**Subject:** New England Grape Notes, March 8, 2018
**From:** Sonia Schloemann <umassfruit@umass.edu>
**Date:** 3/8/18, 6:17 PM
**To:** UMassFruit <umassfruit@umass.edu>

# New England Grape Notes - March 8, 2018

UMass Extension
CENTER FOR AGRICULTURE

**UMass Fruit Team Survey**: Every year we gather feedback from recipients of our programming to help us do a better job serving the fruit growers in Massachusetts and New England. We hope you'll take a few minutes to give us your feedback by taking a brief survey. *We haven't heard from many wine grape growers yet*. The questions are general in nature and help us learn more about how you are receiving information from us, how helpful you find it, and how we might do better.

Please use the link below to access the survey. Responses are anonymous and confidential.
Survey Link: https://www.surveymonkey.com/r/VFWDCQT

Thank you very much for your time!

~ Sonia Schloemann, UMass Extension Fruit Team

## Winter Cold Damage

*Bryan Hed, Penn State Univ. & Lake Eerie Regional Grape Program*

[***Editors Note**: This article appeared in January but is being reprinted here to remind us of the potential for bud damage from cold temperatures earlier in the winter. In Massachusetts there were 4 days of below 0˚F low temps during January. Some places were in double digits below 0˚F at least one of those nights. It is likely that there was some bud damage and possibly some trunk damage from those cold nights. This article will help you assess bud damage which may inform your pruning decisions*.]

Since the new year was ushered in we have had several scary moments when Mother Nature unleashed an “excess of personality.” I’m referring to the cold weather events we experienced around January 1, 7, and 14, when temperatures slipped down below zero in many places across Pennsylvania, even in some south central parts of the state. As many of you might remember, the last time we saw below zero temperatures that far south (February from hell, 2015) primary bud damage was widespread and grapevine trunks in vineyards all over Pennsylvania (and certainly other parts of the Northeast) exploded in crown gall the following spring. This generated a two-year trunk renewal process that we’ve only just recovered from. Therefore, this may be a good time to review grapevine winter hardiness and the factors that affect it, as well as how we can prepare for possible remediation pruning and renewal this spring.

Now I don’t want to raise alarm bells just yet, as the conditions we’ve experienced this January haven’t been as horrific as February of 2015. But it’s always good to be prepared for any potential consequences, like bud loss and trunk damage, so we can anticipate altering our winter pruning plans and production practices this season.

Let’s start with a review of the temperature stats available to everyone on the NEWA website (newa.cornell.edu) and see just how cold it got in various places across the state during the first half of January. In the table below, I’ve listed low temperatures for January 1, 7, and 14 for many of the NEWA locations. Starting at northeastern PA and moving counterclockwise to swing back up into northern New Jersey and finally western New York, we get the following data (Table 1).

**Table 1. Minimum temperatures on January 1, 7, and 14, 2018. Data is from NEWA weather stations.**

| Location in Pennsylvania | | Low temperatures January 1 | January 7 | January 14 |
|---|---|---|---|---|
| Northeast | Scott Township (north of Scranton) | -4.2 | -5.8 | 3.2 |
| | Wilkes-Barre (airport) | 0.0 | -4.0 | 7.0 |
| Northwest | North East lab | 11.8 | 0.7 | 8.7 |
| | Harborcreek | 11.9 | 1.2 | 6.8 |
| | North East escarpment | 10.1 | -1.3 | 5.4 |
| | Erie airport | 12.0 | 0.0 | 7.0 |
| Southwest | Cabot | -0.4 | -6.9 | -3.4 |
| | New Paris | 2.3 | -4.2 | 5.7 |
| | Pittsburgh (airport) | -1.0 | -6.0 | -2.0 |
| | Johnstown (airport) | 0.0 | -5.0 | 3.0 |
| | Altoona (airport) | 7.0 | -4.0 | 8.0 |
| Central | Lewisburg | 3.0 | -2.0 | 6.8 |
| | State College (Rock Springs) | -5.6 | -5.9 | 1.9 |
| | Hostetler airport | -8.5 | -6.9 | 6.3 |
| South central | Biglerville | 6.0 | -0.8 | 10.1 |
| | York Springs | 2.4 | -4.5 | 8.8 |
| | Middletown (Harrisburg) | -2.0 | 3.0 | 12.0 |
| Southeast | Reading | 1.0 | 2.0 | 10.0 |
| | Allentown | 5.0 | 1.0 | 12.0 |
| | New Tripoli | 3.2 | 0.2 | 8.3 |
| | Philadelphia | 6.0 | 3.0 | 14.0 |
| Northwestern NJ | Pequest | -7.0 | -8.0 | 11.0 |
| | Pittstown | 2.0 | -2.0 | 10.0 |
| | Andover | -6.0 | -8.0 | 9.0 |
| Western NY | Versailles | -11.3 | -11.0 | -15.4 |

Areas of southeastern and northwestern Pennsylvania, at opposite corners of the state, appear to have escaped the below-zero temperatures for the most part, but some areas of south central Pennsylvania took a hit (look at York Springs). Areas of southwestern Pennsylvania experienced some of the most extended periods of below-zero weather, and parts of northeastern and central Pennsylvania also got quite cold. The temperature low is the most important bit to consider when sizing up vine bud damage, but the duration of those lows can affect the extent of trunk damage, especially in big old trunks where it may take longer for the core to reach ambient temperatures. Up in the northwestern corner of the state, the buffering effect of Lake Erie probably played a role in our relatively mild temperatures during that period, and we expect little to no damage to most of our vines as our wine industry there is heavily invested in tougher hybrids. The Erie area was also *blessed* (?) with a heap of snow (10 feet!) before the cold snap that provided added protection to bud unions of grafted vines.

If you're anticipating primary bud damage, here's a review of the ranges of temperatures for the LT50 (low temperature at which 50% of primary buds fail to survive) for the cultivars you're growing. For *Vitis vinifera*, the LT50 range of the most winter sensitive cultivars falls between 5º and -5ºF. This includes cultivars like Merlot and Syrah. But for most cultivars of *V. vinifera*, LT50 values fall more in the 0º to -8ºF range (Chardonnay, Cabernet Sauvignon, Pinot gris, Pinot noir, Gewurztraminer). And finally, there's the tougher *V. vinifera* and sensitive hybrids that have buds with LT50 values of -5º to -10ºF. This includes cultivars like Riesling, Cabernet franc, Lemberger, and Chambourcin. On the flip side, most hybrids fall into the -10º to -15ºF range (which is why Northeastern U.S. vineyards are perhaps still more invested in hybrids than *V. vinifera*). Then there are the *V. labrusca* (Concord) and the Minnesota hybrids that range from -15º down to -30ºF for cultivars like Frontenac and LaCrescent. Unfortunately, we don't have such helpful ranges for determining trunk damage, which often comes with more profound consequences and is costlier to address.

Rapid temperature drops are often the most devastating in terms of the extent of damage. Fortunately, December temperatures this winter descended very gradually giving vines time to fully acclimate to cold weather extremes. In fact, recent data from the Cornell research group in the Finger Lakes region of New York shows that LT50 values for primary buds of several cultivars were close to, or at, maximum hardiness. Therefore, it is hoped that many Northeastern U.S. vineyards were well prepped and close to their hardiest when these cold events occurred. On the other hand, any given cultivar in central New York is likely to be a bit more cold hardy than that same cultivar growing in southern Pennsylvania, simply because vines farther north will have accumulated more cooling units than those farther south. So there is the possibility of bud and—worse yet—trunk damage in parts of PA, to the

more sensitive cultivars of *V. vinifera*.

We also had a balmy warm period during the second week in January that pumped temperatures up into the 60s in some places before plunging back down into single digits. However, it's unlikely the brief warm period was long enough to cause any deacclimation of vines before cold temperatures resumed, and little, if any harm, is expected from that event.

The capacity for cold hardiness is mostly determined by genetics. As I alluded to above, *V. vinifera* cultivars are generally the most sensitive to cold winter temperature extremes, French hybrids are generally hardier, and native *V. labrusca* cultivars are often the toughest. Nevertheless, other site specific factors can come into play to affect cold hardiness, and this is often the reason for the *range* in the LT50 values. For example, there's vine health to consider; vines that finished the season with relatively disease-free canopies and balanced crop levels can be expected to be hardier (within their genetic range) than vines that were over-cropped and/or heavily diseased. At times like these, we can't emphasize enough how important it is to maintain your vines and production strategy with a view to optimizing their chances of surviving *every* winter. Other stresses like drought or flooded soils (during the growing season) that we can't do much to control, and infection by leafroll viruses, can also play a significant role in reducing vine cold hardiness.

If you suspect damage, you should delay winter pruning of your vines, according to Dr. Michela Centinari. Feel free to revisit her previous blog posts and others at psuwineandgrapes.wordpress.com. Type "cold hardiness" or "winter injury" into the search box, and you'll quickly and easily gain access to several timely blogs.

Bud damage can be estimated from 100 nodes collected from each potentially compromised vineyard block. Typically, gather ten, 10-node canes from each area, but do not sample from blocks randomly, unless the block is relatively uniform. If a block is made up of pronounced low and high areas (or some other site feature that would affect vine health and bud survival) make sure you sample from those areas separately as they will likely have experienced different temperature lows (Zabadal et al. 2007). You may find that vines in high areas need no or less special pruning consideration than vines in low areas that suffered more primary bud damage and will require increased remediation.

Once you have your sample, bring the canes inside to warm up a bit and make cuts (with a razor blade) through the cross section of the bud to reveal the health (bright green) or death (brown) of primary, secondary, and tertiary buds. You'll need a magnifying glass to make this determination as you examine each bud. You should figure that primaries will contribute two thirds of your crop and secondaries, one third when considering how many "extra" buds to leave during pruning. And remember that some bud damage, up to 15% or so, is normal. If you've lost a third of your primaries, leave a third more nodes as you do your dormant pruning. If you've lost half your primaries, double the nodes you leave, and so on. However, when bud mortality is very high (more than half the primary buds are dead), it may not be cost effective to do any dormant pruning as it is likely there are more sinister consequences afoot, like severe trunk damage that is much harder to quantify. A "wait and see" strategy, or at least very minimal pruning, may be best for severely injured vines (Figure 1) and trunk damage will manifest itself in spring by generating excessive sucker growth (Figure 2). And one more thing: Secondary buds are often more hardy than primaries, may have survived to a larger extent, and in some cultivars, can be incredibly fruitful. This is especially true of some hybrid varieties like DeChaunac. So, to make more informed decisions when winter damage is suspected, you have to know the fruitful potential of your cultivar; and in cases where primary bud mortality is high, it's therefore important to also assess the mortality of secondary buds.

Another great fear is the appearance of crown gall, mainly at the base of trunks. This disease is caused by a bacterium that lives in the vine. However,

the bacterium generally doesn't cause gall formation on trunks until some injury occurs, usually from severe winter cold damage near the soil line or just above grafts on grafted vines (if you hilled over the grafts last fall). Another search at

Figure 1: Riesling vines in early June of 2015. In anticipation of severe bud damage, this row of vines was minimally pruned until it was clear what percentage of buds would emerge.

psuwineandgrapes.wordpress.com will bring up information on how to deal with this disease. You can also visit What we have learned about crown gall for an update on research into this disease from Dr. Tom Burr and his research group at Cornell University. Tom has devoted a lifetime to researching grape crown gall and many advances have been made over the years. But it's still a huge problem for Northeastern U.S. grape growers; and crown gall problems will likely increase as our industry becomes more and more heavily invested in the most susceptible cultivars of *V. vinifera*.

With more sensitive detection methods, Tom's group is getting us closer and closer to crown gall-free mother vines and planting stock, but they're also discovering that the crown gall bacterium is everywhere grapevines are located. Not restricted to internal grapevine tissues; it's also found on external surfaces of cultivated and wild grapevines. So, clean planting stock may still acquire the pathogen internally down the road and management of crown gall, once vines are infected, will continue to be an important part of life in any vineyard that experiences cold winter temperature extremes. However, there is potential for a commercial product that inhibits gall formation, which can be applied to infected vines. The product is actually a non-gall-forming, non-root-necrotizing version of the crown gall bacterium that is applied to grape wounds and inhibits the gall-forming characteristic of the pathogenic strains of the bacterium. This product is still under development in lab and greenhouse tests, awaiting field nursery trials soon.

If you do happen to meet up with some crown gall development this spring, galled trunks can be nursed through the 2018 season to produce at least a partial crop while you train up suckers (from below the galls) as renewal trunks. When our Chancellor vineyard was struck with widespread crown gall in the 2015 season, we were able to harvest a couple of decent sized crops while trunk renewal was taking place (Figure 2), and we never went a single season without *some* crop. There's also the issue of crop insurance to think of; adjusters may want you to leave damaged trunks in place so they can more accurately document the economic damage from winter cold.

Lastly, a great guide to grapevine winter cold damage was published about 10 years ago by several experts. In fact, information

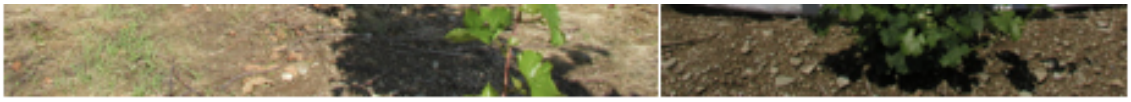

Figure 2: Chancellor (left) and Gruner Veltliner (right) with widespread crown gall in spring. Trunks were not immediately cut down but rather left to provide some crop while sucker growth was encouraged for renewal.

from that guide was used in composing large parts of this blog and I highly recommend you read it. It's an excellent publication, the result of many years of outstanding research by a number of leading scientists and extension specialists from all over the Northeastern U.S. The details of that publication are found below and you can purchase a hard copy for 15 bucksby clicking here: Winter Injury to Grapevines and Methods of Protection (E2930).

For those of you who can spend hours reading off of a computer screen without going blind, you can also access a web version of the document at msue.anr.msu.edu/uploads/files/e2930.pdf.

Zabadal, TJ, Dami, IE, Goiffinet, MC, Martinson, TE, and Chien, ML. 2007. Winter injury to grapevines and methods of protection. Extension Bulletin E2930. Michigan University Extension

(***Source**: Penn State Wine Grape Blog 1/26/18: https://psuwineandgrapes.wordpress.com/2018/01/26/winter-cold-damage-revisited/*)

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## Crown Gall – A Growing Concern in Vineyards

*Bryan Hed, PSU Research Technologist*

[***Editors Note**: This article is from January 22, 2016 but is very relevant to this year*]

The past two winters have ramped up concerns about crown gall in Pennsylvania and other parts of the Northeast. Wine grape growers are discovering, many for the first time, the horrors of this disease and the extent of the damage it can cause in their vineyards. While there is reason for great concern, I would like to start out by saying that research efforts are generating extensive information on management of this disease, and there are new solutions from research in the pipeline.

### CROWN GALL AND INCREASE SUSCEPTIBILITY TO WINTER INJURY

**After the past couple of harsh winters vines have been collapsing in your once "healthy" and productive vineyard. What's going on?**

In some cases, brutal winter cold has simply damaged or killed a vine that was not suitable for its site. It is well known that the many varieties of *Vitis vinifera* that vintners prefer are simply less cold hardy than many of the French hybrid varieties. The crown gall bacterium, *Agrobacterium vitis*, can also play a large role by rendering infected vines incapable of properly repairing the cold damage to their trunks. The most obvious symptom of crown gall infection is gall formation at the base of infected vines. These tumor-like growths eventually choke out the vascular connection between roots and canopy, and the vine collapses (Figures 1 and 2).

**How did vines get contaminated with the crown gall bacterium in the first place and why is it now causing problems?**

There are many sources of the crown gall bacterium and probably many ways in which vines can acquire it. It is now known that the bacterium exists in populations of wild grapevines and can be found on plant surfaces in the vineyard. The most likely or common source, however, is through contaminated nursery stock. Since the bacterium can live systemically as an endophyte inside vines used for propagation material, cuttings from that material will carry the bacterium as well. The bacterium that causes crown gall can probably live inside vines without ever causing any disease, without causing the growth of tumors at the base of the trunk, without bringing about the collapse of

vine trunks. Cuttings, produced from symptomless, contaminated mother vines, may be contaminated with the bacterium from "day one," but may never develop crown gall. This is probably the case in California and other Mediterranean climates where many of the world's wine grapes are grown.

**So why is crown gall such a problem here in the Northeast, and not in California?**

The crown gall bacterium shifts from benign coexistence, as an endophyte inside vines, into a tumor-inducing organism when there is damage or injury to grapevine vascular tissue. When injury occurs to the cambium, the bacterium attaches to plant cells at the wound site and literally inserts a copy of a self-replicating DNA strand (called a plasmid) into the plant cells (infection). The plasmid contains genes that code for hormone production that leads to the growth of tumors. These genetically modified grapevine cambium cells begin to grow tumor tissues with poorly organized vascular structure (that is, not capable of adequately conducting resources needed by the vine) at the wound site instead of organized vascular tissues. The injured trunk areas are never properly repaired by functional vascular tissue and as the tumor tissues grow, the trunk becomes more and more non-functional and eventually the vine collapses. And what is the most common cause of widespread grapevine trunk damage in the Northeast? Severe winter cold—which does not occur in most parts of California and similar warm, wine grape production climates.

**Figures 1 and 2**: Crown gall on a trunk of French hybrid 'Chancellor' before and after bark is stripped away. Galls appear in spring as white callous tissue, most often at the base of the trunk, gradually turning green/brown and finally dying to turn into dark brown/black corky tissue.

**All is not lost—tips on vineyard renovation**

A collapsed vine with healthy roots will throw new shoots from the base of the plant, and these can be used to make new trunks and restore the vine to productive status. Here in the "Great White North" of Erie County, we renovate vines almost every year (Figure 3). Vines "laid low" by crown gall are often capable of being completely restored to productive life. Rather than ripping out your 7 or 10-year-old vineyard and replacing it, it can be more cost-effective to train up new trunks with the potential for a partial crop this year and a full crop in Year 2. An exception to this remedy is when trunks of grafted vines were not hilled with soil in the fall and the base of scions experienced the full force of the severe cold. This can completely kill the scion and leave growers with nothing but the rootstock. In this case, growers may have to start over with new vines, unless there is potential for field grafting of new scion wood. Also, when very young or newly planted vines develop crown gall, it is best to remove the plants, and replace them. The bacterium can be found in roots as well as trunks and can survive for long periods of time (years) in the soil, and it is important to remove all parts of infected plants.

**Figure 3:** Picture from the NE1020 grape variety trial at North East in Erie county PA. Note the six-year-old Gruner veltliner/101-14 vines (foreground) that were laid low by the 2014 Polar Vortex. Although existing canopies are dead or nearly dead, a flush of sucker growth from the scion (protected by hilling during the previous fall) provides the means for trunk renewal. Also note the full canopies of cold hardy French hybrids within the same block. While ALL cultivars of V. vinifera were killed back to the ground, all hybrids went on to produce partial to full crops in that year.

All of us would love to be able to train up one original trunk and rely on that single trunk for every vine, every year. Unfortunately for many in the Northeast, that's a pipe dream. Now that you know about crown gall in your vineyard, you can assume that more vines are contaminated than you previously thought. For example, we have a Chambourcin vineyard at the North East lab in which just about every vine is host to the crown gall bacterium. I had no idea this was the case until the winter of 2003-2004, when brutal cold caused nearly every vine trunk to explode with crown gall the following spring (Figures 4 and 5). Apparently, nearly every vine was contaminated with the bacterium and the vineyard collapsed! After discussing my conundrum with Dr. Tom Burr at Cornell University, an expert in crown gall biology/pathology, we spent the 2004 season training up new trunks for every vine, ***using only shoots that originated from below the galls***. From 2005 on, the vineyard was enormously productive for almost ten years. Then came the polar vortex of January 2014, followed by the severe winter cold of February 2015, and with it more devastating bouts with crown gall.

**Improving your odds that a winter cold event will not lead to complete loss**

Growers of *V. vinifera* in Erie County, PA have pretty much resigned themselves to losses from winter cold and crown gall every few years, and they deal with it in a number of ways. The first way is by growing vines on multiple (2 to 3) trunks. The logic follows that if one or two trunks collapse from crown gall there may still be one trunk that produces a crop and provides some income until new trunks can be groomed to replace the galled/damaged ones. Trunks do not need to be replaced as a matter of regular maintenance, but rather when they become injured and/or diseased. The maintenance of more than one trunk can greatly improve your odds that a winter cold event will not lead to complete loss.

**Figure 4 and 5**: Collapsed vine of French hybrid 'Chambourcin' (left) following winter cold damage to the trunk and onset of crown gall at the base of the trunk (right). The entire vineyard eventually collapsed, but was completely restored with new trunks from shoots (suckers) emanating from below galls.

Growers of the hardier French hybrids generally suffer fewer economic down times from winter cold-induced crown gall than growers of *V. vinifera*. We cannot escape bouts of brutally cold winter weather, but we can (and should) plan for the worst and try to wisely match variety with site in order to minimize or eliminate losses to winter trunk damage and crown gall. Simply put, cultivars of *V. vinifera* and cold-sensitive hybrids should be planted only on the best sites in Pennsylvania—sites that ensure good cold air drainage during the worst bouts of winter weather. Where a vineyard is already established, vine management that maximizes vine cold hardiness (balanced timely nutrition, effective disease control, proper balance between growth and yield, good weed and water management) is absolutely essential for minimizing trunk damage and the onset of crown gall after a severe winter cold event.

For grafted vines, hilling soil around the graft union in late fall will protect the base of the scion and may ensure that scion bud wood will survive to throw shoots for replacement trunks the following spring. During the following spring, hilled soil should be removed from around the graft to prevent rooting of the scion, which would otherwise defeat the purpose of the rootstock. Although an added expense, this practice is commonplace in many wine growing regions of the Northeast. Farther south and especially in the mid-Atlantic region, many growers have been avoiding this management practice because it represents a substantial added expense, can contribute to erosion on steep sites, and can increase the odds that vines may become mechanically damaged. Unfortunately, severe cold during the past two winters caused heavy damage to the less favorable variety/site combinations even in parts of southern PA and the mid-Atlantic. Where grafts were not protected, the supply of scion buds that would have provided for new trunks was killed. In such cases, all but the rootstock dies and the vine must be replaced—a much more expensive operation than trunk renewal. So in these more southerly regions, the decision to hill or not, may be less clear. In southern PA, proper variety matched to the site along with multiple trunk maintenance may be sufficient for sustainability. However, on poorer sites that suffer more frequently from a severe winter cold event, annual hilling of grafts may be necessary **or** a grower may need to rethink his/her established variety/site combination. As in all matters of farming, growers must weigh the expense of a practice against the magnitude of the consequences for not doing so as well as the odds that he or she will get hit with another severe cold event. The prudent integration of these management practices will help to guarantee that farms can remain sustainable and profitable in the Northeast.

**Research in the pipeline**

Once contaminated, there is no practical way to rid a vine of the crown gall bacterium. The best long term solution rests with the production of crown gall-free planting stock so that growers can at least

***start*** with a clean vine/clean vineyard. To that end, through funding from the National Clean Plant Network, Dr. Tom Burr's grape research program and others are devoted to the generation of mother vines free of crown gall that can be used to start clean sources of grapevine nursery material. The emphasis in this effort is the development, and ongoing refinement, of extremely sensitive tests used to detect the presence of the pathogen, in order to determine whether a vine that might be used for propagation is "clean" or contaminated. Clean vine material can then be confidently used to establish grapevine mother blocks that will serve as the foundation of nursery propagation stocks. In turn, the mother blocks and nursery stocks can be continuously monitored for the presence of the bacterium using these same tests. The latest research has indicated that plants free of the crown gall pathogen can be generated but they will need to be assayed periodically to ensure they remain clean. Remember, however, that the crown gall pathogen, once introduced into a vineyard through contaminated plants, can live in the soil for many years. Therefore, the availability of crown gall free planting stock is not going to end our encounters with this pathogen. Clean planting stock will reduce or help to eliminate the incidence of crown gall in new plantings, but the pathogen will likely always remain present and northeastern growers will still have to manage their vineyards with a view toward minimizing the incidence of crown gall.

**Extension Support for the Upcoming Season:**

- This blog post and others will continue to be made available at ***Wine and Grapes U.*** to assist growers with the latest information. We hope you find this useful for managing crown gall and we encourage feedback.
- You can sign up for the Penn State Extension V&E News listserv by email Denise Gardner at dxg241@psu.edu. This will keep you current when we release crown gall related information.
- Bring your crown gall questions and concerns to the upcoming **Mid-Atlantic Fruit and Vegetable Convention in Hershey PA (February 3, 2016)**; let's discuss them.
- Bryan will discuss current disease updates at the 2016 PA Wine Marketing & Research Board Symposium at the Nittany Lion Inn (University Park, PA) on March 30, 2016.
- Participate in a series of webinars being organized by Tim Martinson, Cornell University, that will enable growers to tap into Tom Burr's long standing research program on managing crown gall and what we have to look forward to in the future. Stay tuned for more details later this winter.
- Check out this recent presentation by Dr. Burr at this **link**.

Information used in composing this article was from personal communication with Dr. Tom Burr and:

Compendium of grape diseases, disorders, and pests. Second edition. 2015. Wayne F. Wilcox, Walter D. Gubler, and Jerry K. Uyemoto, eds. American Phytopathological Society Press. Pages 95-98.

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Wine Grape Production Guide for Eastern North America. 2008. Tony Wolf, ed. Natural Resource, Agriculture, and Engineering Service. Cornell Cooperative Extension.

(**Source**: *Penn State Wine Grape Blog 1/26/18: https://psuwineandgrapes.wordpress.com/2016/01/22/what-to-do-about-crown-gall/)*

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Sonia Schloemann
UMass Extension Fruit Program
umassfruit@umass.edu