.

3. As you've lived and worked in the Finger Lakes wine region of New York for almost 30 years now, you've had the opportunity to see vineyard and winery operations open their doors and "make it" as successful businesses. What's one piece of advice you can give to our readers, many of whom are just starting out, that you've learned by watching this?
Collaborate with your neighbors. The best growers and wineries freely share information and knowledge and are constantly looking for ways they can be more efficient at producing quality grapes and wines. Most winery owners in the Finger Lakes started out as grape growers – and had to learn winemaking and retail management skills when they opened wineries following the consolidation of major processors in the mid 1980s. They didn't have a lot of capital but they did have a community of fellow growers and wineries to draw upon. The collaborative culture among winemakers and growers has contributed greatly to the regions' success.

4. What do you enjoy most about getting to work with the grape and wine industry?
The best part of working with the industry is the growers I've worked with over the years. I've been setting up research trials in commercial vineyards since I worked with eastern grape leafhopper control in the early 90s. I've found growers to be receptive to on-farm research, and their ideas are often incorporated in the projects we do.

I believe in the application of science to agriculture, and the whole grape and wine production system offers so many different ways to apply science to making great products. The great thing about Cornell is that we have diverse research and extension programs that can address these different areas.

5. In your opinion, what is the most exciting research-based information that will come out of the *Northern Grapes Project?*
Overall, I hope our project will save northern grape and wine producers years of trial-and-error in developing best practices for growing the grapes, making wine, and marketing it. In the vineyard, we know the basic principles; it's just a matter of applying them in a cost-effective way to produce the quality that wineries need. But the winemaking practices are really key. Choice of yeast, vinification protocols and deacidification methods all influence what kinds of wines are made and wine styles that fit the cultivars and are pleasing to consumers. Over the longer term, the genomics–to–sensory work that Anne Fennell, Jacek Koziel, Adrian Hegeman, and Zata Vickers are doing is cutting-edge science that will link genetics to gene expression to flavor components – and provide breeders like Jim Luby and Peter Hemstad tools to select grape seedlings for specific flavors and aromas.

NGP Team Profile: Chrislyn Particka

Chrislyn is an Extension Support Specialist at Cornell University and is the Project Manager of the Northern Grapes Project. In addition to these responsibilities, she also assists with the vineyard management research being conducted at Coytoe Moon Vineyards in Clayton, NY, and assists with research and extension outside of the Northern Grapes Project on occassion.

1. You have a PhD in Horticulture/Plant Breeding and Genetics and industry experience. What did you do before you came to Cornell?

My career in horticulture started when I was 13 - my family moved from Indiana to northwest Arkansas and purchased a four-acre blueberry farm. We later added blackberries, red raspberries, apples, and Asian pears. Curt Rom (a professor in the Department of Horticulture at the University of Arkansas) easily persuaded me to major in horticulture; I earned my BS and MS at the U of A and then went to Michigan State for my PhD. After finishing my PhD, I took a job with Sakuma Bros. (one of the largest berry growers, processors, and nurseries in Washington State) as their research director. After five years there, my husband's job brought us to the Finger Lakes area of New York, and I found this job as Project Manager of the Northern Grapes Project.

2. What does the *Northern Grapes Project* Manager do?

The bulk of my job centers around the *Northern Grapes Project* extensive outreach. I publish this newsletter, coordinate the webinar series and act as moderator during webinars, design and update the website, write the *News You Can Use* series, and put together the yearly public progress reports. I also handle the project reporting that is required by the USDA, assist with some of the financial management of the project, and keep the lines of communication open among team members – with 30 Co-PIs/collaborators on the project, it can really add up! I also communicate with our Advisory Committee when necessary.

3. What have you learned about grapes and wine that interested you?

I think that I've really come to truly appreciate how intensively managed grapes are. All fruit crops require a lot of management in comparison to, say, soybeans, but grapes require even more time than the berry crops that I have a lot of experience with! As for wine, I've learned how many different things can influence the flavor of a wine. One day not long after I started working at Cornell, I joined in on a tour of some of the Finger Lakes wineries, and was treated to a barrel tasting of different Rieslings with Peter Bell, the winemaker at Fox Run Vineyards. One thing we did was to taste wines made with grapes from the same vineyard, but different yeasts. I was (and still quite am) a wine novice, so it was astounding to me to taste the incredible difference in flavor that different yeasts can produce.

4. Where do you think this experience might take you next?

When I started my PhD program, I figured I'd end up in a tenure-track research/extension/teaching (or some combination thereof) fruit crops position at a university. However, after I graduated, I went into industry instead and in the five years I was there, I realized that a tenure-track position really wasn't for me. While I certainly never thought I'd end up as a grant manager (or even realized that it could be a job), I've found that it is a great fit. I really enjoy being back in the university setting, but I don't have the stress and time requirements that a tenure-track professor does – because I have two young kids, this is pretty ideal. So my hope is that I can make a career out of grant management. I think it'll be fun to work on a lot of different big grants like the *Northern Grapes Project*, because I'll get to learn more about different areas of agriculture in the process.

5. In your opinion, what is the most exciting research-based information that will come out of the *Northern Grapes Project?*

Because I have such a strong personal interest in horticulture, I'm most excited to see the results from the various vineyard management practice studies. I'm interested in seeing which training methods produce the best grapes, and if there's any continuity among the different locations that are doing these studies. However, like others have said, I'm also excited about the project as a whole, and the positive impact that I hope it'll have on the Northern Grapes industry – I don't think the project would be nearly as effective if any of the parts were removed.

Training Systems for Grapevines

Paul Domoto, Professor Emeritus, Iowa State University

There are many training systems that have been developed for grapevines. They can be grouped in a variety of ways, such as whether the vines are pruned to long canes as in kniffin/head systems or to 2- to 5-node spurs as in a cordon system; if the shoots are allowed to grow downward from a high trellis wire, or if catch-wires are used to vertically position the shoots (VSP); and whether the vines are trained to a single, double or split curtain. In selecting a training system for cold hardy grapevines, one needs to consider:

- Cold hardiness of the cultivar relative to the local climatic conditions.
- Growth habit of the cultivar.
- Vigor of the cultivar and vineyard fertility.
- Cost of the trellis system.
- Annual cultural requirements for maintaining the vines under each of the systems.

If any one of these factors is not taken into account, the vineyard can become uneconomical due to additional labor expenses, low productivity, and/or poor fruit quality.

Frontenac grapevines trained (from left to right) high-wire cordon, mid-wire cordon with VSP, Geneva double curtain, and Smart Dyson in the Iowa Northern Grapes training system trial.

Cold hardiness. If a cultivar is considered marginally cold hardy for your climatic conditions, it is often better to select a cane-pruned head system rather than a spur-pruned cordon system. In a head-pruned system, the fruit bearing area (canes) is replaced each year. Whereas along a cordon, cold injury induced "blind" areas can develop that reduce the production potential.

Blind nodes along a cordon.

Growth habit. The orientation of the shoots developing from a cane or spur can be rather upright, as with most *Vitis vinifera* cultivars, to trailing (procumbent) for most American species. The growth habit of our cold-hardy interspecific hybrid cultivars, which are based on *V. riparia,* can range from semi-upright to procumbent. It is much easier to train an upright or semi-upright cultivar to a VSP system than a procumbent cultivar. Procumbent and semi-procumbent cultivars can be trained to a VSP, but much more labor will be required. A Review of Cold Climate Grape Cultivars includes the growth habit of 73 cultivars.

Upright (left) vs. procument (right) growth habit.

Vine vigor. Most cold-hardy interspecific hybrid cultivars are vigorous to very vigorous in stature and can easily produce pruning weights in excess of four pounds in fertile soil. This vigor has to be considered in selecting a training system and vine spacing in the row. VSP training systems were developed for *V. vinifera* cultivars that exhibit moderate vigor. When VSP is used for vigorous northern hybrid cultivars, additional in-row spacing, catch-wire extensions, or split/divided canopy training may be required. On high-wire trellis systems, high vine vigor is often accommodated by increasing the in-row spacing or using the Geneva double curtain system.

Catch-wire extension (left) and split canopy training system (Smart- Dyson).

Cost of the trellis system. The basic essentials for a trellis system are the end posts, line posts and trellis wire. The difference in cost between various trellis systems is determined by the number of wires per row and any additional supports. A typical high-wire cordon system will

have two wires – one for the cordon and a mid-level wire to aid in supporting the trunk. VSP system will often have three or more sets of catch-wires and the possible need for post extensions. Cross arms for the Geneva double curtain and complex twin VSP supports for the Lyre system substantially add to the cost of establishment.

Geneva double curtain (left) and Lyre (right) support structures.

Annual cultural requirements. Grapevines under any of the various training systems require annual cultural practices to optimize fruit quality. However, the amount of time required and number of times a practice needs to be performed will vary between training system and the vigor of the vines.

- **Shoot thinning.** Pre-bloom shoot thinning is performed to remove non-count shoots. These could be from multiple shoots emerging from a node, and adventitious (basal) shoots developing along a cordon at the base of spurs and renewal spurs. Vines trained to a head system with long canes have fewer basal shoots, which are confined to the head, while on a cordon system, basal shoots can develop at every node along the cordon.

Non-count shoots on a cordon and spur.

- **Shoot positioning.** Shoot positioning (combing) is practiced on high-wire training systems to improve light distribution within the fruiting zone. With single curtain systems it is typically performed once a season between bloom and veraison. On Geneva double curtain, it often needs to be performed twice to keep the area between the curtains open. On VSP systems, shoot positioning or tucking the shoots between the catch-wires may need to be performed three or more times during the growing season. Using movable catch-wires can shorten the time required to perform the practice.

Shoot positioning on a high-wire cordon (left), tucking shoots on VSP, and using movable catch wires on VSP (right).

- **Lateral shoot removal.** Removing lateral (axillary) shoots is the fruiting zone may also be necessary, but need to do it is more dependent upon the cultivar and vine vigor than on the training system.

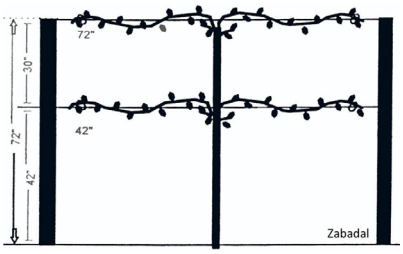
Other considerations in selecting a training system. For large vineyards, another consideration is how adaptable the system is to mechanization. Machinery is available for dormant pruning and summer hedging, shoot positioning, leaf pulling, and harvesting.

The following illustrates various grapevine training systems and lists some of the advantages and disadvantages of each.

Systems for Trailing (Procumbent) Growth Habit

<u>Head (Long Cane) Training Systems:</u>

4 and 6-cane Kniffin:



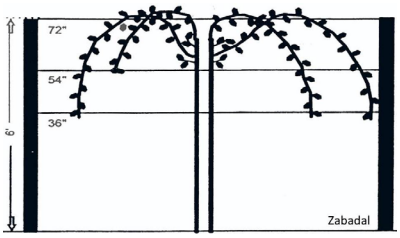
Advantages:

- Ease of pruning to long canes.
- Vertical distribution of fruit.
- Better tolerates winter injury than cordon systems.

Disadvantages:

- Requires annual tying of canes.
- Difficult to maintain quality on lower wires (shading).
- Not compatible with systematic leaf removal & shoot positioning.

Umbrella Kniffin:



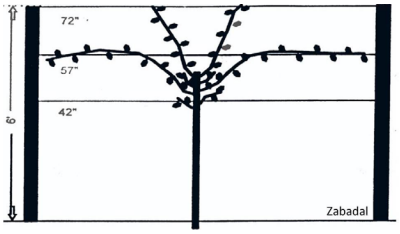
Advantages:

- Easy to learn system.
- Fruit high, distributed, and well exposed.
- Simple trellis construction.

Disadvantages:

- Requires of annual tying of canes.
- Less adaptable to shoot positioning.

Keuka High Renewal:

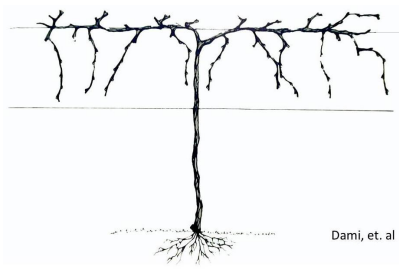


Advantages:
- Easy to replace vine parts due to winter injury.

Disadvantages:
- Requires of annual tying of canes.
- Difficult for inexperienced pruners.
- Not adaptable to leaf removal & shoot positioning.

Cordon Systems:

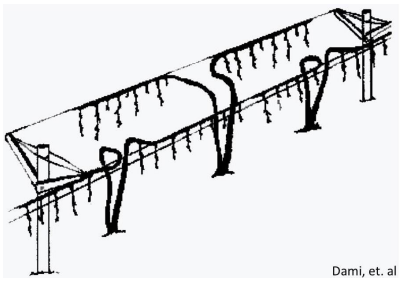
Single Curtain Bi-lateral Cordon (High Trellis):



Advantages:
- Adaptable to mechanical pruning and shoot positioning, and unskilled manual pruning
- Fruit are high for good sun exposure.
- Requires little annual tying.

Disadvantages:
- Can reduce vine vigor, especially if shoots are positioned.
- Difficult to establish cordons with frequent winter injury.
- Old cordons hard to remove from wires.
- Old cordons may become a reservoir for diseases.

Geneva Double Curtain:



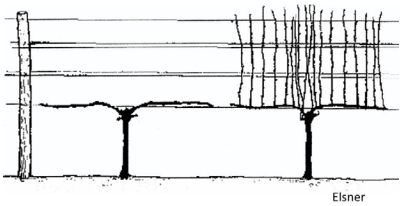
Advantages:
- Good method to handle high vigor vines.

Disadvantages:
- Requires additional labor to shoot position.
- Cost of the cross arms.

Systems for Upright/Semi-upright Growth Habits

Head (long cane) Systems:

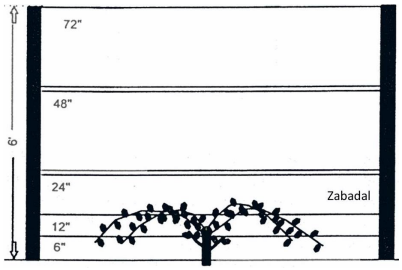
Guyot:



Advantages:
- Fruit can be situated low to ground to benefit from radiant heat.
- Minimal vine structure makes it easy to cope with winter injury.
- Long canes retain more fruitful nodes.
- Can be converted to a mid-wire cordon system.

Disadvantages:
- Difficulty in pruning & harvesting if low to ground.
- Possible congested fruit zone.
- Greater risk of spring freeze injury.

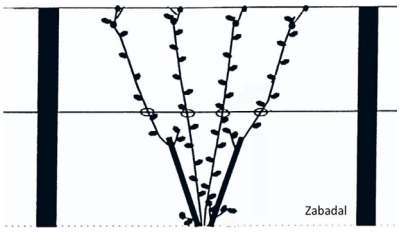
Pendlebogen:



Advantages:
- All the benefits of Guyot, plus….
- Arching of canes creates better vertical distribution of fruit on the trellis.
- Relatively few ties per vine.
- Can be spur pruned for next 1-2 years.
- Can bury canes for winter protection.

Disadvantages:
- More challenging if fruiting wires are low to the ground.

Fan:

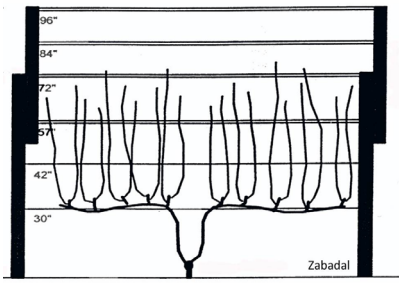


Advantages:
- Maximum flexibility to adjust to frequent winter injury.
- Minimal retention of permanent vine parts.
- Easy to learn.
- Can bury canes for winter protection.

Disadvantages:
- Requires annual tying of canes.
- Not adaptable to systematic shoot positioning or leaf removal.
- Fruit can be hard to find and harvest.

Cordon Systems:

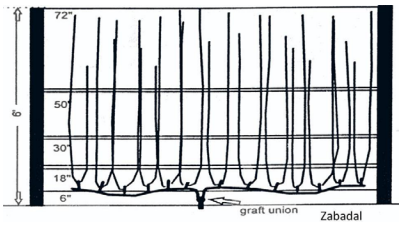
Mid-wire Cordon:



Advantages
- Ease of establishment (2nd year Guyot!).
- Adaptable to unskilled manual pruning.
- Little tying required.

Disadvantages
- Fruiting zone may become crowded and shaded on large vines.
- Nodes on fruiting spurs may be of lower quality.
- Bud counts may be low during renewal years.
- Often requires post extensions.

Low Cordon:



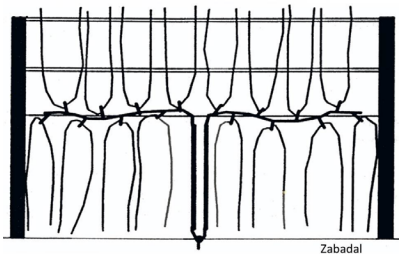
Advantages:

- Fruiting zone close to ground utilizes radiant heat to promote ripening.
- Low fruiting and renewal zone utilizes snow cover or artificial covers to avoid winter injury.

Disadvantages:

- Difficult on labor - low to ground.
- Requires excellent weed management.
- Soil residues on fruit.
- Spring freeze susceptible.

Smart-Dyson:



Advantages:

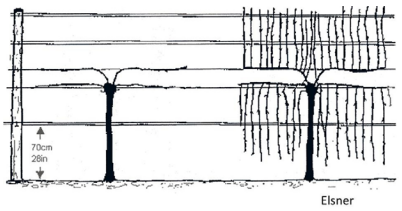
- Adaptable to mechanical pruning.
- Uses shoot positioning to expose fruit for ripening.
- Less likely to develop differences in fruit maturity and bud quality than with Scott Henry system.

Disadvantages:

- Requires excellent weed management.

<u>Head or Cordon Systems or a Combination:</u>

Scott Henry:



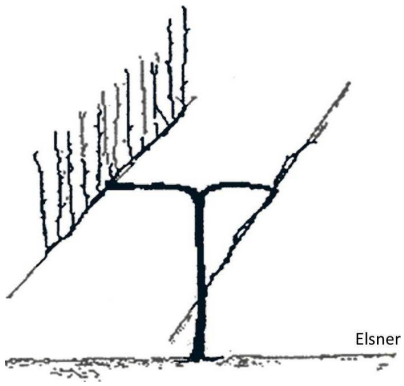
Advantages:

- Promotes a systematic display of a large canopy and good exposure of fruit to sunlight.
- Well organized fruiting zones are easy to hand harvest.

Disadvantages:

- Fruit maturation in lower fruiting zone is often behind the upper.
- Canes and buds developing in lower portion of trellis are of inferior quality.
- Complicated shoot positioning is required.
- Tall trellis is required.
- No advantage to weak vines.

Lyre:



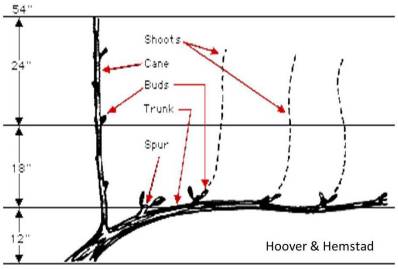
Advantages

- Excellent distribution of the grapevine canopy.
- Desirable upward growth of all shoots.
- Good exposure of fruit for ripening.
- Adaptable to mechanical pruning.

Disadvantages

- Complex and expensive support structure.
- Extensive shoot positioning required.

Mini J:



Advantages

- Modification of the fan system.
- A semi-permanent trunk is developed.
- Trunk is positioned low to the ground to better facilitate removing it from the wires and burying it for winter protection.
- Can be head or cordon pruned.

Additional Sources of Information

- Dami, I, B. Bordelon, D.C. Ferree, M. Brown, M.A. Ellis, R.N. Williams, D. Doohan. 2005. Midwest Grape Production Guide. Ohio State Univ. Extension, Bull. 919.
- Elsner, Duke. 2007. Trellis Systems vs Varieties vs Management: Pros & Cons & Ideas from Michigan. Presentation given at the 2007 Iowa Wine Growers Annual Convention.
- Hoover, E. and P. Hemstad. 2008. Growing Grapes for Home Use. Univ. of Minn. Ext. WW-01103.
- Zabadal, T. Vine Training Systems for Winegrape Production in Cool Climates. SWMREC Report # 10.

The Northern Grapes Project is funded by the USDA's Specialty Crops Research Initiative Program of the National Institute for Food and Agriculture, Project #2011-51181-30850

Visit us on-line at
www.northerngrapesproject.org

The Northern Grapes Project is on Facebook!

We post updates about workshops, field days, webinars, newsletters, and more!

Visit our sister site

eViticulture.org

eViticulture.org is the national online viticulture resource containing the latest science-based information for viticulturists.

Cornell University