ASEV Merit Award

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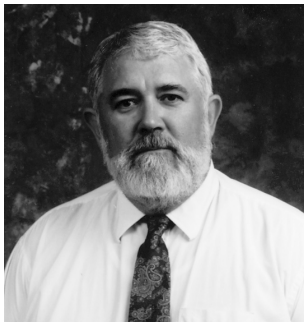
Developing a Research Program Near the Climatic Limits of Commercial Vine Culture

Invitations to speak at state venues led me to a very instructive web-based survey of the status of commercial grape and wine production in the United States. Every state has commercial wine production. While some of these operations do not produce wine from grapes, at least 50% of the states also have a commercial grape production capacity (based on my arbitrary assessment that a state with 500 or more acres of grapes constituted a commercial industry). Based on these data, I suggest that in addition to the period of unprecedented growth in grape production worldwide, U.S. production is also rapidly expanding. Thus, grape production is quickly coming to geographic areas where there is limited experience with the crop and its culture, and even less with the assessment of those local environmental conditions that limit successful economic production.

All grape production areas encounter limits, whether environmental, as climate and soils, vineyard pests, or production economics. Those viticultural areas currently exhibiting success have evaluated these limits and have either found locales with fewer such limits or, through research and its application, overcome the limits.

In 1969 we found ourselves in the same position as the newer, more recently developing viticultural areas. Thus, it is the goal of this presentation to outline those approaches that have proved useful (and not so useful) in developing a research base for information outreach for Michigan and the Great Lakes Region. I present here a breakdown of approaches that have worked for the conditions faced when our Michigan efforts began. This is not a blueprint for areas emerging as new regions for commercial viticulture. Rather, it is an outline describing a response to our specific conditions and experiences in the Great Lakes Region. Other regions will have different environmental limits and thus different priorities. However, the key to success is an evaluation that can be used in setting those priorities.

The Value of the California and New York Models. At the outset of our efforts in Michigan there were two obvious examples of approaches that had been historically effective: one example in California with the University of California Davis (UCD) and Fresno State University (CSUF) and another example in New York with Cornell University's New York Agricultural Experiment Station at Geneva (NYAES).



Maynard Amerine and Albert Winkler at UC Davis demonstrated that good science, effectively applied, could hugely influence the choice of grape cultivars grown and the locations that could effectively express their best characteristics. That changed the California industry. I am old enough to recall when the popular perception expressed in the media was that "imported" wine was the high-"quality" wine and that "domestic" wine was, at best, mediocre. The growing-degree-day revolution that substituted Cabernet Sauvignon and Chardonnay for Angelica and other dessert cultivars growing in Napa and Sonoma Valleys set the stage for world-class table-wine production and set the standard for the California industry and for other U.S. producers and, indeed, producers of practically all New World wines.

In NYAES, and subsequently at CSUF, research efforts led to harvest mechanization. At the same time, NYAES undertook a simultaneous effort in training systems that ultimately led to concepts of canopy management promulgated by Richard Smart, Nelson Shaulis, and Edward Lemon in New York. These concepts are now accepted worldwide.

Based on these examples, we believed in the early 1970s that improvement for Michigan viticulture and enology could come only through challenging the status quo for (a) choice of grape cultivars used for wine and (b) selection of production methods in the vineyard specifically for juice or for winegrapes. The basis for judgment rested not only on vine performance in the vineyard but equally on the impact of the proposed change on acceptability of the result in the wineglass. We became convinced, based on the California and New York models, that the only way to achieve this goal was through application of rigorous science coupled with effective outreach.

Grape Production in Michigan Is a Condition of Limits. As noted above, the viticultural concerns amenable to scientific evaluation are the abiotic and biotic limits imposed by climate and pests. As a physiologist I focused on environmental limits found in Michigan and the Great

Lakes Region, which is characterized by short growing seasons (150 to 175 days from 0°C to 0°C), with cool-climate conditions (typically 1000 to 1250 GDD, base -10°C or 2200 to 3200 GDD, base -50°F), where winter cold, spring freezes (50% chance of frost as late as May 15), early fall frosts, highly variable annual GDD conditions, high humidity, and the potential for rainfall during harvest can limit both yield and fruit quality. Michigan growers have faced an array of biotic pests. Thankfully we have had quality colleagues in departments of entomology and plant pathology and weed control scientists in horticulture to address those concerns while we were assessing the impact of the abiotic limits.

Michigan Status in 1969. So, what was the status of the Michigan grape and wine industry at the outset of the effort? There were 12,000 acres of grapes, mostly Concord, about 10% Niagara, 1% Delaware, <1% non-*Vitis labrusca* (hybrids), and 5 acres of *V. vinifera*. Our understanding of *labrusca* culture flowed from the defining efforts of Newton Partridge and the subsequent refinements by Shaulis on the growth-yield relationship (AJEV 52:165-174).

The Michigan grape industry could have been easily described as a Concord grape industry in 1969. The National Grape Cooperative and their processing arm, Welchs, were the most significant producers and processors of juice grapes, although there were several others. Of grapes used for Michigan wine, 95% were from Concord, Niagara, and Delaware. One juice processor (not the National Grape Coop) commented, "Wine in Michigan is not the tail of the dog, it is the tip of the tail of the dog."

Michigan State University Administrative Attitudes in 1969. Attitudes about grape research were not much removed from those of the "tip of the tail of the dog" view. The political power in high-value crops in Michigan rested with the tree fruit industry, particularly apples and sour cherries, and grapes were viewed as not being in the same class. Additionally, there was some on-campus anti-alcohol hostility and that, unfortunately, remains true today. However, in the early 1970s the dean of the College of Agriculture and Natural Resources and the chair of the Department of Horticulture were supportive, which made the difference in terms of opening the door to wine-based research.

Attitudes about viticulture were commonly negative. "Can't grow those hybrids in Michigan," was expressed by one nationally recognized horticulturist. When I pressed as to the basis of the opinion I was told that, "If we could grow them, they would already be being grown." I loved that logic!

Media Attitudes. These views were based on the image of *V. labrusca*-based dessert wines and were almost uniformly negative; a few felt there was potential. Even early efforts with hybrids and *V. vinifera* were panned by the media. When President Ford served a Michigan wine at the 1974 inauguration, Johnny Carson quipped on the "Tonight Show" that it had, "an aroma of tailpipe exhaust." In the early 1970s, the columns by Ruth Ellen Church at the *Chicago Tribune* and Leon Adams' book *Wines of America* were nearly alone in their support.

My Status in 1969? My status was a condition of ignorance. While that was uncomfortable, it had its value; I was unencumbered by the facts. I was insufficiently informed to know that "we can't grow those hybrids or *viniferas* in Michigan." Oh yes, my response to that dogmatic view was "Well, let's plant them anyway and watch them die." We are all ignorant, but ignorant about different things. But I hated being so ignorant about grapes that I could not even ask a good question. However, I had previously done research in a challenging program at the University of Minnesota and I was confident that the ignorance could be overcome. I had already learned how to learn.

The Value of Learning. While reading the grape literature was clearly obligatory, much was gained by reading broadly in science and literature. Two books had considerable impact: Jacob Bronowski's *The Ascent of Man* and John Naisbitt's *Megatrends*, in which he notes "In a world that is constantly changing, there is no one subject or set of subjects that will serve you for the foreseeable future, let alone for the rest of your life. The most important skill to acquire now is learning how to learn." To overcome my ignorance, I began by reading all grape publications by Newton Partridge and, later, Shaulis and Robert Steel (1969. J. Am. Soc. Hortic. Sci. 94:422-429).

Setting Philosophical Goals. On their album *Déjà Vu*, Crosby, Stills, Nash, and Young produced a great song called "Teach Your Children" that begins "You who are on the road must have a code that you can live by." So it is for one who would aspire to success in viticultural science. Here is a partial list of those values that have resonated for me.

1. Strive for excellence.
2. Listen to and critique the experiences of successful viticulturists and other plant scientists.
3 Listen to local industry leaders for areas of their concerns that can be approached by science. (A caveat: not all problems can be approached by science.)
4. Use the latest tools and methods of science to solve practical problems in the vineyard.
5. Surround yourself with similarly committed individuals.
6. Avoid individuals with preconceived ideas.
7. Understand that a viticultural scientist is a plant scientist working on grapes BUT that not all plant scientists working on grapes are viticulturists (thanks to Mike Trought).
8. Keep abreast of literature but think critically and remain skeptical. My view is "We are skeptical about our own data and do not believe anyone else's." Ideas, data, even research articles should be evaluated with interest and skepticism. In the early 1970s, an article in *Science* suggested that research efforts in microbiology that were making the most progress were based on experiments to specifically challenge the scientists' most recent results.
9. Be aware of your limits and areas of ignorance.
10. Seek help when needed regarding #9 in order to get the job done.

Unanswered Questions vs Unquestioned Answers. Ten years ago the ASEV Merit Award was presented to Dr. Shaulis, and he made a point about unanswered questions versus unquestioned answers. The rapid expansion of commercial viticulture nationally since then makes this worth repeating. I share the view put forward at that time that we are more hindered in the pursuit of understanding by the "unquestioned answers" than its alternative. Indeed, Bill Nail, a friend and former graduate student sent me the following

quote that I will share because I accept its value: "Always try to surround yourself with those who seek the truth, and stay the hell away from those who believe that they have found it" (musician Chuck Pyle, the "Zen Cowboy").

In Chapter 11 of Bronowski's *The Ascent of Man*, titled "Knowledge vs Certainty," the author posits the thesis that a philosophical position of certainty precludes advancement in knowledge. Voltaire agreed, "Doubt is not a pleasant condition, but certainty is absurd." I believe that doubt and skepticism are major values to cultivate for a scientist.

Get Support. Great ideas, good cooperators, and excellent facilities are important to success but are only indicative of possibilities unless there is funding to support the efforts. We have likened the university's facilities and expertise to a Cadillac, just waiting to get on the road, but we need to have help from growers with the purchase of gasoline. Important to the analogy is that the individuals who help with the gasoline purchase are also those most needing to travel, and they will also get to enjoy the ride.

Those who will directly benefit from the efforts—the growers—must be involved in the setting of priorities and helping with vineyard plot maintenance. One should also anticipate that the highest priority for a typical grower will be the problem(s) experienced during the most recent growing season. Since good science cannot be done with an annual elimination of old efforts and initiation of new efforts, this will be a big challenge as one seeks to secure industry support. Grower involvement in vineyard plot activities means that they "buy in" to the efforts. In developing grape production areas, it is also an effective outreach tool.

You must get industry leaders to be supportive of your efforts and to speak favorably of them to administrative decisionmakers to whom you are responsible. Also, you must encourage administrative respect for the grape and wine industries by word and deed. Similarly, encourage state government interest/respect and encourage media respect and support. Be available whenever media people want information about the industry or your program's efforts in support of the industry. Remember that the industry is the story, not you.

Program Direction. Ideas come all the time. These should be collected like gold nuggets, squirreled away and frequently examined and polished. To do this, I have kept an "idea" notebook for inputs gained from all sources. Upon careful examination, some are pyrite (fool's gold) and can be discarded. For others, formulate experimental approaches and constantly revise and set priorities. Like fine wine, some nuggets improve in quality with age.

Set aside a section for ideas too "far-out" to be even mentioned. What do I mean by far-out? These are ideas with a strong risk of failure, but success with one or two over the span of a career can have enormous positive impact for your industry. Set researchable ideas into three groups: (1) problems of immediacy; (2) problems that need solutions for 5-, 10-, to 20-yr impact; and (3) the far-out ideas. At the outset for Michigan there was much practical effort needed, so 65% of available effort was for solving immediate problems, 35% was for future anticipated needs (5, 10, 20 years later), and 5% for far-out ideas.

Learn the Nomenclature of the Vine. This approach seems so obvious that I hesitate to include it. However, for effective communication, the participants in a conversation must communicate in the same language. Clear understanding and use of nomenclature regarding grapevine morphology, anatomy, and physiological function is "Critical for clear expression of data and ideas about vines" (N. Shaulis).

Immerse Yourself in the Vineyard. There is no better way to determine whether viticultural science is a good personal fit than to get into the vineyard. That is where you can learn the realities of the vine's growth and productivity and can get an idea of the conditions and limits a commercial grower faces in the region of your responsibility. I have to thank Bernard Rink of Michigan's Boskydel Vineyard for quoting Matthew 20:6-7: "Why stand ye here idle; go ye into the vineyard."

In order to survive in the academic bureaucracy, I have adhered to Ben Franklin's admonition "To study, to finish, to publish." The importance of publishing is often poorly understood by growers. The suggestion that publishing is for individual ego and takes time away from other work that could be finding answers for the industry should be rejected. Publishing is far more important than that. Publishing in AJEV and other peer-reviewed journals is the quality-control mechanism for our science. Even when the effort is well done, the "fates" controlling probabilities can produce an incorrect result (type I or type II errors). The best evidence of this is the list of foods that have oscillated back and forth as negative or positive for health. The best we can do is to conduct our own research as well as possible and be severely critical of our own and other's efforts that are sloppy or have flawed design or logic. Having said that I recall a comment by a colleague that "incorrect decisions based on inadequate data are fewer than those made based on no data at all."

Finally, to the value of vineyard plots over a range of experiments and locations, I recall Shaulis' suggestion that such plots could act as a "net" and catch data opportunistically when unique weather or other stresses were experienced. We have found that observation very useful as related to spring freeze damage (see AJEV 29:192-198; 29:229-232).

Value of Sabbaticals/Research Leaves. Sabbaticals have great value if used properly. They should not be vacations, should involve some personal and economic sacrifice, and require preplanned, specific goals for activities to be accomplished. Here is a list of my sabbatical leaves, the scientists I interacted with, the projects undertaken, and resulting reports.

•1975-76 Geneva, NY: Nelson Shaulis, Bob Pool, Alan Lakso, and Gary Howard. Value of stratified random sampling and within canopy cold hardiness variation. (AJEV 31:158-161).

•1990 Wadenswil, Switzerland: Werner Koblet, Carmo Vasconcelos, and Pierre Basler. Perennial wood, rootstock, net photosynthesis (Pn) and fruit maturity/ trunk volume (AJEV 45:173-180; 181-187; 188-191).

•1996 Lincoln University, New Zealand: Mike Trought, Paul Petrie, Leah Clearwater. Mildew and Pn, leaf area, whole vine Pn (see bibliography).

•2003 UC Davis: Jim Wolpert, Mike Anderson, Jason Benz, Hildegard Heymann. Timing and amount of crop reduction, fruit ripening, and flavor development (in preparation).

Fun Research Efforts. Over the last 37 years, learning how to help our producers become more efficient, more productive, and produce better quality has provided great personal pleasure. A general list includes: spring freeze (critical temperatures and bud phenology); winter hardiness; cultivar/clone evaluation, for which we had to learn winemaking (with the input of Nate Stackhouse, UC Davis graduate enologist); balanced cropping; whole-vine photosynthesis and carbon partitioning; rootstock/scion relations and Marechal Foch/Vidal blanc reciprocal grafts. Future approaches to "limits": biotic stresses will be integrated with abiotic stresses to fully quantify annual environmental limits and thus lead to cultural methods to accommodate the limit(s).

Finally: Select Cooperators Carefully. Knowledge and intelligence are critical in cooperators, but useless if an individual is lazy or has questionable ethics or honesty. Some will believe that their education makes physical work beneath them. Remember the Little Red Hen. Some may talk a good game, but will not be available when work is needed; however, they will be on hand when it comes time to take the credit. Put another way, few will volunteer to help collect the wood, but all will want to stand by the fire when it gets cold. Look for a cooperator who will "carry her/his end of the log." But in the end, the synergy of cooperation can produce a result that is larger than the sum of the parts. Good cooperators are to be treasured as surely as poor cooperators are to be shunned. I have been most fortunate in the fine quality of cooperators I have had over the last 37 years.

And thus I come to retirement with the opportunity for reflection both personally and professionally. I am ready for the next phase of my life with grapes and wine. Grapegrowers, winemakers, and the scientists and extension persons who work with them are the group of individuals I have observed who enjoy life and live it to the fullest. They are my kind of folks.

> If a man knows he will sooner or later be robbed upon a journey he will have a bottle of the best in every inn, and look upon all of his extravagances as so much gained upon the thieves. And, above all, where, instead of simply spending, he makes a profitable investment for some of his money when it will be out of risk of loss. So every bit of brisk living, and, above all, when it is healthful, is so much gained upon the wholesale filcher, death. We shall have the less in our pockets, the more in our stomachs, when he cries, "Stand and deliver."
>
> (Robert Louis Stevenson, 1878)

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Thanks to AJEV and their editors and reviewers over the last 37 years. Their critical inputs have made the process of publishing there both rewarding and humbling. And, thank you to ASEV and the selection committee for considering me worthy to be and enter the pantheon of the greats of viticultural and enological science to receive the Merit Award. I am deeply appreciative.

And finally, thanks to my wife Nancy, of almost 43 years, who has endured endless hours of grape and wine talk over those years without becoming severely bored. She has great self-control.

—G. Stanley Howell, ASEV 2007 Merit Award Recipient, Professor and Viticulturist Emeritus, Michigan State University

Bibliography of Relevant Publications By Category (alphabetical listing by author)

Grapevine Frost & Cold Hardiness

*Anderson, K.A., G.S. Howell, and J.A. Wolpert. 1980. Phenological development of different *Vitis* cultivars. Fruit Var. J. 34:5-7.

Howell, G.S. 1976. Frost damage in Michigan: What our 1976 experience tells us. Great Lakes Fruit Growers News (November).

*Howell, G.S. 1988. Cultural manipulation of vine cold hardiness. *In* Proceedings of the Second International Symposium for Cool Climate Viticulture and Oenology. R.E. Smart et al. (Eds.), pp. 98-102. New Zealand Society for Viticulture and Oenology (NZSVO), Auckland.

*Howell, G.S. 1988. Cold hardiness: How small a difference in relative hardiness is viticulturally important. *In* Proceedings of the Second International Symposium for Cool Climate Viticulture and Oenology. R.E. Smart et al. (Eds.), p. 105. NZSVO, Auckland.

Howell, G.S. 1988. Factors affecting vine survival in winter. Practical Winery 9(4):35-40.

*Howell, G.S. 1991. Approaches to solving the problem of low temperature damage to grapevines. *In* Proceedings Frost Protection Strategies for Trees and Grapevines, pp. 149-166. CATI Publ. 911104. California State University, Fresno.

*Howell, G.S. 2000. Grapevine cold hardiness: Mechanisms of cold acclimation, mid-winter hardiness maintenance, and spring deacclimation. Am. J. Enol. Vitic. 51:35-48.

Howell, G.S. 2003. Winter hardiness of grapevines: The challenges of culture under continental conditions and recovery approaches when damage has occurred. *In* Proceedings of the 22nd Annual Hort. Industry Spring Show, pp.131-134. Springdale, AK.

Howell, S. 2004. Cold hardiness in Mid-west vineyards. Illinois Grape Growers and Vintners Association Conference, pp. 50-60. Springfield, IL.

*Howell, G.S., R.M. Pool, and M.C.T. Trought. 2006. Managing cold, frost and other weather related grapevine damage–A review. *In* Proceedings of the Sixth International Cool Climate Symposium for Viticulture and Oenology, pp. 192-205. Christchurch, New Zealand.

*Howell, G.S., and N. Shaulis. 1980. Factors influencing within-vine variation in the cold resistance of cane and primary bud tissues. Am. J. Enol. Vitic. 31:158-161.

*Howell, G.S., B.G. Stergios, and S.S. Stackhouse. 1978. Interrelation of productivity and cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 29:187-191.

Howell, G.S., M.C.T. Trought, A.P. Friend, and I. Dami. 2006. Keeping out the cold: Frost damage and recovery. *In* Proceedings of the Sixth International Cool Climate Symposium for Viticulture and Oenology, p. 241. Christchurch, New Zealand.

*Howell, G.S., and J.A. Wolpert. 1978. Nodes per cane, primary bud phenology, and spring freeze damage to Concord grapevines. A preliminary note. Am. J. Enol. Vitic. 29:229-232.

*Jiang, H., G.S. Howell, and J.A. Flore. 1999. Efficacy of chlorophyll fluorescence as a viability test for freeze-stressed woody grape tissues. Can. J. Plant Sci. 79:401-409.

*Jiang, H., and G.S. Howell. 2002. Correlation and regression analysis of cold hardiness, air temperatures, and water content of Concord grapevines. Am. J. Enol. Vitic. 53:227-230.

*Jiang, H., and G.S. Howell. 2002. Applying chlorophyll fluoresence technique to cold hardiness studies of grapevines. Am. J. Enol. Vitic. 53:210-217.

*Johnson, D.E., and G.S. Howell. 1981. Factors influencing critical temperatures for spring freeze damage to developing primary shoots on Concord grapevines. Am. J. Enol. Vitic. 32:144-149.

*Johnson, D.E., and G.S. Howell. 1981. The effect of cane morphology and cultivar on the phenological development and critical temperatures of primary buds on grape canes. J. Am. Soc. Hort. Sci. 106:545-549.

*Mansfield, T., and G.S. Howell. 1981. Response of soluble solids accumulation, fruitfulness, cold resistance and onset of bud growth to differential defoliation stress at veraison in Concord grapevines. Am.J. Enol. Vitic. 32:200-205.

*Miller, D.P., G.S. Howell, and R.K. Striegler. 1988. Cane and bud hardiness of selected grapevine rootstocks. Am. J. Enol. Vitic. 39:55-59.

*Miller, D.P., G.S. Howell, and R.K. Striegler. 1988. Cane and bud hardiness of own-rooted White Riesling and scions of White Riesling and Chardonnay grafted to selected rootstocks. Am. J. Enol. Vitic. 39:60-66.

*Stergios, B.G., and G.S. Howell. 1973. Evaluation of viability tests for cold stressed plants. J. Am. Soc. Hortic. Sci. 98:325-330.

*Stergios, B.G., and G.S. Howell. 1974. In situ destruction of dormant 'Concord' grape primary buds without secondary bud kill. HortScience 9:120-122.

*Stergios, B.G., and G.S. Howell. 1977. Effects of defoliation, trellis height, and cropping stress on the cold hardiness of Concord grapevines. Am. J. Enol. Vitic. 28:34-42.

*Stergios, B.G., and G. S. Howell. 1977. Effect of site on cold acclimation and deacclimation of Concord grapevines. Am. J. Enol. Vitic. 28:43-48.

*Striegler, R.K., and G.S. Howell. 1991. The influence of rootstock on the cold hardiness of Seyval grapevines. I. Primary and secondary effects on growth, canopy development, yield, fruit quality and cold hardiness. Vitis 30:1-10.

Trought, M.C.T., G.S. Howell, and N. Cherry. 1999. Practical consideration for reducing frost damage in vineyards. Report to the New Zealand Wine Growers Assn. 42pp.

*Wolpert, J.A., and G.S. Howell. 1984. Effects of cane length and dormant season pruning date on cold hardiness and water content of Concord bud and cane tissues. Am. J. Enol. Vitic. 35:237-241.

*Wolpert, J.A., and G. S. Howell. 1985. Cold acclimation of Concord grapevines. I. Variation in cold hardiness within the canopy. Am. J. Enol. Vitic. 36:185-188.

*Wolpert, J.A., and G.S. Howell. 1985. Cold acclimation of Concord grapevines. II. Natural acclimation pattern and tissue moisture decline in canes and primary buds of bearing vines. Am. J. Enol. Vitic.36:189-194.

*Wolpert, J.A., and G.S. Howell. 1986. Effect of night interruption on cold acclimation of 'Concord' grapevines. J. Am. Soc. Hortic. Sci. 111:16-20.

*Wolpert, J.A., and G.S. Howell. 1986. Cold acclimation of Concord grapevines. III. Relationship between cold hardiness, tissue water content, and shoot maturation. Vitis 25:151-159.

Grapevine Photosynthesis & Carbon Partitioning

*Candolfi-Vasconcelos, M.C., W. Koblet, G.S. Howell, and W. Zweifel. 1994. Influence of defoliation, rootstock, training system and leaf position on gas exchange of Pinot noir grapevines. Am. J. Enol. Vitic. 45:173-180.

Edson, C.E., and G.S. Howell. 1993. A comparison of vine architecture systems at different crop loads: Leaf photosynthesis, vine yield, and dry matter partitioning. Vitic. Enol. Sci. 48:90-95.

*Edson, C.E., G.S. Howell, and J.A. Flore. 1993. Influence of crop load on photosynthesis and dry matter partitioning of Seyval grapevines. I. Single leaf and whole vine response pre- and post-harvest. Am. J. Enol. Vitic. 44:139-147.

*Edson, C.E., G.S. Howell, and J.A. Flore. 1995. Influence of crop load on photosynthesis and dry matter partitioning of Seyval grapevines. II. Seasonal changes in single leaf and whole vine photosynthesis. Am. J. Enol. Vitic. 46:469-477.

*Edson, C.E., G.S. Howell, and J.A. Flore. 1995. Influence of crop load on photosynthesis and dry matter partitioning of Seyval grapevines. III. Seasonal changes in dry matter partitioning, vine morphology, yield, and fruit composition. Am. J. Enol. Vitic. 46:478-485.

*Howell, G.S., M. Carmo Candolfi-Vasconcelos, and W. Koblet. 1994. Response of Pinot noir grapevine growth, yield and fruit composition to defoliation the previous growing season. Am. J. Enol. Vitic. 45:188-191.

Howell, G.S. 1999. Issues in vine capacity: Growth, yield, photosynthesis, and carbohydrate partitioning. *In* Proceedings of the 7th Annual Lake Erie Regional Grape Grower's Conference, pp. 8-14.

Howell, G.S. 2003. Setting economic thresholds for grape leaf pests using photosynthesis and carbon budget. Ohio Grape-Wine Short Course, pp. 47-53. Feb 9-11.

*Miller, D.P., G.S. Howell, and J.A. Flore. 1996. A whole-plant, open, gas-exchange system for measuring net photosynthesis of potted woody plants. HortScience 31:944-946._

*Miller, D.P., G.S. Howell, and J.A. Flore. 1996. Effect of shoot number on potted grapevines: I. Canopy development and morphology. Am. J. Enol. Vitic. 47:244-250.

*Miller, D.P., G.S. Howell, and J.A. Flore. 1996. Effect of shoot number on potted grapevines: II. Dry matter accumulation and partitioning. Am. J. Enol. Vitic. 47:251-256.

*Nail, W.R., and G.S. Howell. 2004. Effects of powdery mildew of grape on carbon assimilation mechanisms of potted "Chardonnay" grapevines. HortScience 39:1670-1673.

*Nail, W.R., and G.S. Howell. 2005. Effects of timing of powdery mildew infection on carbon assimilation and subsequent seasonal growth of potted Chardonnay grapevines. Am. J. Enol.Vitic. 56:220-227.

*Petrie, P.R., M.C.T. Trought, and G.S. Howell. 2000. Growth and dry matter partitioning of Pinot noir (*Vitis vinifera* L.) in relation to leaf area and crop load. Austr. J. Grape Wine Res. 6:40-45.

*Petrie, P.R., M.C.T. Trought, and G.S. Howell. 2000. Fruit composition and ripening of Pinot noir (*Vitis vinifera* L.) in relation to leaf area. Aust. J. Grape Wine Res. 6:46-51.

*Petrie, P.R., M.C.T. Trought, and G.S. Howell. 2000. Influence of leaf aging, leaf area, and crop load on photosynthesis, stomatal conductance and senescence of grapevine (*Vitis vinifera* L. cv. Pinot noir) leaves. Vitis 39:31-36.

*Petrie, P.R., M.C.T. Trought, G.S. Howell, and G.D. Buchan. 2003. The effect of leaf removal and canopy height on whole-vine gas exchange and fruit development. Functional Plant Biol. 30:711-717.

*Smithyman, R.P., G.S. Howell, and D.P. Miller. 1998. The use of competition for carbohydrates among vegetative and reproductive sinks to reduce fruit set and Botrytis bunch rot in Seyval blanc grapevines. Am. J. Enol. Vitic. 49:163-179.

Roots & Rootstocks

Howell, G.S. 1985. Factors to consider in rootstock selection. Proc. Arkansas State Hortic. Soc. 106:132-135.

*Howell, G.S. 1987. *Vitis* rootstocks. *In* Rootstocks for Fruit Crops. R.C. Rom and R.F. Carlson (Eds.), pp. 451-472. Wiley & Sons, New York.

Howell, G.S. 1994. Seyval responds to grafting and rootstock choice. Vineyard Winery Mgt. 20:58-59.

Howell, G.S. 2005. Rootstock influence on scion performance. *In* Proceedings of the 2005 Rootstock Symposium. Grapevine Rootstocks: Current Use, Research and Application. P. Cousins and R.K. Striegler (Eds.), pp. 47-55.

*McLean, M., G.S. Howell, and A.J.M. Smucker. 1992. A minirhizotron system for *in situ* root observation studies of Seyval grapevines. Am. J. Enol. Vitic. 43:87-89.

*Striegler, R.K., G.S. Howell, and J.A. Flore. 1993. Influence of rootstock on the response of Seyval grapevines to flooding stress. Am. J. Enol. Vitic. 44:313-319.

Training & Crop Control

*Byrne, M.E., and G.S. Howell. 1978. Initial response of Baco noir grapevines to pruning severity, sucker removal, and weed control. Am. J. Enol. Vitic. 29:192-198.

Howell, G.S. 1990. Approaches to pruning and training Vignoles grapevines in Michigan. *In* Proceedings of the 5th Mid-West Regional Grape and Wine Conference, pp. 1-5. Missouri Department of Agriculture.

Howell, G.S. 1998. Carbohydrate partitioning in grapevines. *In* Proceedings of the 4th Annual Romeo Bragato Conference, pp. 57-69. New Zealand Grape Growers Council.

Howell, G.S. 2000. Grapevine crop control: Implications for yield, fruit composition and subsequent wine quality, cold hardiness and sustainable production. Wine East Sept-Oct:12-19, 47-49.

*Howell, G.S. 2001. Sustainable grape productivity and the growth-yield relationship: A review. Am. J. Enol. Vitic. 52:165-174.

Howell, G.S. 2003. Selecting an appropriate trellis/training system based on specific variety characteristics. *In* Proceedings of the 22nd Annual Hort. Industry Show, pp. 121-129. Springdale, AK.

Howell, G.S. 2003. Vine productivity: What are the limits? Proc. Viticulture 2003, pp. 56-65. Buffalo, NY.

*Howell, G.S., T.K. Mansfield, and J.A. Wolpert. 1987. Influence of training system, pruning severity, and thinning on yield, vine size and fruit quality of Vidal blanc grapevines. Am. J. Enol. Vitic. 38:105-112.

*Howell, G.S., D.P. Miller, C.E. Edson ,and R.K. Striegler. 1991. Influence of training system and pruning severity on yield, vine size, and fruit composition of Vignoles grapevines. Am. J. Enol. Vitic. 42:191-198.

*Howell, G.S., and R.K. Striegler. 1986. Pruning grapevines in Michigan. Michigan Coop. Ext. Bull. E-1935. 4 pp.

*Koblet, W., M.C. Candolfi-Vasconcelos, E. Aeschimann, and G.S. Howell. 1993. Influence of defoliation, rootstock, and training system on Pinot noir grapevines. I. Mobilization and reaccumulation of assimilates in woody tissue. Vitic. Enol. Sci. 48:104-108.

*Koblet, W., M.C. Candolfi-Vasconcelos, W. Zweifel, and G.S. Howell. 1994. Influence of leaf removal, rootstock, and training system on yield and fruit composition of Pinot noir grapevines. Am. J. Enol. Vitic. 45:181-187.

*Koblet, W., M.C. Candolfi-Vasconcelos, S. Howell, and W. Zweifel. 1994. Einfluss von Erzeihungssystem, Unterlage und Auslauben auf die Leistung der Rebe. Schweiz Zeitchrift für Obst- und Weinbau 23(4):554-556.

*Miller, D.P., G.S. Howell, and R.K. Striegler. 1993. Reproductive and vegetative response of mature grapevines subjected to differential cropping stress. Am. J. Enol. Vitic. 44:435-440.

*Miller, D.P., and G.S. Howell. 1996. Influence of vine capacity and crop load on the yield, fruit composition and sugar production per unit land area of Concord grapevines. *In* Proceedings for the Fourth International Symposium on Cool Climate Viticulture & Enology. T. Henick-Kling et al. (Eds.), pp. 94-98. NYSAES, Geneva, NY.

*Miller, D.P., G.S. Howell, and J.A. Flore. 1997. Influence of shoot number and crop load on potted Chambourcin grapevines. II. Whole-vine vs. single-leaf photosynthesis. Vitis 36:109-114.

*Miller, D.P., and G.S. Howell. 1998. Influence of vine capacity and crop load on canopy development, morphology, and dry matter partitioning in Concord grapevines. Am. J. Enol. Vitic. 49:183-90.

Nail, W.R., and G.S. Howell. 2006. Pruning and training system effects on yield and vegetative growth of Concord grapevines in Michigan. *In* Proceedings of the Sixth International Cool Climate Symposium for Viticulture and Oenology, p. 68. Christchurch, New Zealand.

*Smithyman, R.P., G.S. Howell, and D.P. Miller. 1997. Influence of canopy configuration on vegetative development, yield and fruit composition of Seyval blanc grapevines. Am. J. Enol. Vitic. 48:482-91.

Enology

*Giannakopolus, P.I., P. Markakis, and G.S. Howell. 1984. The influence of malolactic strain on the fermentation and wine quality of three Eastern red wine grape cultivars. Am. J. Enol. Vitic. 35:1-4.

*Howell, G.S., and D.P. Miller. 1992. Method for producing and using oak in divided form for flavoring wine. U.S. Patent No. 5, 102, 675.

*Miller, D.P., and G.S. Howell. 1989. The effect of various carbonic maceration treatments on must and wine composition of Marechal Foch. Am. J. Enol. Vitic. 40:170-174.

Miller, D.P., and G.S. Howell. 1989. Techniques and equipment for small scale wine production. Proc. Mich. State Hortic. Soc. 119:147-156.

Miller, D.P., and G.S. Howell. 1990. Evaluating methods for producing Nouveau style wines. Vineyard Winery Mgt 16(2):27-28.

*Miller, D.P., G.S. Howell, C.S. Michalis, and D.I. Dickman. 1992. The content of phenolic acid and aldehyde flavor components of white oak as affected by site and species. Am. J. Enol. Vitic. 43:333-338.

*Miller, D.P., and G.S. Howell. 1995. American white oak: Is it time for a regional classification system? Prac. Winery Vineyard 15(5):53-57.

*Wampfler, D.J., and G. S. Howell. 2004. Simplified method for detection and quantification of 2-methoxy-3-isobutylpyrazine in wine. Am. J. Enol. Vitic. 55:276-278.

Statistics & Sampling

*Evert, D.R., and G.S. Howell. 1979. The modified Friedman Test: A simple alternative to the F-test for the randomized complete blocks design. HortScience 14:19-20.

*Wolpert J.A., G.S. Howell, and C.E. Cress. 1980. Sampling strategies for estimates of cluster weight, soluble solids and acidity of 'Concord' grapes. J. Am. Soc. Hortic. Sci. 105:434-438.

*Wolpert, J.A., G.S. Howell, and T. Mansfield. 1983. Sampling Vidal blanc grapes. I. Effect of training system, pruning severity, shoot exposure, shoot origin, and cluster thinning on cluster weight and fruit quality. Am. J. Enol. Vitic. 34:72-76.

*Wolpert, J.A., and G.S. Howell. 1984. Sampling Vidal blanc grapes. II. Sampling for precise estimates of soluble solids and titratable acidity of juice. Am. J. Enol. Vitic. 35:242-246.

Variety Evaluation

Howell, G.S., and S.S. Stackhouse. 1974. Wine grape research at Michigan State University. Wines Vines (Sept):45-47.

Howell, G.S. 1986. Grape varieties for Michigan's vineyards. Michigan Coop. Ext. Bull. E-1899. 4 pp.

Howell, G.S. 1995. Chardonel: How does this new variety compare with Eastern industry standard cultivars? Vineyard Winery Mgt. 21(6):43-44.

Howell, G.S., D. Miller, M. McLean, and R. Smithyman. 1993. Pinot noir, Cabernet Sauvignon and Champagne Clonal Evaluation Trials and Seyval Cultural Trial. 1992 Annual Report, Southwest Michigan Research Extension Center. 68 pp.

Howell, G.S., D. Stocking, D. Miller, J.A. Wolpert, and C. Vasconcelos. 2000. Status of Pinot noir in Michigan: A Report of Clonal Trials. Michigan Grape and Wine Ind. Council and Michigan State University. 31 pp.

*Reisch, B.I., R.M. Pool, W.B. Robinson, T. Henick-Kling, J.P. Watson, K.H. Kimball, M.H. Martens, G.S. Howell, D.P. Miller, C.E. Edson, and J.R. Morris. 1990. 'Chardonel' Grape. New York Food and Life Science Bull. No. 132.

Smithyman, R., E. Weber, G.S. Howell, and M. Redford. 2006. Clones and cultivars for cool climates. *In* Proceedings of the Sixth International Cool Climate Symposium for Viticulture and Oenology, p. 35. Christchurch, New Zealand.

Striegler, R.K., G.S. Howell, and D.P. Miller. 1987. On some marginal sites, growing vinifera is an economic–not a viticultural question. Vineyard Winery Mgt. 13:52-53.

*Indicates referred publication.