2017

VITICULTURAL CONSULTING

FOR THE COLORADO GRAPE INDUSTRY

FINAL REPORT

Colorado Wine Industry Development Board

Prepared by:

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Colorado Viticultural Consulting Project

By: Dr. Imed Dami, Professor & Viticulture Specialist

Final Report

Executive Summary

This project hired a viticultural consultant, Dr. Imed Dami with experience in cold-climate viticulture to provide one-on-one assistance to participating grape growers as well as to offer educational seminars to the entire Colorado wine and grape industry. In March, April, and August 2017, Dami made three (3) trips to Colorado and visited vineyards in all four grape growing regions including northeastern Front Range, Grand Valley AVA and Mesa County, West Elks AVA and Delta/Montrose Counties, and the Four corners area. Growers' experience in grape growing ranged from 4 to 20+ years and their vineyard size ranged from less than one acre to more than 50 acres. During these visits, Dami interviewed growers to learn about issues in their vineyards. Dami also made his own assessments by investigating the vineyards for additional issues not reported by growers. During the visits, Dami provided on-site recommendations to participating grape growers followed with written reports. Dami also presented three seminar series, two in Grand Junction and one in Fort Collins that covered several topics with the primary focus on improving fruit quality and vine health. In this final report, Dami provides recommendations of future viticulture research and enhancing growers' education using methods that have been proven successful in other industries.

Summary of Performance Activities During Visits

Performance Activities – Trip 1:

1. Date of trip: March 28 to April 1, 2017.
2. Date and time of seminar: March 29, 9:00am - 2pm.
3. Location: Western Colorado Community College campus, Grand Junction.
4. Presentation title: "Mitigating Cold Damage of Grapevines" (See Appendix).
5. Number of consultations (6): four in Grand Valley AVA; one in West Elks AVA. Dami also visited the CSU research vineyard.

Performance Activities – Trip 2:

1. Date of trip: April 25 to April 28, 2017.
2. Date and time of seminar: April 26, 2 pm - 5pm.
3. Location: Colorado State University, Fort Collins.
4. Presentation title: "Mitigating Cold Damage of Grapevines" (See Appendix).
5. Number of consultations (6): two in Front Range; four in Four Corners Area.

Performance Activities – Trip 3:

1. Date of trip: August 9 to 12, 2017.
2. Date and time of seminar: August 11, 1 pm - 5pm.
3. Location: Western Colorado Community College campus, Grand Junction.
4. Seminar theme: "Best Viticulture Practices for Premium Wines from Healthy Vines".
5. Presentations titles:
   a. Vine Balance & Crop load
   b. Irrigation Management
   c. Managing Hybrids vs. Vinifera
   d. Vine Nutrition
6. Number of consultations (2): one in Grand Valley AVA. Dami also visited the CSU research vineyard to be informed with current viticulture research projects.

During the third trip, Dami organized a half-day seminar and presented topics that he deemed important for grape growers based on his earlier vineyard visits in April and May 2017 and issues shared by growers during those visits. Dami coordinated presentations with Dr. Caspari to compliment CSU outreach program and to provide consistent viticultural information and avoid redundancy.

Summary of Issues Reported by Growers

Issues described by growers were often dependent on their years of experience in growing grapes and level of familiarity and/or involvement with the grape and wine industry in Colorado. The following is a summary of the main issues/concerns reported by growers.

<u>Experienced Growers</u>:

- Cold damage from early frost fall, mid-winter freeze, and late spring frost events
- Lack of consistent production due to cold damage
- Cultural issues related to specific varieties grown in specific areas
- No incentives by wineries for higher quality grapes
- Low yields (mostly in cold injury-prone or short season/high elevation areas)
- Inexperience with hybrid varieties and how to manage them
- Recent concern about phylloxera introduction to and infection of Colorado vineyards
- Challenges of "higher" elevation (6000 - 7000 ft asl) viticulture
- Regional isolation reported mostly from the new growing regions.

New Growers:

- Basic vineyard practices: pruning, training system, canopy management
- (Perceived) Lack of cooperation and networking between existing and new growers
- Deficiency (not enough) of direct contact and one-on-one consultation
- Sourcing local technical information.

Summary of Issues Based on Dami's Observations

The following is a summary of observations made by Dami during his vineyard visits (12 to commercial vineyards and 2 to CSU vineyards) and interviews with growers (one or two growers present during each visit). These consultations lasted between 2.5 and 3.5 hours each. Overall, clients are enthusiastic growers who have good viticulture skills and apply good cultural practices and have genuine interest in improving their products. So they may not necessarily represent all growers in any given region. Even though wine tasting was not the focus of Dami's consultation, some winery owners offered tastings. Wines from locally–grown varieties were sampled from four wineries in two regions (Grand Valley and Four Corners). All wines were of good to excellent quality. It is noteworthy that the wines from both vinifera and hybrid grapes grown in the Four Corners area were of high quality, an indication of the potential of the area.

1. [Variety – site] matching: In many instances, types of varieties grown and where they are grown are not ideal matches. For example, the most common mistake is growing a cold sensitive variety on a site prone to cold injury. Therefore, matching varieties with site is critical for consistent production and one way to improve yield and total state production.

2. Cold damage: Losses due to cold damage are exacerbated due to poor [variety - site] matching. Some regions (higher elevation and colder) will continue to have more frequent cold damage issues if mitigation strategies are not implemented.

3. Production practices: Even though all growers-vintners, that Dami interviewed, want to produce quality wines, many don't have a solid grasp of all the cultural practices involved in the vineyard to achieve that. Basic viticultural principles are not well understood and thus not applied properly, or not adopted. Examples include managing vine balance through crop load control, irrigation and nutrient managements. All these practices, considered required, were addressed by Dami during the summer seminar (see Appendix).

4. Managing hybrids: Most growers, Dami consulted with, are experienced vinifera producers, but almost all are not familiar with managing hybrids especially the "newer" varieties that have been released in the past 5-15 years.

5. Extending research findings: Many growers addressed area-specific issues encountered in their vineyards (e.g. cover crop) and asked me for recommendations. Yet, almost all are not aware that Dr. Caspari at CSU is actively working on those issues through research funded by the Colorado Wine Industry Development Board (CWIDB). This was noticed by Dami in more than one instance and in all regions. There is an obvious communication issue of extending research findings by CSU to the end users.

6. Phylloxera: Dami visited infected vineyards including that at CSU. The level of concern by growers was mixed. Some want to take immediate action to remedy the problem. Others are still weighing the magnitude of the problem and are in the "wait and see" mode. This a serious problem that needs to be addressed immediately with short- and long-term mitigations strategies.

7. Communication: communication among industry partners and leaders is almost always an issue in many industries and not unique to Colorado. Some communication issues, though, are simple and easy to fix such as having a COMMON MASTER LIST of all industry members that is shared and updated by industry leaders and involved associations. This way all members receive the same updates and news. Some growers I visited indicated they did not know about my visits until late because they were on one mailing list and not another.

Recommendations

Dami is a strong proponent of stakeholder's engagement. This approach develops producers' empowerment, leaders' transparency, and trust among industry partners. Seeking industry input on research and education priorities through surveys is one way to engage growers. Dami has used this approach for many years in Ohio and it has worked. Dami is willing to share further details on this topic with the CWIDB if this is an option to pursue. Furthermore, the following list of recommendations (below) have been adopted in other industries (e.g. Illinois, Virginia, Ohio) with positive outcomes.

Research:

1. [Variety – site] matching research: Addressing the matching between variety and site is a long-term endeavor. It took hundreds of years for Europeans to master terroirs and wine regions that are now world famous. Colorado is still a relatively young industry

and it is important to evaluate and identify the unique terroirs in Colorado by pursuing the following objectives:

a. *Establish variety evaluation trials in new AVAs in Colorado* (e.g Front Range and Four Corners). This is important for the new AVAs to determine what grows best, and just as important what not to grow. Dami noted that there are mesoclimates in the Four Corners that have tremendous potential to grow premium grapes (vinifera or interspecific hybrids). Dr. Caspari is involved in variety evaluation and this effort should continue and be supported at the state level. Dami is aware of CSU trials at Orchard Mesa and Roger Mesa and another one with a cooperating grower in Fort Collins. It would be ideal to expand and establish another variety trial with a cooperating grower in the Four Corners Area.

b. *Establish variety evaluation trials in "old" AVAs in Colorado:* It is just as important to introduce *new varieties and clones* in the Grand Valley AVA and test their viticultural and enological performances as well.

2. Vineyard site suitability research using GIS: The determination of suitable vineyard sites and varieties can be accelerated using new technologies such as GIS, GPS, remote sensing, and prediction models. Dami was involved with a GIS project in collaboration with Virginia Tech that produced online tools to predict suitable vineyard sites in 20 states in the East. An example of a vineyard report using this online tool is included (See Appendix). This service has been very popular and has helped thousands of existing and potential grape growers. Dr. Caspari is currently conducting similar GIS work in the Four Corners Region. It would be worthwhile that the CWIDB considers funding this project by purchasing the service from Virginia Tech. This collaboration will enhance and accelerate the project outcome. Dami has worked on this project for five years and would be glad to provide guidance.

3. Phylloxera research: First, the efforts by CSU, CDA, and CWIDB and fast response to conduct a timely state-wide phylloxera survey are highly commendable. Second, the existing rootstock trial at CSU which was established 20+ years ago is an excellent example of preparedness for worst case scenarios and the benefits of long-term research projects. The current information collected on rootstocks by Dr. Caspari will be extremely valuable to make objective recommendations and provide research-based information to the industry in Colorado. Nevertheless, rootstock trials need to be expanded with more varieties of rootstocks tested in different regions of the state where grafted vines are grown. Short-term remedies should also be researched such as testing chemicals to eradicate phylloxera in infected vineyards.

4. Rootstock research: Rootstock trial is also critical for purposes other than phylloxera tolerance. In fact, most vineyard soils in Colorado have high pH (>7). Historically, own-rooted vinifera have tolerated these soils. However, once vinifera are grafted on rootstocks, their performances in these soils will be a completely different "ball game". Rootstocks have varying tolerance to pH, nutrient absorption, and drought. For example, C-3309 is the most common rootstock in the East and Midwest. However, C-3309 has performed poorly in Colorado soils (due to dry soils with high pH). The focus should be on rootstocks with a high tolerance to drought and high pH (e.g. rootstocks with *V. berlandieri* parentage including 5C, 420A, 110 R, etc).

5. Research on mitigating cold damage: This is an active area of research at CSU that is being addressed by Dr. Caspari. This research should continue and can be enhanced with collaboration with researchers who have experience dealing with similar issues in the East. Dami provided two talks on the topic of mitigating cold damage (See handouts in Appendix).

6. Hybrid production practices: To enhance growers' knowledge on managing hybrids, research should be conducted on best production practices (e.g. training system, cropload, pruning, etc) of new hybrids. Also, to avoid redundancy and reinventing the wheels, current best production practices of those varieties grown in the East and Midwest can be adopted in Colorado.

Extension/Outreach Education

1. Enhancing Extension education: Establish educational programs specific to grower's knowledge and experience on grape growing. In other words, short-courses (half-day) on "Grape Growing for Beginners" should be developed and presented. A similar approach could be used for intermediate and advanced viticulture teaching. Dami developed similar courses/training in three states and they were very effective.

2. Narrow/close the "know-how" gap in new regions: Provide more support to regions that are geographically isolated. For example, organize roadshows by bringing the experts to growers' backyards. Another example is to conduct the same workshop (e.g. pruning) in the different regions in Colorado. Also, use growers' vineyards as sites for workshop and research demonstrations. Again, this approach has worked well in other states and Dami has adopted it in Ohio and has been effective and appreciated by growers.

3. Enhance extension delivery methods: to reach the end-users timely and on a regular basis, so they remain abreast of new technical information and about upcoming educational events. This can be achieved via electronic newsletter and/or using social

media. There is a need to improve communicating research findings from CSU to the growers. In the same token, growers also need to be actively seeking this information (the summer seminar was not well attended). It is up to the CWIDB and CSU to determine the best methods of delivery of education programs.

4. New Viticulture Extension Specialist: The proposed ideas listed above would not be possible without a dedicated full-time positon in extension and outreach. This person will provide technical support, daily assistance via calls, emails, and conduct site visits (Dami has a template for position description if desired). It would not be realistic to expect Dr. Caspari to conduct the above Extension activities and at the same time maintaining his research program (I understand he also teaches in Fort Collins). In my 20+ years as an Extension specialist, extension education activities are most impactful and beneficial to growers in states where they have full-time Extension Specialist. This was true in Virginia (I held that position when I worked with Dr. Wolf), Illinois, and now in Ohio. We currently have a full-time position as Outreach specialist to address the day-to-day needs of the grape industry. Therefore, I highly recommend create a full-time position of a Viticulture Extension Specialist. If funds are not available, the CWIDB should consider funding a part-time position (for example during the growing season).

Additional thoughts

1. Uniqueness of high-altitude viticulture: Take advantage of Colorado's unique natural resources. The biggest is high elevation with intense sunlight. This unique resource is a free manufacturer of flavor compounds (phenolics, anthocyanins, tannins) that are desired in wines. Other industries would envy Colorado's conditions because they have to artificially add and/or modify vineyard practices to increase them. Think of and emulate the "Palisade Peaches" model which is famous nation-wide from growing to marketing and promoting the product.

2. Uniqueness of Colorado climate & terroir: Take advantage of the unique climate during the growing season with dry air and low to non-existent disease pressure. There is potential for low input viticulture which is highly desired world-wide. Also, organic viticulture should be explored and promoted in Colorado since organic farming is one of the fastest growing sectors in U.S. Agriculture. All this leads to a lower-cost product thus more competitive product in the market.

3. Uniqueness of variety portfolio diversification: Turn challenging areas where hybrids are grown to opportunities by producing premium wines. It should be known that the largest industries in the East have hybrids as their main grape acreage and production. I predict wines from hybrids to be unique like nowhere else in the country (CA, WA, and OR do not grow hybrids in high elevation). I tasted Baco noir in Colorado and wines

were excellent. Imagine adding to that list Aromella, Marquette, Noiret, LaCrescent, Frontenac gris/blanc, Itasca, etc. The point is variety diversification is part of grape production in cold regions. Having stated that, this does not mean vinifera should be abandoned; rather both should co-exist (even blended) to produce outstanding wines unique to Colorado.

4. Industry benchmark: Designate one or two industries with similar conditions as benchmarks for the Colorado grape and wine industry. Establish goals as milestones to accomplish in 5, 10, and 20 years. The best example of a benchmark industry that fits Colorado climate and challenges is that of Washington. Further, I had the opportunity to visit Chile and the Chilean grape and wine industry is a perfect example of how an industry has come from nowhere to become one of the largest and most prestigious in the world. The Chilean industry has emulated the California industry and has been transformed in the past 30 years.

Respectfully submitted by,

Imed Dami

Appendix

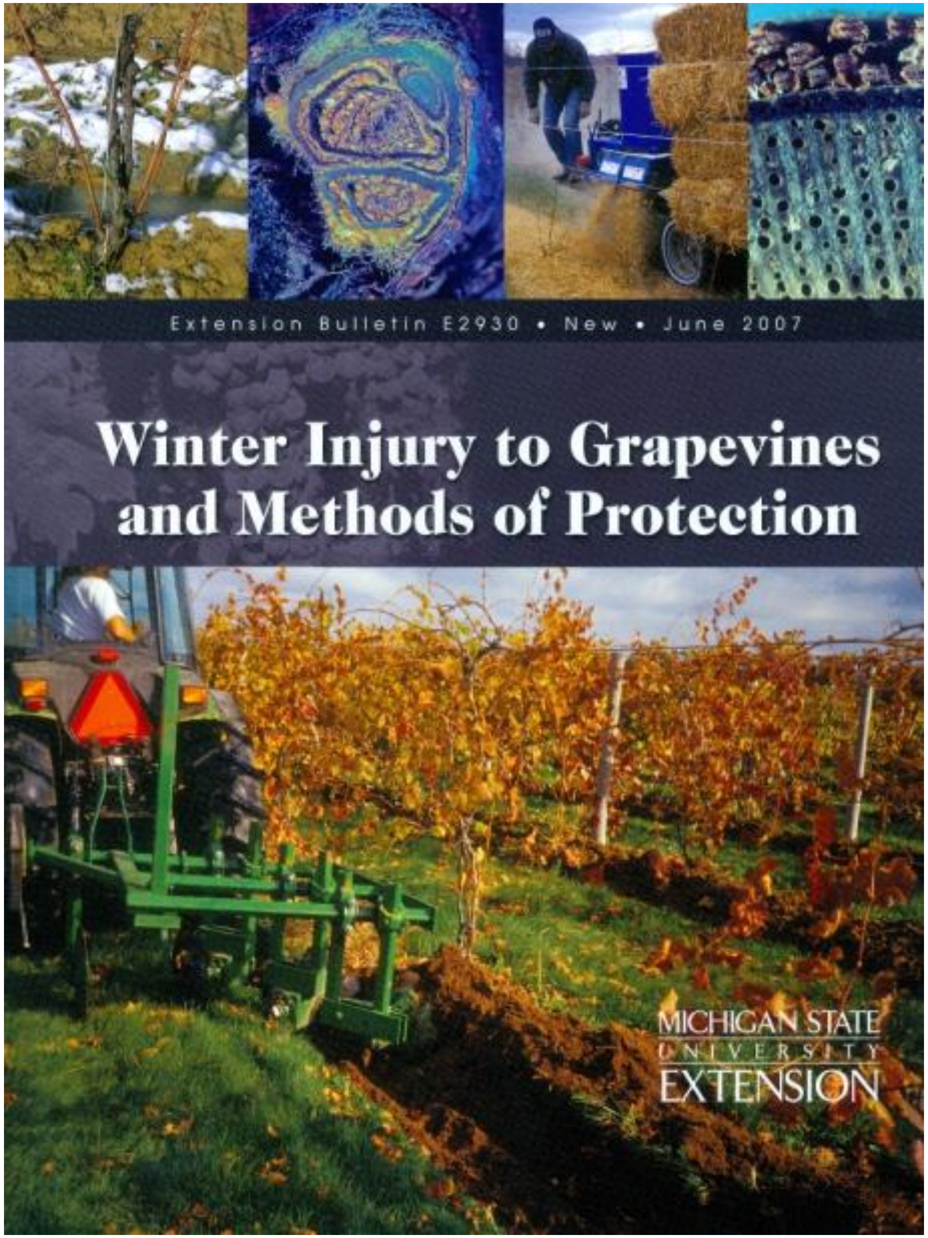
1. Cold Hardiness of Grapevines (Seminar 1)
2. Grapevine Recovery from Winter Damage (Seminar 2)
3. Best Viticulture Practices for Premium Wines from Healthy Vines (Seminar 3):
    a. Vine Balance and Crop load
    b. Irrigation Management
    c. Managing Vinifera vs. Hybrids
    d. Vine Nutrition
4. Vineyard Site Evaluation Report from Ohio (Online GIS Tool)

COLD HARDINESS OF GRAPEVINES
PART I

Imed Dami, PhD

Seminar Outline

- General information
- Grapevine cold hardiness
- Assessing grapevine cold injury
- Preventing grapevine cold injury



“Winter Injury to Grapevines and Methods of Protection”

Zabadal, T., I. E. Dami, M. Goffinet, T. Martinson, and M. Chien. 2007.

Extension Bulletin E2930, 106 pages. Michigan State University.

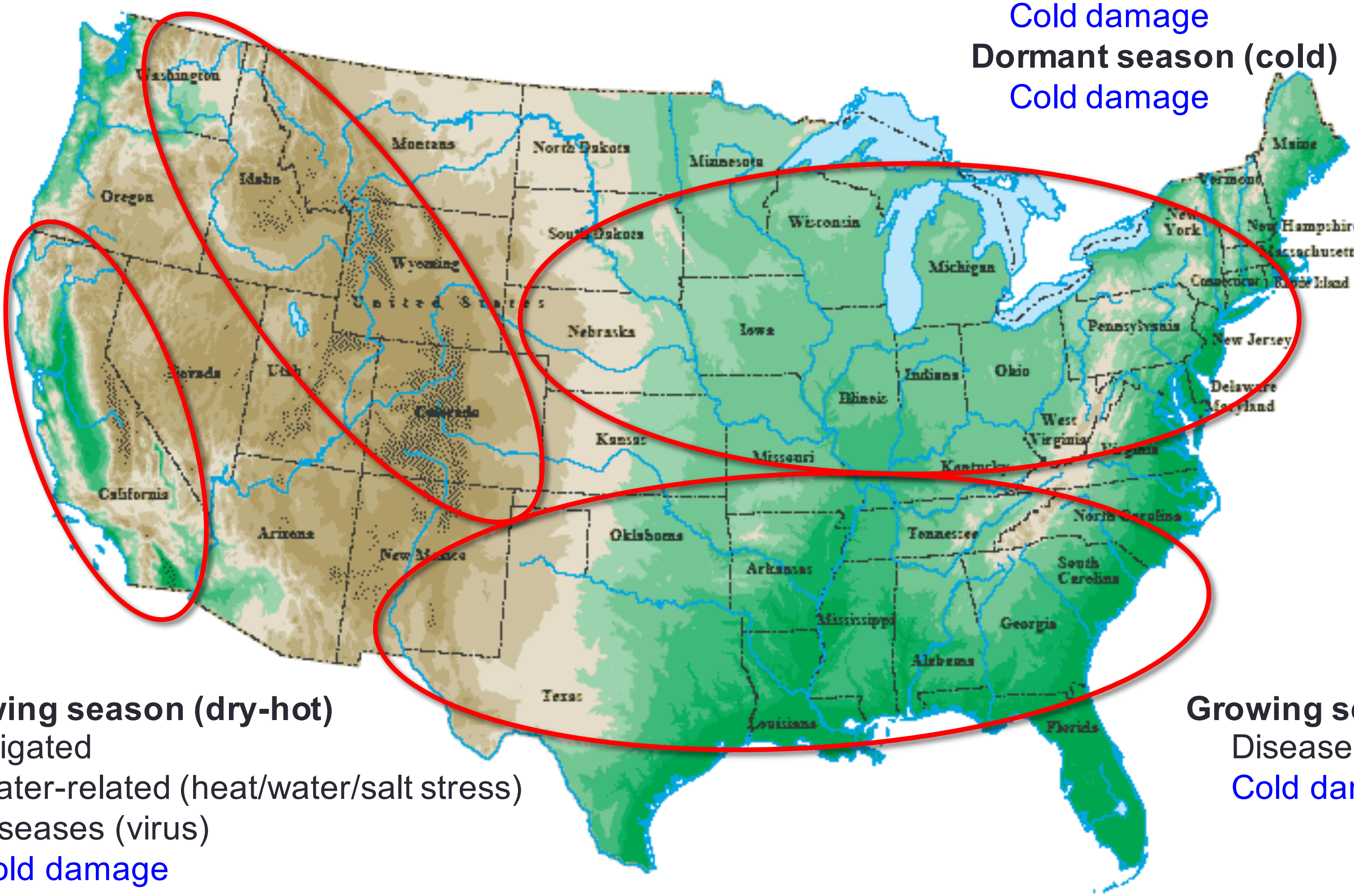
Challenges of Grape Growing

Growing season (dry-hot)
- Irrigated, own-rooted
- Cold damage

Dormant season (cold)
- Cold damage

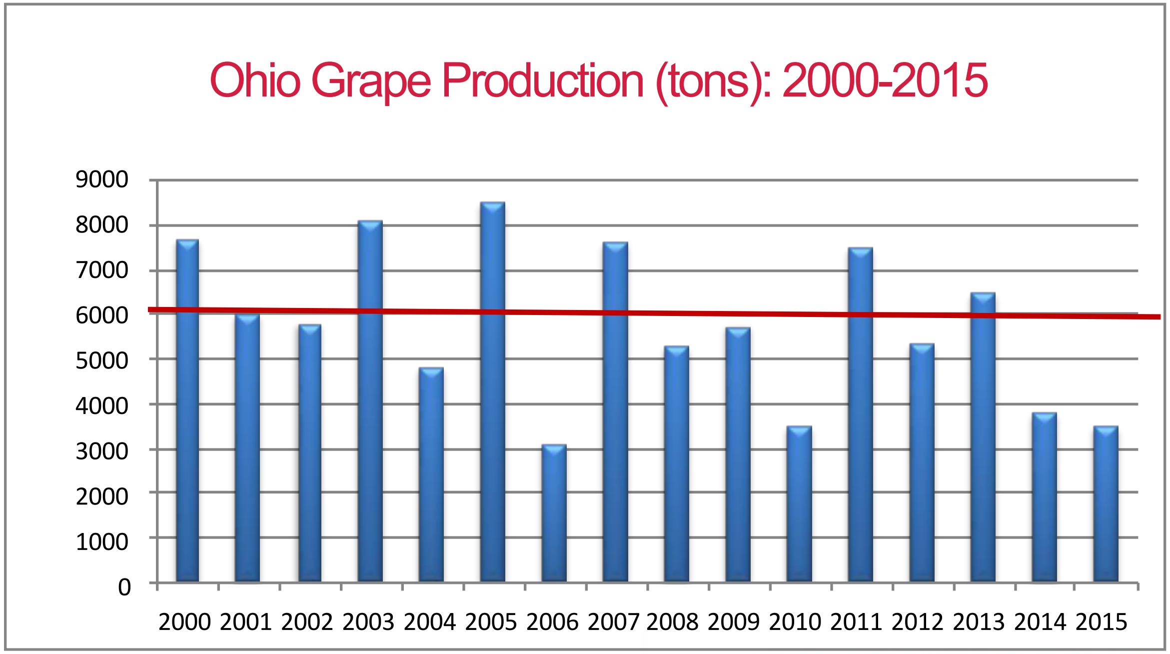
Growing season (wet-humid)
- Grafted
- Diseases, insects
- Cold damage

Dormant season (cold)
- Cold damage

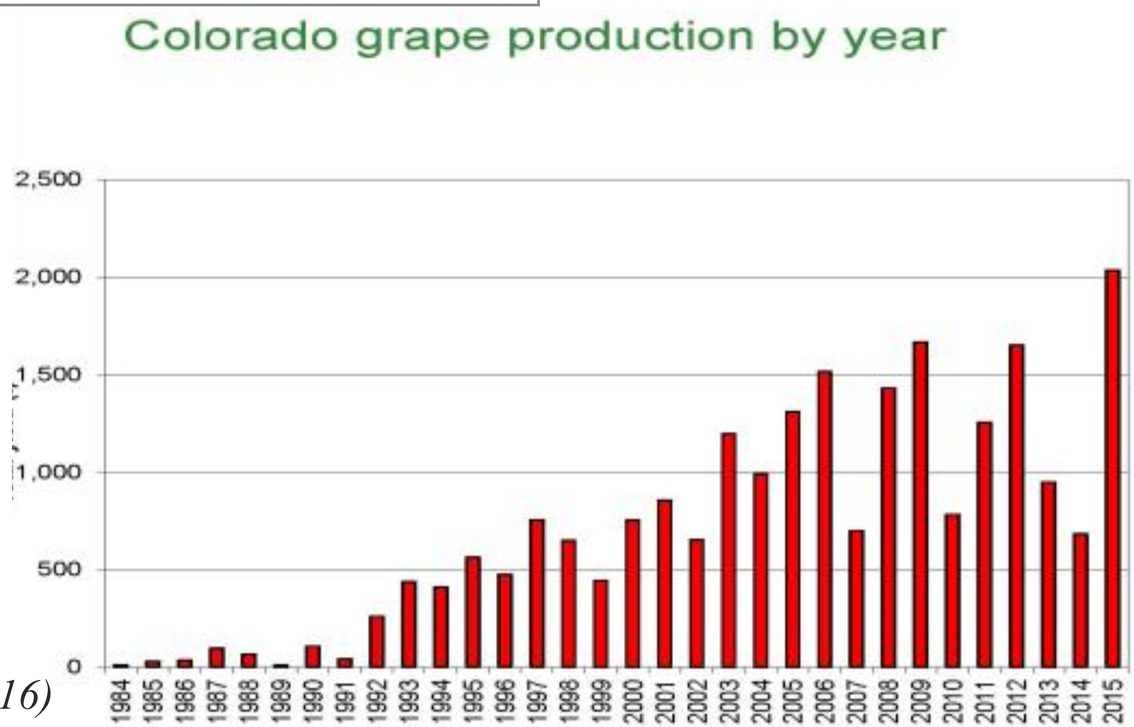


Growing season (dry-hot)
- Irrigated
- Water-related (heat/water/salt stress)
- Diseases (virus)
- Cold damage

Growing season (wet-hot)
- Diseases
- Cold damage



(Source: NASS)



(Source: Caspari, CSU 2016)

COLD DAMAGE IS A MAJOR LIMITING FACTOR FOR GRAPE PRODUCTION

Fall

Winter

Spring

*NY (2004): **$64M** total grape & wine loss*
*OH (2014): **$12M** 1-year loss*
*New York study: **$155/vine** loss (**$100K+/acre**)!*
*U.S. ('10 - '15): **$250M/year** (fruit)*

Cold acclimation vs. cold hardiness

Cold acclimation (hardening off): seasonal changes that result in a transition from a cold-tender to a cold-hardy state

Cold hardiness (freezing tolerance): ability of dormant grapevine tissues to survive freezing temperature stress during fall and winter

Cold Acclimation (Hardening-off)

- Induced by:
  - Short days
  - Low but above freezing temperatures

- Dormancy induction

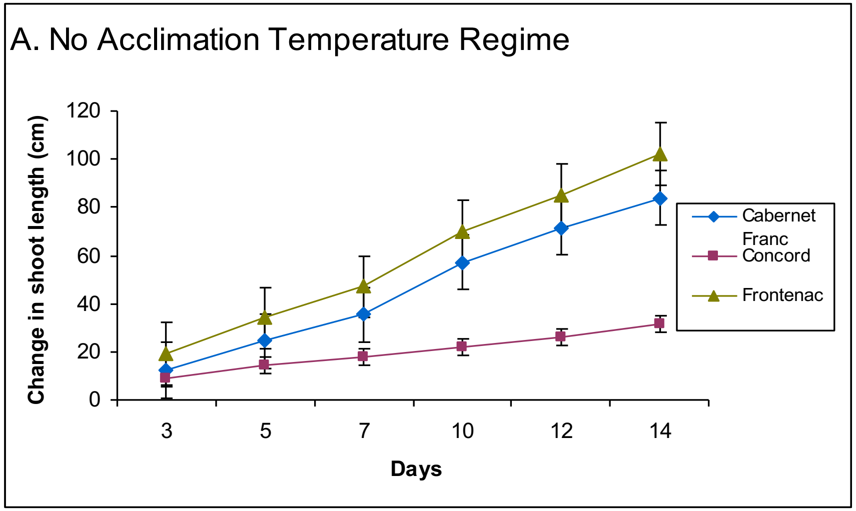
Visible Changes

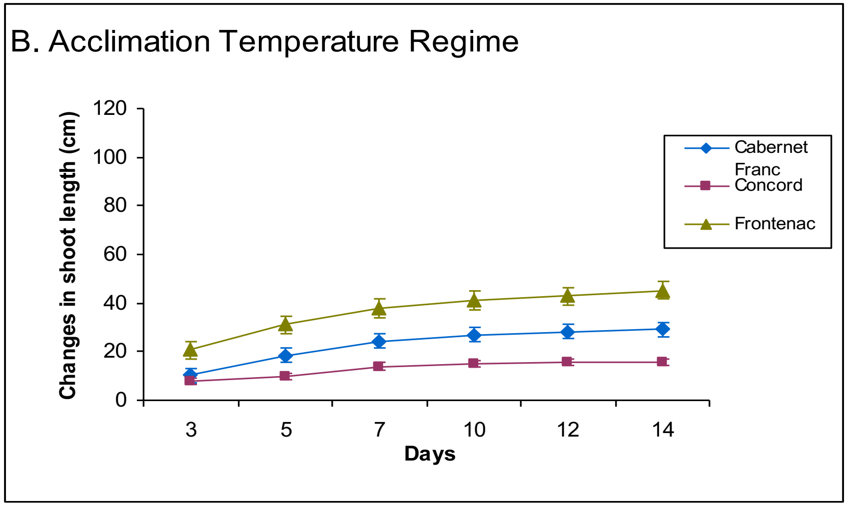
1) Shoot growth cessation

2) Shoot maturation (cane), periderm formation

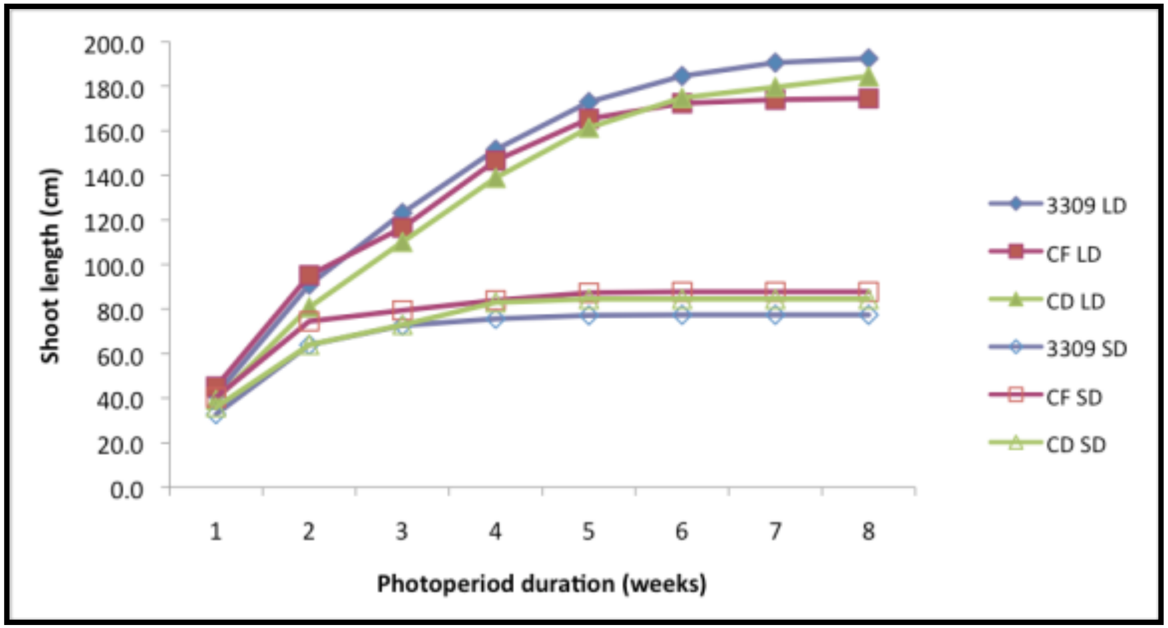
3) Leaf senescence and fall

Low temperature slows down shoot growth





Short days slow down shoot growth

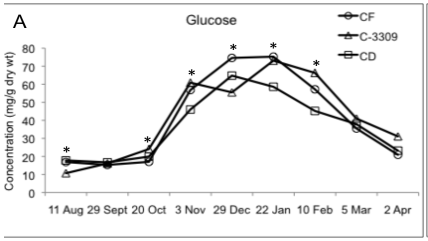


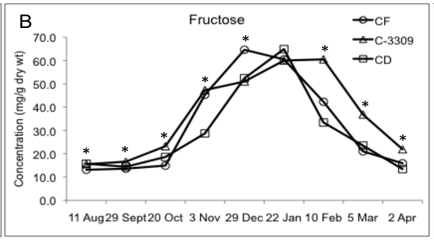
Short Day Long Day

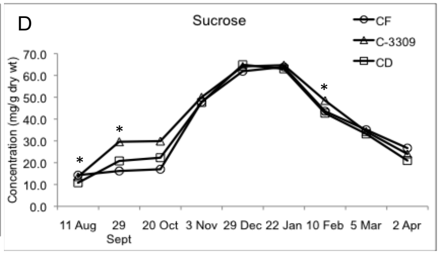
Cold Acclimation (Hardening-off)

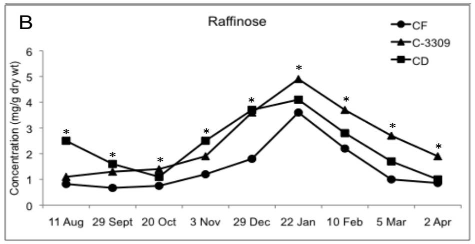
Internal Changes

- Tissue dehydration: decreased water content
- Accumulation of cell solutes (soluble sugars, proteins, amino acids)
- Changes in membrane composition (increased unsaturated fatty acids)
- ***Acquisition of cold hardiness (freezing tolerance)***



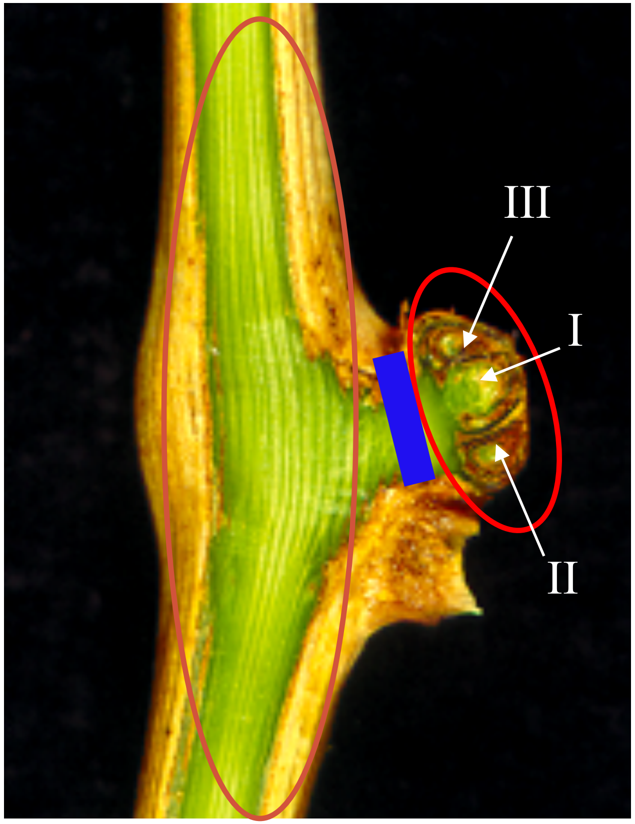






How do grapevines survive freezing stress?

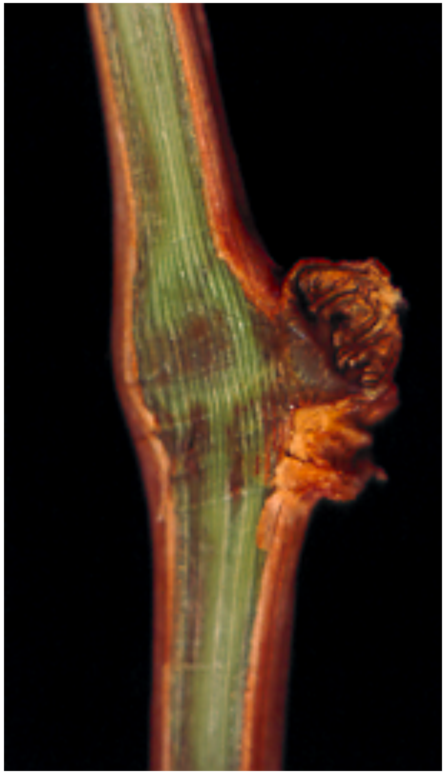
1) Freeze avoidance of buds by "**supercooling**": ability of water to remain liquid inside cells with subfreezing temperature
2) Freeze tolerance of canes: ability to tolerate intracellular dehydration in presence of extracellular ice
3) Presence of physical barrier (pectin) that stops ice propagation from cane to bud



Bud Cold Injury

Healthy

Freeze Event



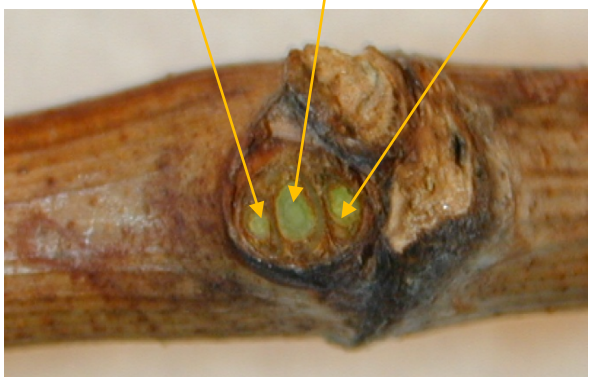
Cold Injured

How Do we Measure Cold Hardiness?

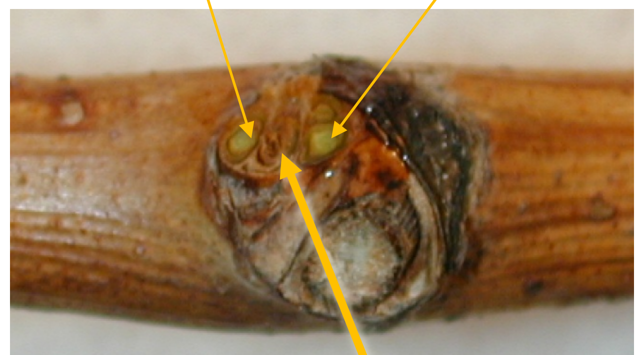
1) Field (outdoor) observations following a freezing event

- Canes collected, thawed, and buds excised and evaluated

Bud Damage Assessment

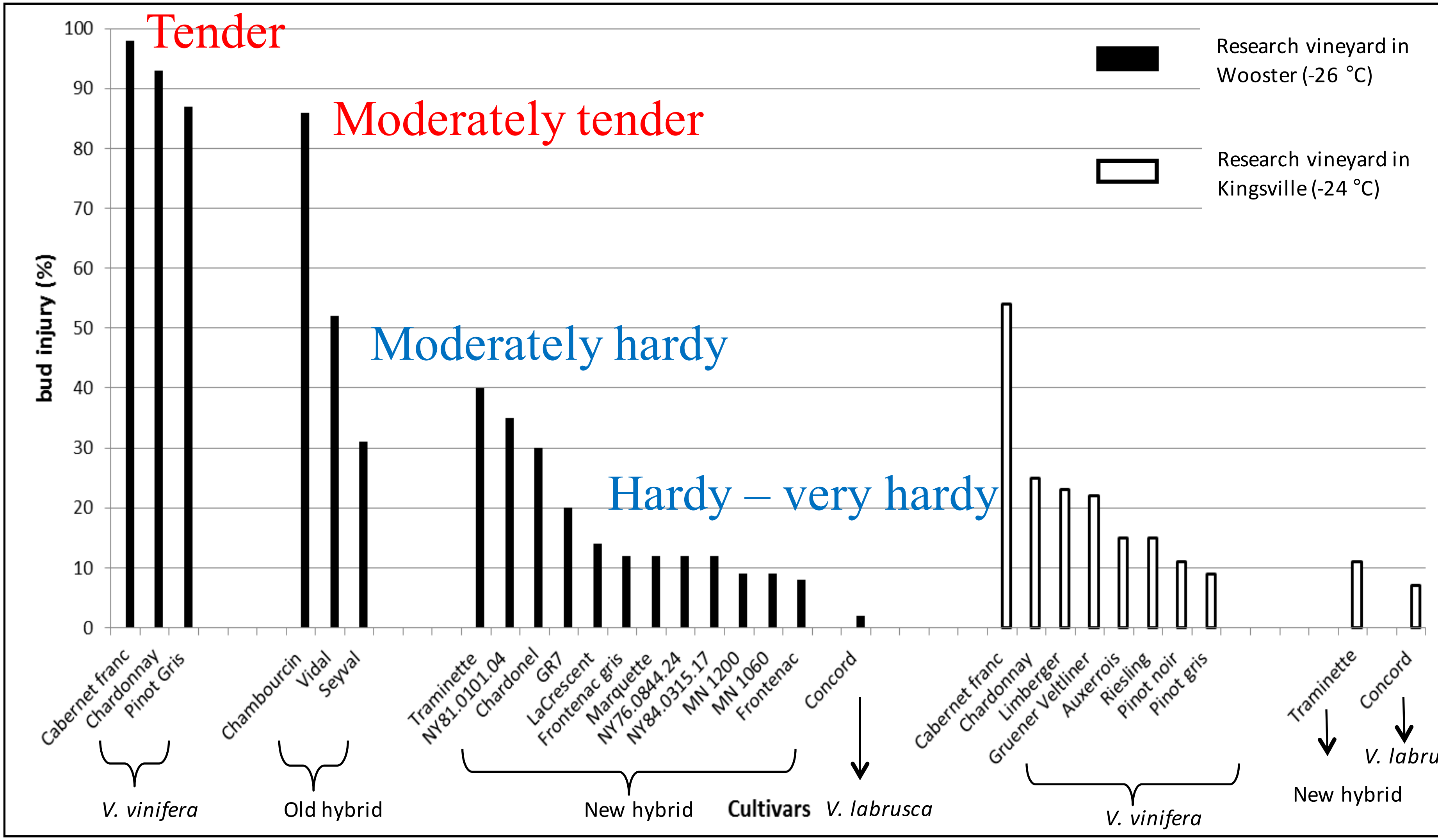


All 3 buds alive



Primary bud dead

Cold Hardiness -- Field Observation



Dami et al. 2012. AJEV

Freezing Injury Varies with Vine Parts

Least crop loss

1. Primary bud
2. Secondary bud
3. Tertiary bud

Bud injury

4. Cambium/phloem in cane
5. Xylem in cane

Cane injury

6. Cambium/phloem in arm/cordon/trunk
7. Xylem in arm/cordon/trunk
8. Whole trunk(s)

Cordon/trunk injury

9. Graft union, scion (die-back)
10. Scion/rootstock (vine death)

Vine death

Most crop loss

Cold hardiness is different among buds

Collection: 20 February 2015

Minimum temperatures and dates:

-6F (1/8), -9F (2/15), -10F (2/16), -9F (2/20), -11F (2/24)

Variety	I Bud damage	II Bud damage	III Bud damage
Frontenac	0	0	0
Marquette	3	3	3
Riesling	12	2	4
Traminette	16	12	10
Chardonnay	19	15	15
Aromella	30	4	4
Chambourcin	33	19	19
Cabernet franc	48	42	26

Cane size affects cold hardiness

Characteristics of “bull” shoot/cane

- Rapid and vigorous growth
- Long internodes (5-6 inches)
- Large diameter (>1/2inch)
- Flattened shape
- Many persistent laterals
- Poorly fruitful
- More cold tender (bud and vascular tissues) than normal cane.

Cold hardiness is different every season:
% Bud damage: 2015 vs. 2014 vs. 2009

Variety	% damage @ T = -10F 2015	% damage @ T= -11F 2014	% damage @ T= -11F 2009
Cab franc	48	100	54
Chardonnay	19	100	25
Traminette	16	80	11

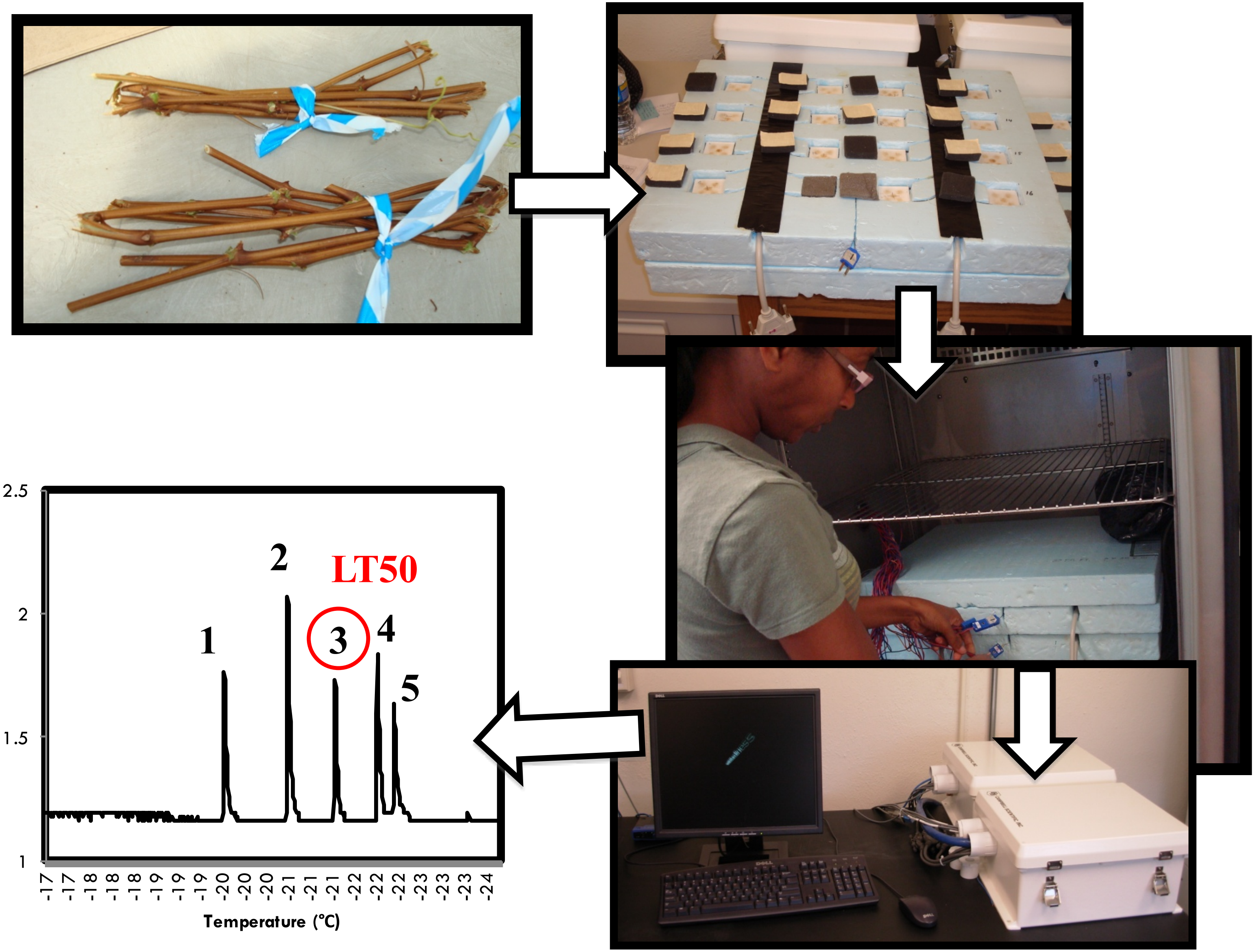
- Vines are very cold hardy in 2015 vs. 2014

Field Assessment

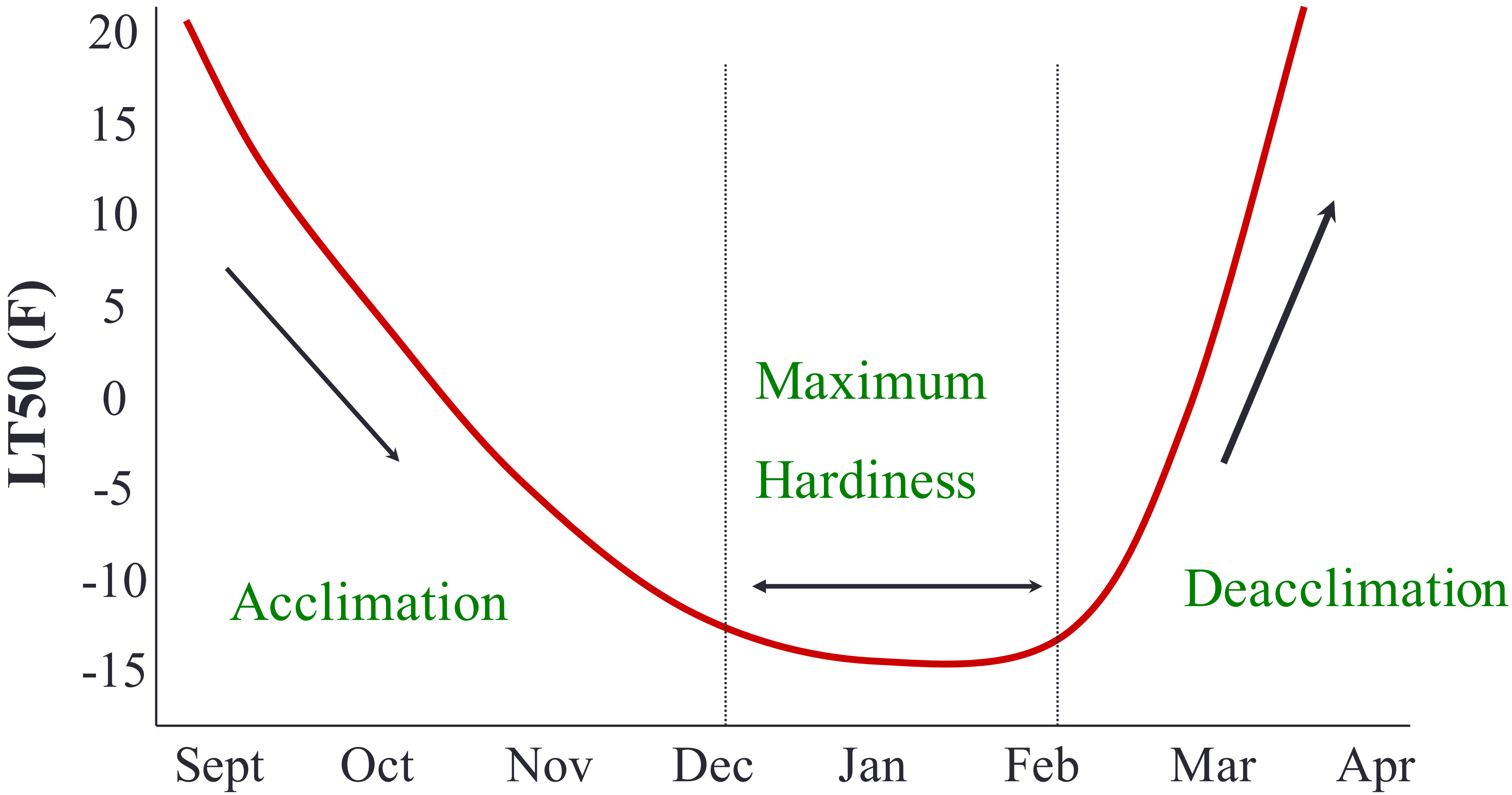
How Do we Measure Cold Hardiness?

1) Field (outdoor) observations following a freeze event
   - Canes collected, thawed, and buds excised and evaluated
2) Freeze event simulation (indoor) using a freeze chamber
   - Measure temperature that causes 50% bud kill called “Lethal Temperature 50” or **LT50**
   - LT50 expressed in ^{o}F or ^{o}C
   - E.g. LT50 = -10^{o}F means 50% of buds are killed at -10^{o}F

Cold Hardiness Determination in the Lab

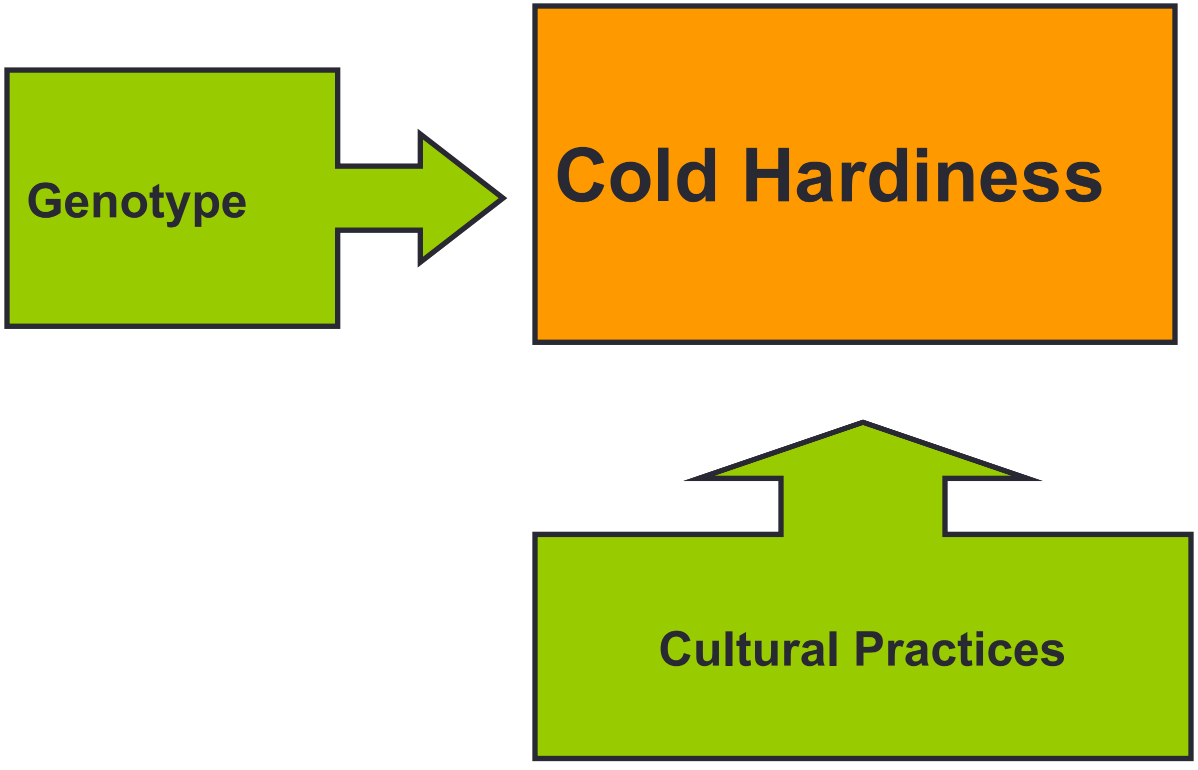


Profile of Grape Bud Hardiness
IT'S DYNAMIC

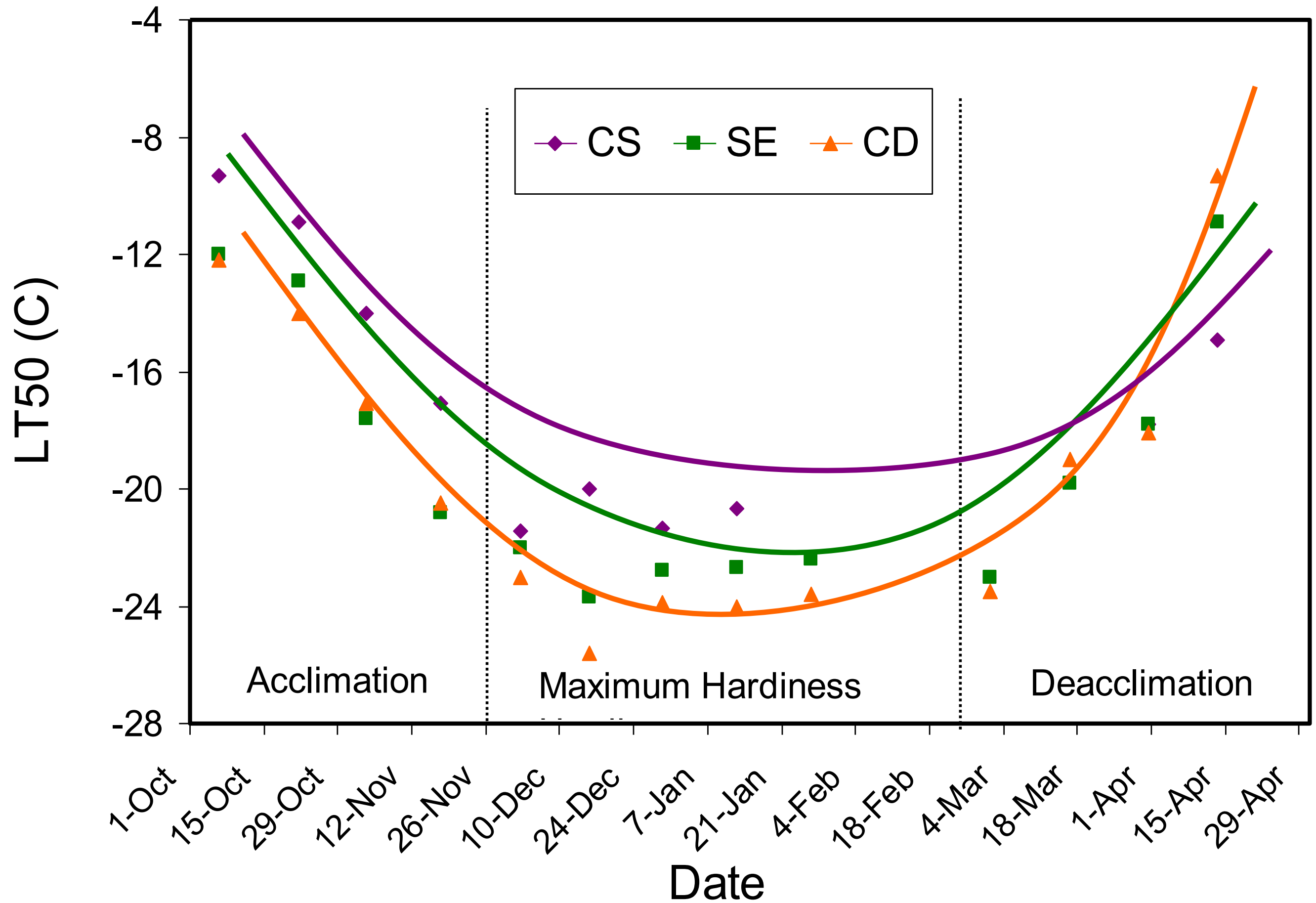


Factors Affecting Cold Hardiness

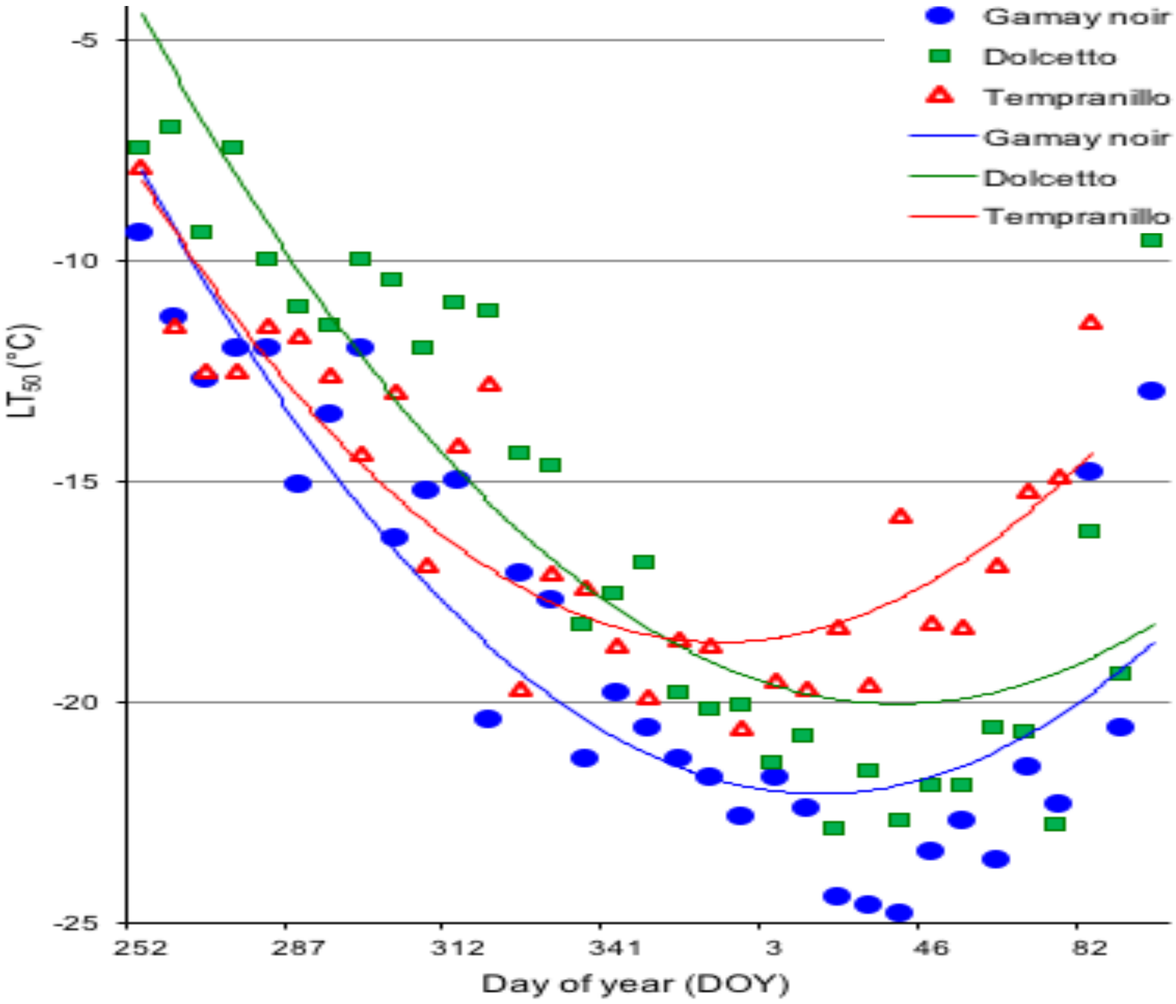
Genotype determines a vine's maximum cold hardiness potential. Environment and grower management determines how much of that potential is realized



Seasonal Changes of Cold Hardiness in Concord, Seyval, & Cabernet Sauvignon



Seasonal Changes of Cold Hardiness in Gamay, Dolcetto, & Tempranillo

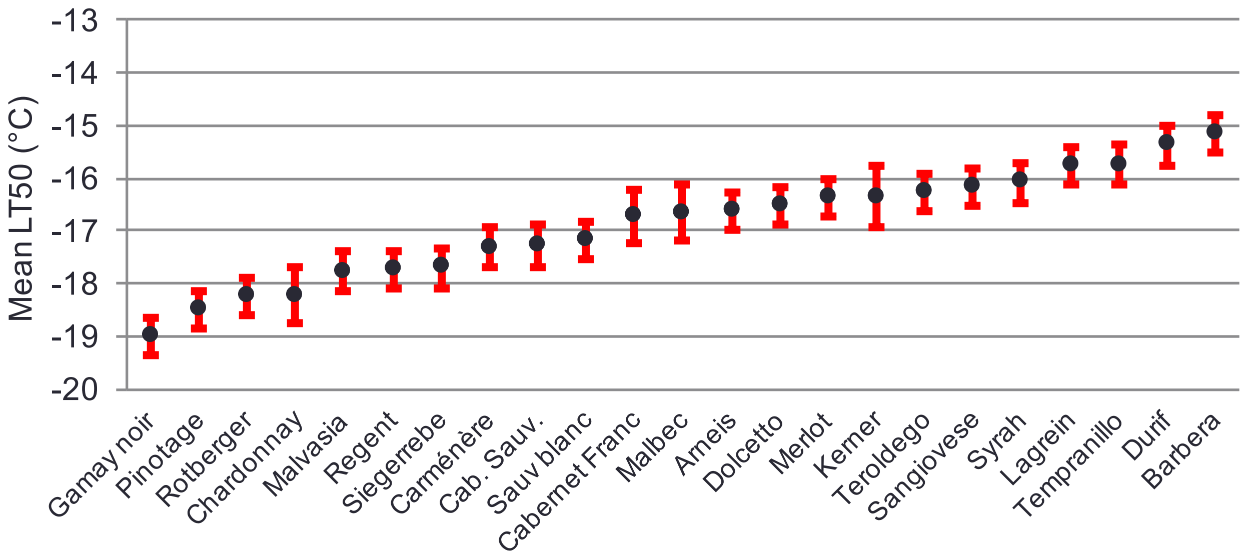


Cold Hardiness of Grape Genotypes

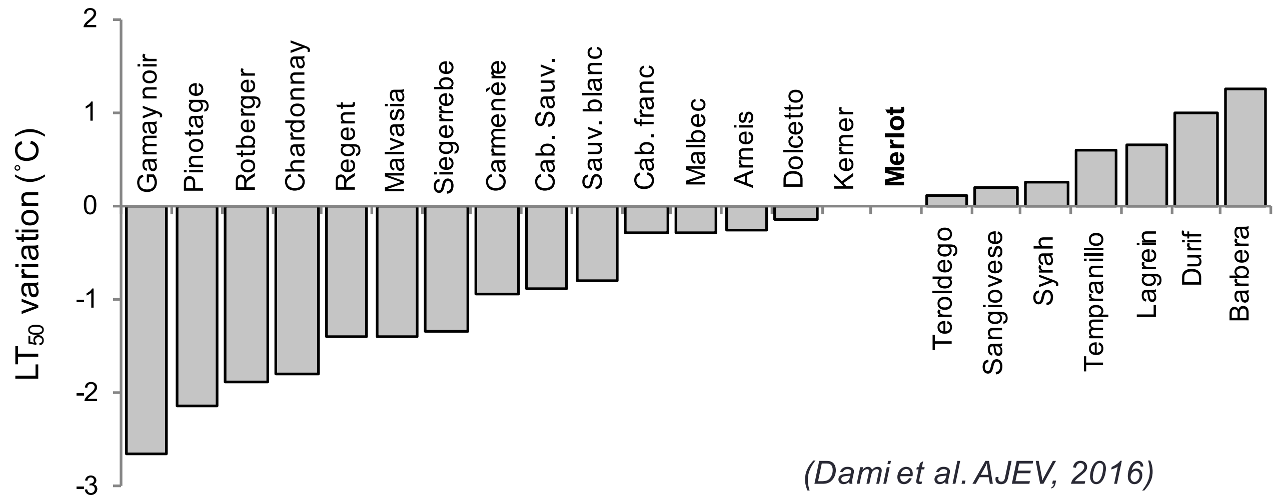
Cold hardiness class	Range of critical temp (LT50)	Species	Examples of varieties
Very tender	5 to -5	Most *V. vinifera*	Barbera, Merlot, Semillon, Syrah, Tempranillo, Durif
Tender	0 to -8	Most *V. vinifera*	Chardonnay, Cab Sauv, Gewurztraminer, Pinot gris, Pinot noir, Sauv. Blanc
Moderately tender	-5 to -10	Some *V. vinifera*, some hybrids	Riesling, Gamay, Lemberger, Chambourcin
Moderately hardy	-10 to -15	Most hybrids	Chardonel, Traminette, Norton, Seyval
Hardy	-15 to -20	Most *V. labrusca*	Catawba, Concord, Delaware
Very hardy	-20 to -30	Some hybrids	Frontenac, Foch, LaCrescent

(Zabadal et al. 2007)

Cold Hardiness of 23 Cultivars



AFT
Annual
Freezing
Tolerance



RAFT
Relative
Annual
Freezing
Tolerance

(Dami et al. AJEV, 2016)

Cold-Hardy & Super-Hardy Grapes

Cultivar/selection	% Bud Injury after -15F/2009	3/1/10	11/13/10	12/28/10
NY76.0844.24	12	-28	-25.9	-28.4
NY81.0315.17	35	-27	-25.8	-23.3
NY84.0101.04	13	-25.8	-23.3	--
Frontenac	8	-29.9	-25.2	-26.9
Frontenac gris	12	-29.5	-26.3	-27.4
LaCrescent	14	-27.4	-27.6	-27.7
MN 1200	9	-29.2	-26.6	-25.8
MN 1211	12	-26.7	-26.4	-28.6

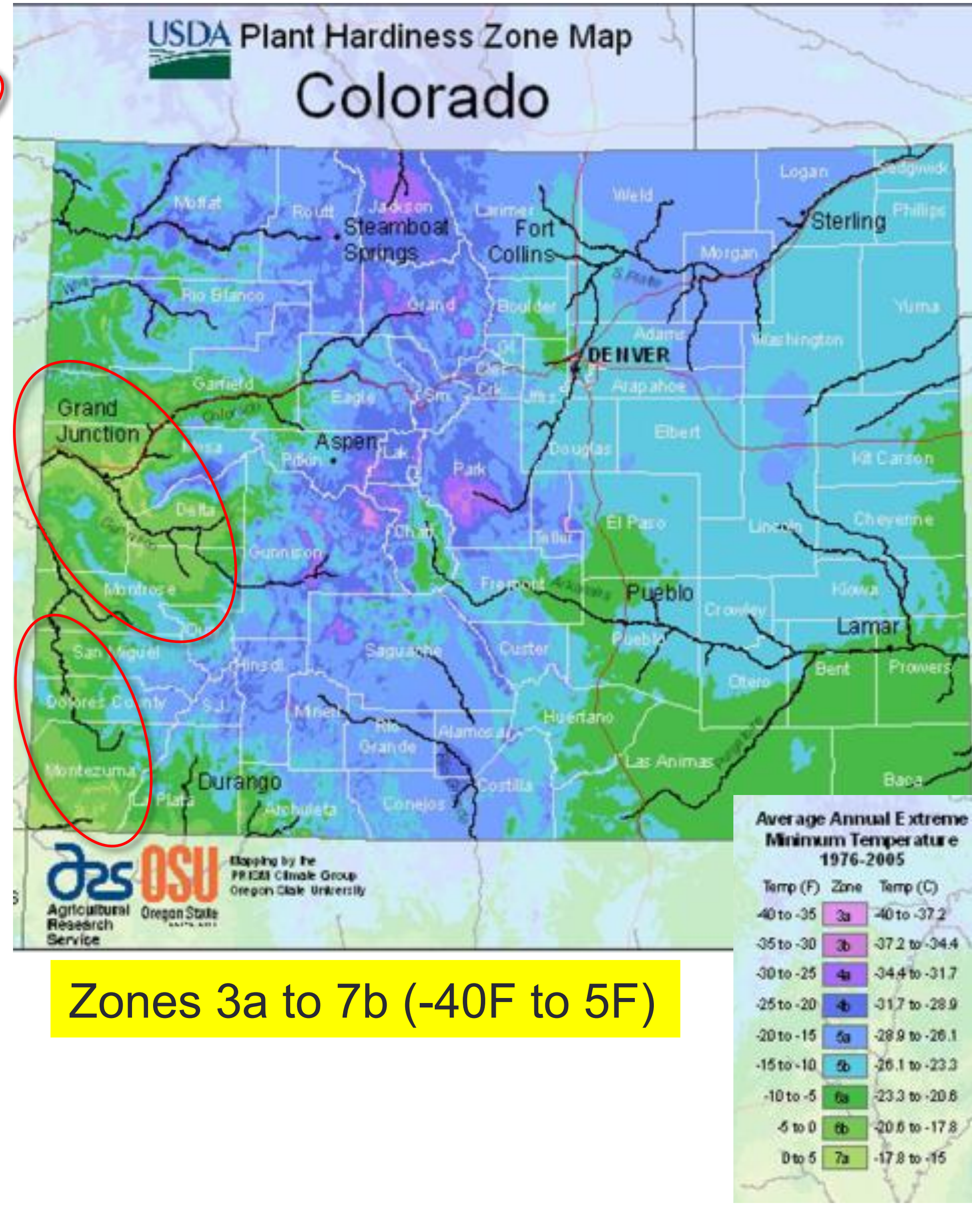
Environment

- Location (vineyard, region): macro- and meso-climate
- Temperature preceding the freezing event
- Temperature fluctuations in midwinter
- Duration of extreme low temperature
- Type of freeze event: advective vs. radiative

Plant Hardiness Zone Map

Zone 1 (coldest) to zone 11 (warmest)

Zones 5b to 6b (-15F to 0F)



Zones 3a to 7b (-40F to 5F)

Matching Genotype with Environment [Variety x Site]

Vidal Blanc (more cold hardy)

Cabernet franc (less cold hardy)

Cultural Practices

Preventative methods before every winter

Effect of cluster thinning on bud injury and yield of Chambourcin after 0F exposure

Target clusters/vine	Actual clusters/vine	Shoots/vine	%Bud injury at 0 °F
10	14	22	22
20	23	22	44
30	32	21	60
Linear	***	NS	*

Cultural Practices

Graft Union Protection

Exposed Graft Union

Vines hilled-up in Fall 2013

Graft union exposed in 2014

➢ No snow cover in 2014

Chemical Applications for Cold Protection

- Alginate (seaweed) with sugar (early 1990's)
- Oil (vegetable- and petroleum- base) (early 2000's)
- Growth regulators (ABA) (2008-2015)

Oil Application

Vegetable-base oil

- Oil & rate: soybean oil at 8% (v/v)
- Add adjuvant (emulsifier)
- Time of application: Mid-winter
- Bud break delay: 7-10 days
- No effect on yield or fruit quality
- Low cost and easy to apply

Oil Delays Bud Break 'Chambourcin'

Control

Oil Treated

(Dami & Beam. AJEV. 2004)

Abscisic Acid (ABA) for Winter Protection

Goal: Improve freezing tolerance (cold hardiness) of cold sensitive grape cultivars.

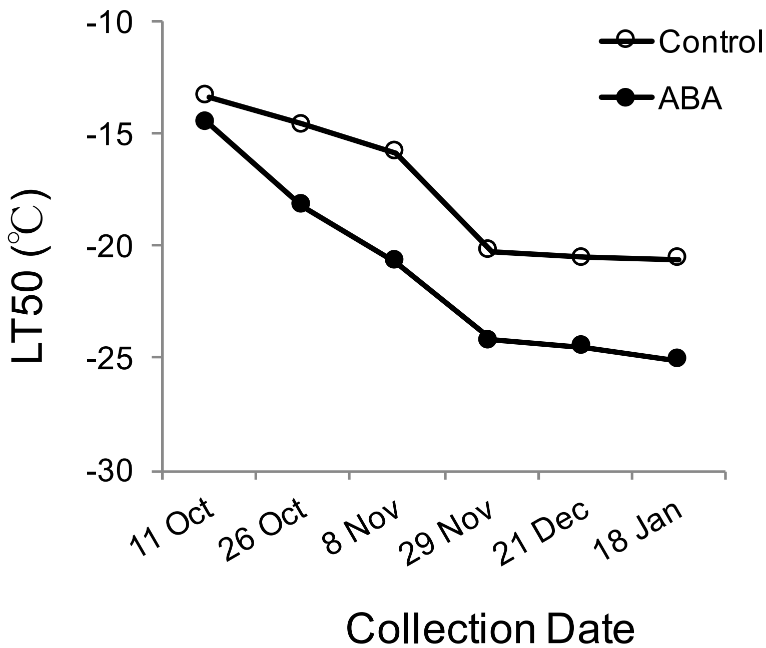
Hypothesis: ABA advances cold acclimation and enhances dormancy.

Objectives: Evaluate the response of field-grown winegrape cultivars to foliar ABA:

- Effects of ABA on yield, fruit quality, growth, dormancy and **freezing tolerance**
- **Optimum timing** of ABA application

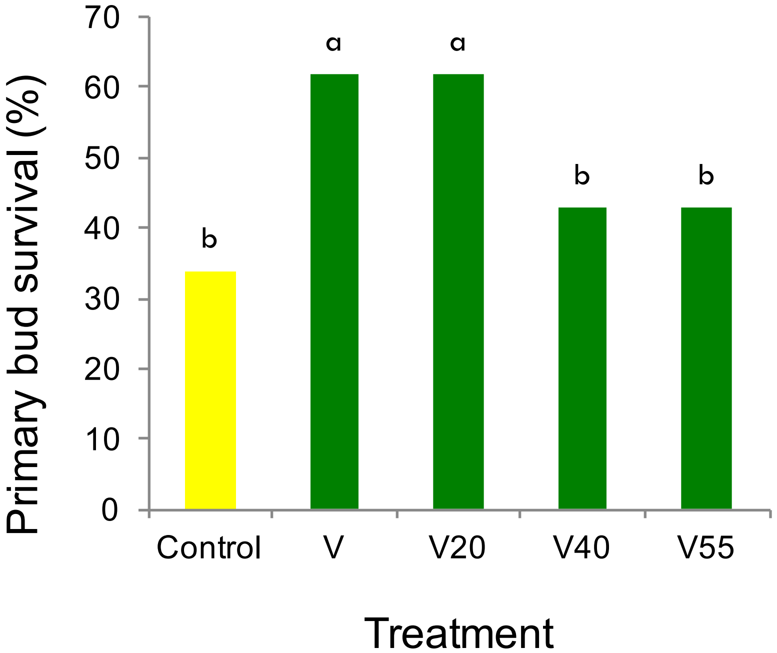
ABA Increased Freezing Tolerance

Bud freezing tolerance



Lab freezing event

Bud survival after -10 F in Jan 2011



Natural freezing event

(Zhang and Dami, AJEV 2012)

ABA Works

- Foliar ABA (**400-600 ppm**) improved bud FT without affecting yield or fruit composition.
- Best application timing: **véraison** and **post-véraison.**
- Foliar ABA is no “silver bullet”, but useful tool in the cold protection box.

Cultivar	**ABA decreased LT50 by**	**Reference**
Cabernet franc	Up to 4 °C	*Zhang and Dami. AJEV. 2012*
Chambourcin	3.5 °C	*Zhang and Dami. HortScience. 2012*
Chardonnay	1 to 3 °C	*Dami et al. HortTechnology. 2015*
Pinot gris	2 °C	*Li and Dami. JPGR. 2015*

Facts about Cold Hardiness

- Fact 1: Influenced by vineyard location, weather conditions, variety, and vine parts
- Fact 2: Basal buds are hardier than apical (distal) buds
- Fact 3: Cane size matters: small (diameter <1/4”) and large (diameter >1/2”) canes are less hardy
- Fact 4: Vines with more perennial wood (cordons, trunks) survive winter better
- Fact 5: Younger vines (<5 years old) sustain more damage
- Fact 6: Rootstocks: little effect on winter hardiness of scions
- Fact 7: Cultural practices (crop control, nutrient, disease, insect, weed management) that optimize fruit quality will maximize winter hardiness.

Summary

*“**Genotype** determines a vine's maximum cold hardiness potential. **Environment** and grower **management** determine how much of that potential is realized”*

Take Home Message:

- *Critical to take cold hardiness in consideration when selecting a variety in a given site*
- *Know whether environment will enhance or limit cold hardiness*
- *Don’t underestimate the impact of cultural practices on vine cold hardiness*

Grapevine Recovery from Winter Damage: Lessons Learned Part II

Imed Dami, PhD

Outline

- Winter damage in 2014-2015
- Managing winter-damaged grapevines
- Results of trials in the past 3 years
- Lessons learned and take-home messages

Cold Protection Methods

Winter Damage during 2014 & 2015 Winters

Bud damage | Trunk damage | Vine dieback | Vine death

Least crop loss → Most crop loss

Management Issues after Winter Damage

Issues:

- Pruning
- Cropping levels
- Fertilization
- Canopy management
- Pest management
- Weed management
- Retraining
- Sucker management
- Cost

Goals:

- Return vineyard to full productivity
- Optimize fruit quality
- Minimize cost

Trials on Managing Vines after Cold Damage

(1) Bud damage:

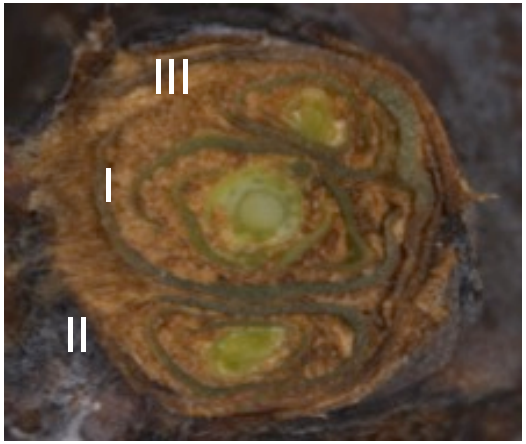
Managing vines by adjusting ***pruning***

(2) Trunk damage:

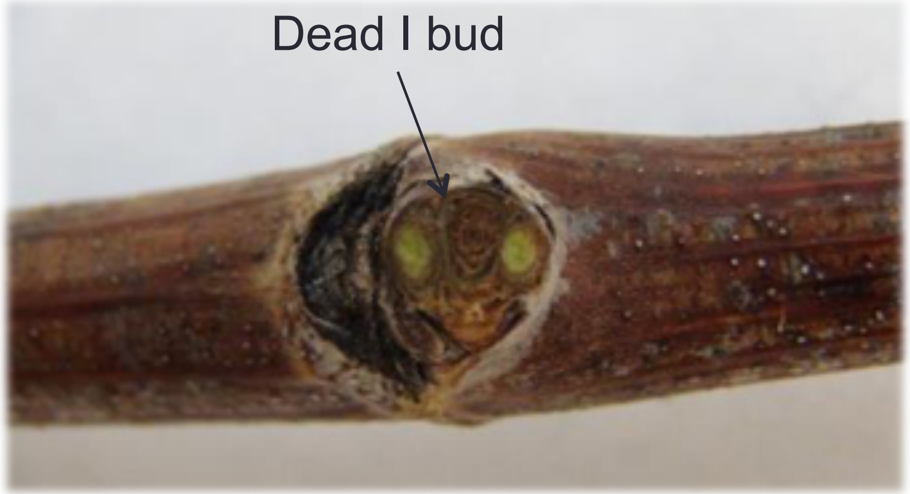
Managing vines by ***trunk renewal***

Bud Assessment

Alive



Injured

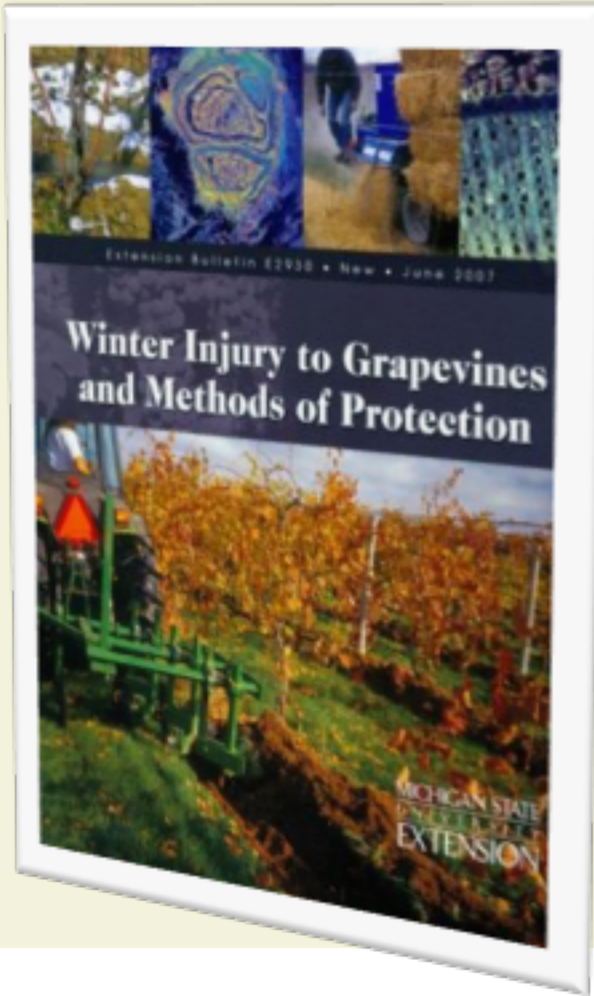


Pruning Strategies after Winter Injury

1) Less than 75% primary bud damage:

% Primary bud damage	Adjusted bud number
0-14	None
15-34	Increase by 35%
35-50	Double
50-75	Triple (minimal pruning)

- ✓ Vines pruned 2- and 3-bud spurs.
- ✓ Bud number increased by increasing spur number not length.
- ✓ Cane pruning not economical, not productive, and bud break not uniform – **Not Recommended**



Yields Following Winter Injury in WA

Variety	% Injury	Yield (T/A)
Cabernet franc	57	4.2
Riesling	62	4
Cabernet Sauvignon	64	4.3
Gewurztraminer	66	4
Lemberger	68	3.4

(Wolfe W., 2000)

Pruning Strategies (cont'd)

2) <u>75% to 100% primary bud damage:</u>

- Vines hedge-pruned to 5-bud spurs
- Pruning can be delayed after budburst to assess damage (die-back, death)
- **@75-90% damage:** trunk vascular system recovery – low to moderate crop production
- **@100% damage:** weak growth and die-back – remove trunks and train multiple suckers, no crop.

Pruning After -15 F in 2009

(Pinot gris (I) bud damage = 88%)

No pruning
(not recommended)

2-bud hedging (not recommended)
5-bud hedging (recommended)

Spur pruning
(not recommended)

(Dami et al. AJEV. 2012)

‘Regent’ hedge-pruned in 2014

(I=100%,II=99%, III=93%)

Hedged 5-bud spurs →

At harvest

Yield (‘14) = 0.8 t/a

After removal of dead spurs

Yields Following Winter Injury in WA

Variety	% Injury	Yield (T/A)
Cabernet franc	57	4.2
Riesling	62	4
Cabernet Sauvignon	64	4.3
Gewurztraminer	66	4
Lemberger	68	3.4
Chardonnay	78	2.7
Merlot	87	2.2
Sauvignon blanc	87	2.8
Syrah	99	0

(Wolfe W., 2000)

Yields Following Winter Injury in Ohio

Variety	(I) bud damage (%)	Yield 5-Bud (t/a)	Yield 4-year avg (t/a)	% Yield variation from avg
Frontenac	42	6.8	6.4	(+) 6
La Crescent	38	7.8	5.7	(+) 37
Marquette	45	6.0	2.9	(+) 107
Aromella	58	2.0	5.7	(-) 65

- % bud damage does not equate % crop loss
- All is not lost, compensate for damage by leaving additional buds

Pruning Strategies (cont'd)

2) 75% to 100% primary bud damage:

- **@75-90% damage:** trunk vascular system recovery – low to moderate crop production
- Many questions how to prune:
  - Do nothing?
  - Hedge prune?
  - Cordon and/or trunk damage?
  - Cut trunks? Where?
  - Delay pruning after budbreak?
  - How to train suckers for trunk renewal?

Chambourcin 2014

I Bud damage = 95%; II Bud damage = 94%; III Bud damage = 88%

(1) No pruning

(2) Hedge pruning/spurs

(3) Hedge pruning/no spurs

(4) Cordon pruning

(5) Trunk pruning 1/2 height

(6) Trunk pruning 10” height
2 suckers

(7) Trunk pruning 10” height
4 suckers

Take-Home Message:

@90+% I bud damage:

- Be patient!
- Delay pruning after budbreak to assess damage (growth, die-back, death)
- Do nothing (*no pruning*) is **no option**!
- *Pruning* portion of *cordon* and/or *trunk* is **not ideal** either
- *Hedge pruning* is **good option**…BUT, watch for trunk damage (suckers and crown gall)
- *Train suckers* (4 in this trial) and *replace trunks* if old and not healthy - **Best option**

Pruning Strategies (cont'd)

2) **75% to 100% primary bud damage:**

- **@100% damage:** weak growth and die-back – remove trunks and train multiple suckers, no crop.

Pruning Strategies (cont'd)

ALL Vinifera Varieties in 2014

I Bud damage = 100%; II Bud damage = 100%; III Bud damage = 100%

Hedge pruning did not work!

Commercial: Dieback & Retraining vinifera in 2014

Train or not train? How to train suckers? How many suckers? What type of suckers? How about “Bull” canes?

To Train or not to Train?

2014

2015 Harvest

Fan

2.2 tons/acre

VSP

0 ton/acre

Fan-VSP

1.5 tons/acre

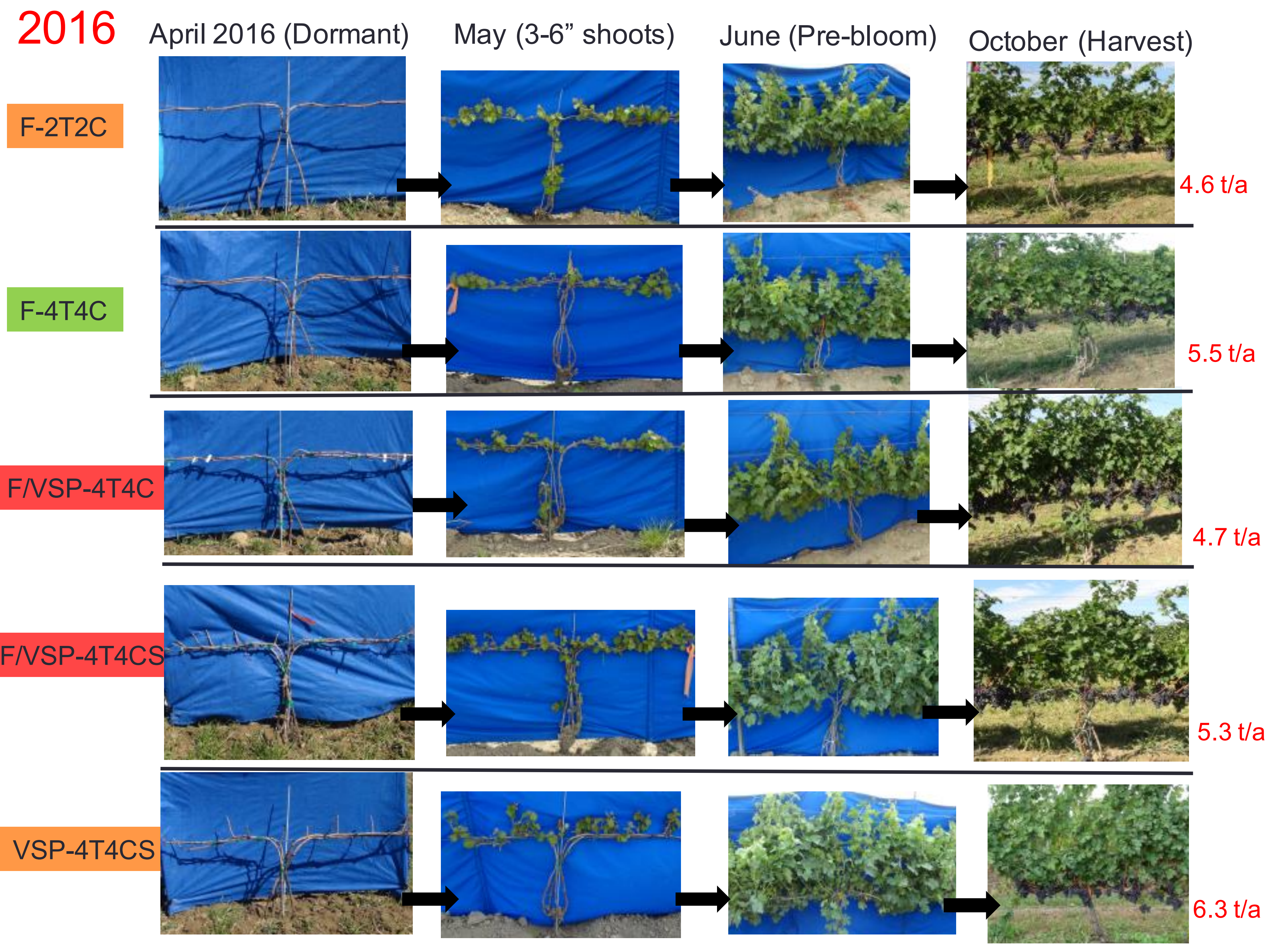
Spring 2016

Fan

VSP

Fan-VSP

Prior to converting to VSP

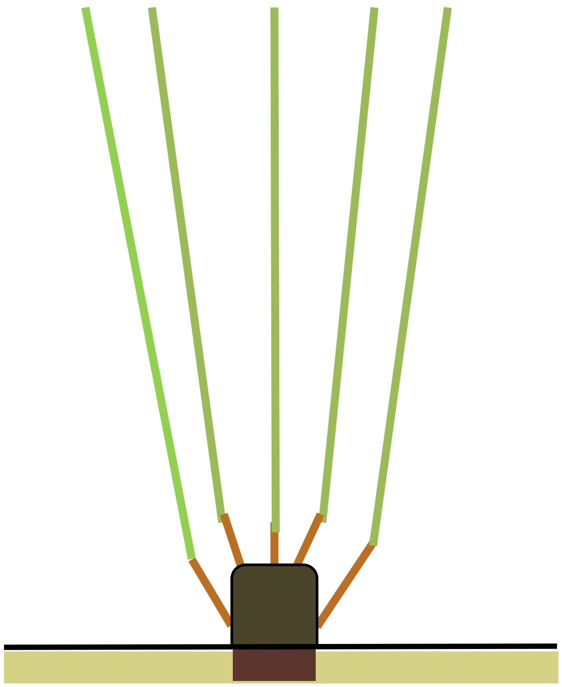


2016
April 2016 (Dormant)
May (3-6" shoots)
June (Pre-bloom)
October (Harvest)
F-2T2C
4.6 t/a
F-4T4C
5.5 t/a
F/VSP-4T4C
4.7 t/a
F/VSP-4T4CS
5.3 t/a
VSP-4T4CS
6.3 t/a

Take-Home Message

Year 1: Retain as many shoots (suckers) as produced by vine and train to Fan system

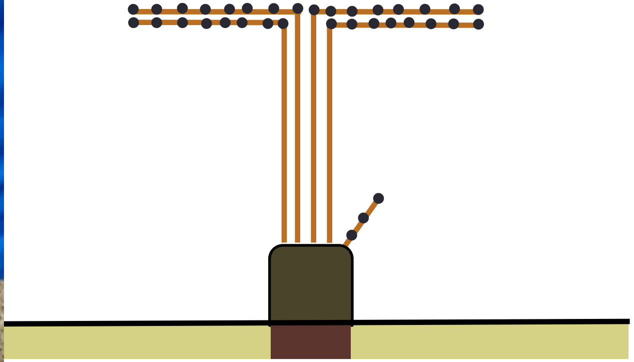
FAN



Take-Home Message

Year 2: When pruning, select medium size canes and remove bull canes. Train 4 trunks & canes

F-4T4C



Best Viticultural Practices for Premium Wines from Healthy Vines

Imed Dami

11 August 2017

Grand Junction, CO

Factors Affecting Wine Quality

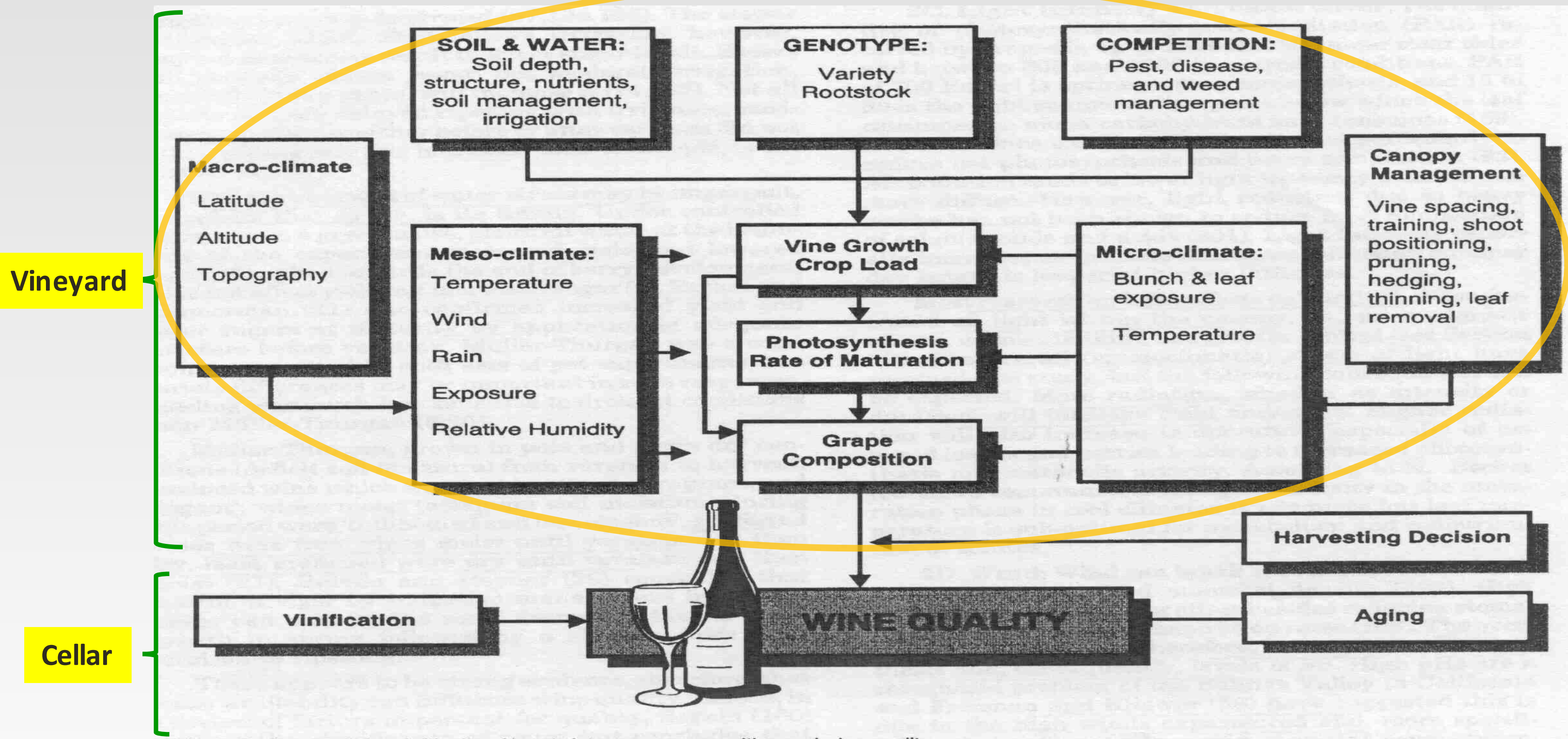


Fig. 2. Environmental and viticultural inputs into grape composition and wine quality.

(Jackson & Lombard 1993)

Factors Affecting Wine Quality & Vine Health

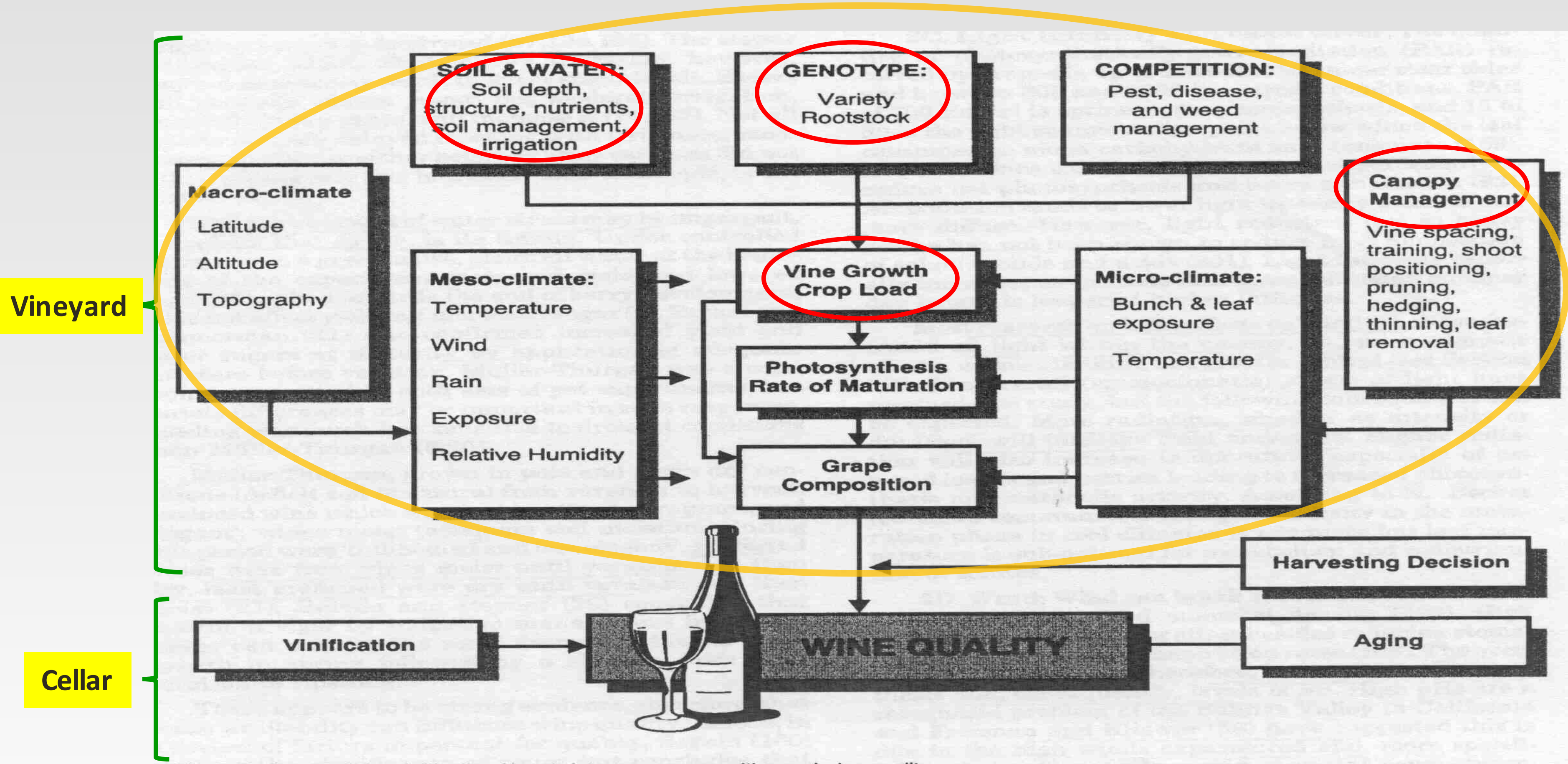


Fig. 2. Environmental and viticultural inputs into grape composition and wine quality.

(Jackson & Lombard 1993)

Vine Balance & Crop Load

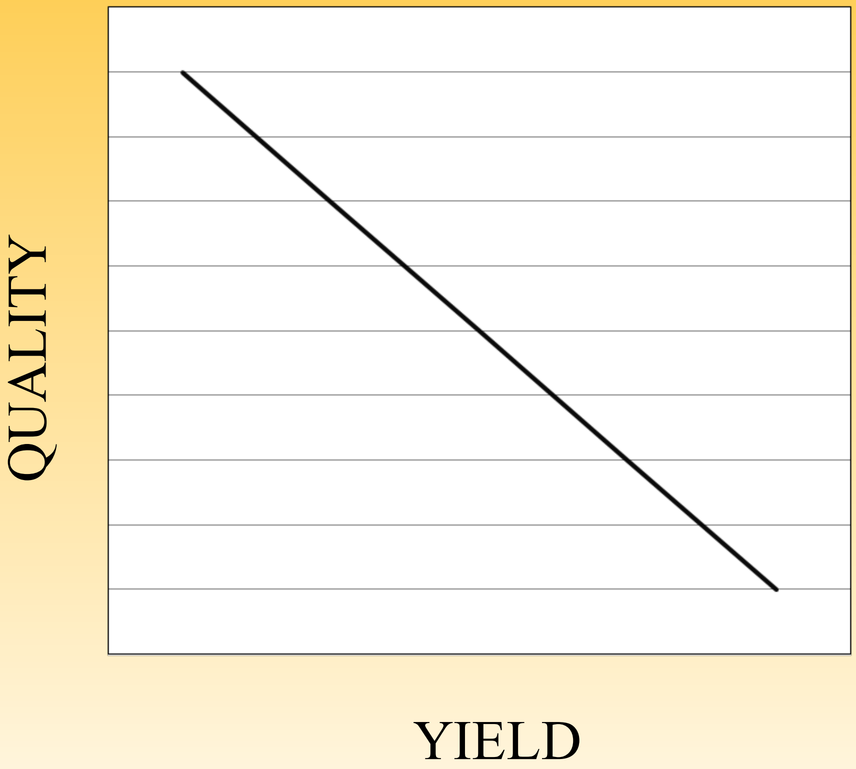
Grenache, Southern Rhone

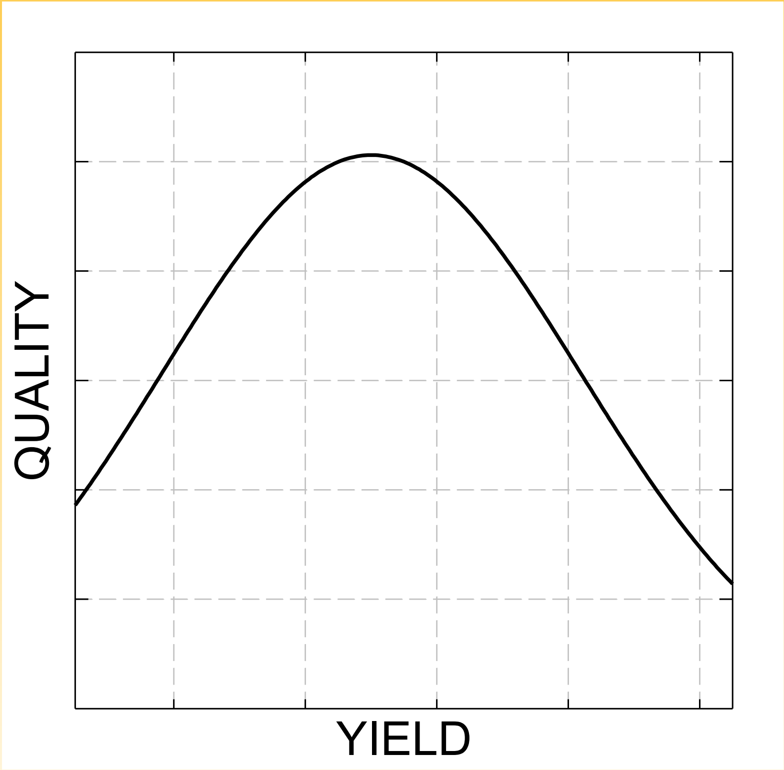
Cabernet Sauvignon, Bordeaux

Cabernet Sauvignon, Coonawarra

Myth: High yield = low quality

"Best quality when vine struggles…"

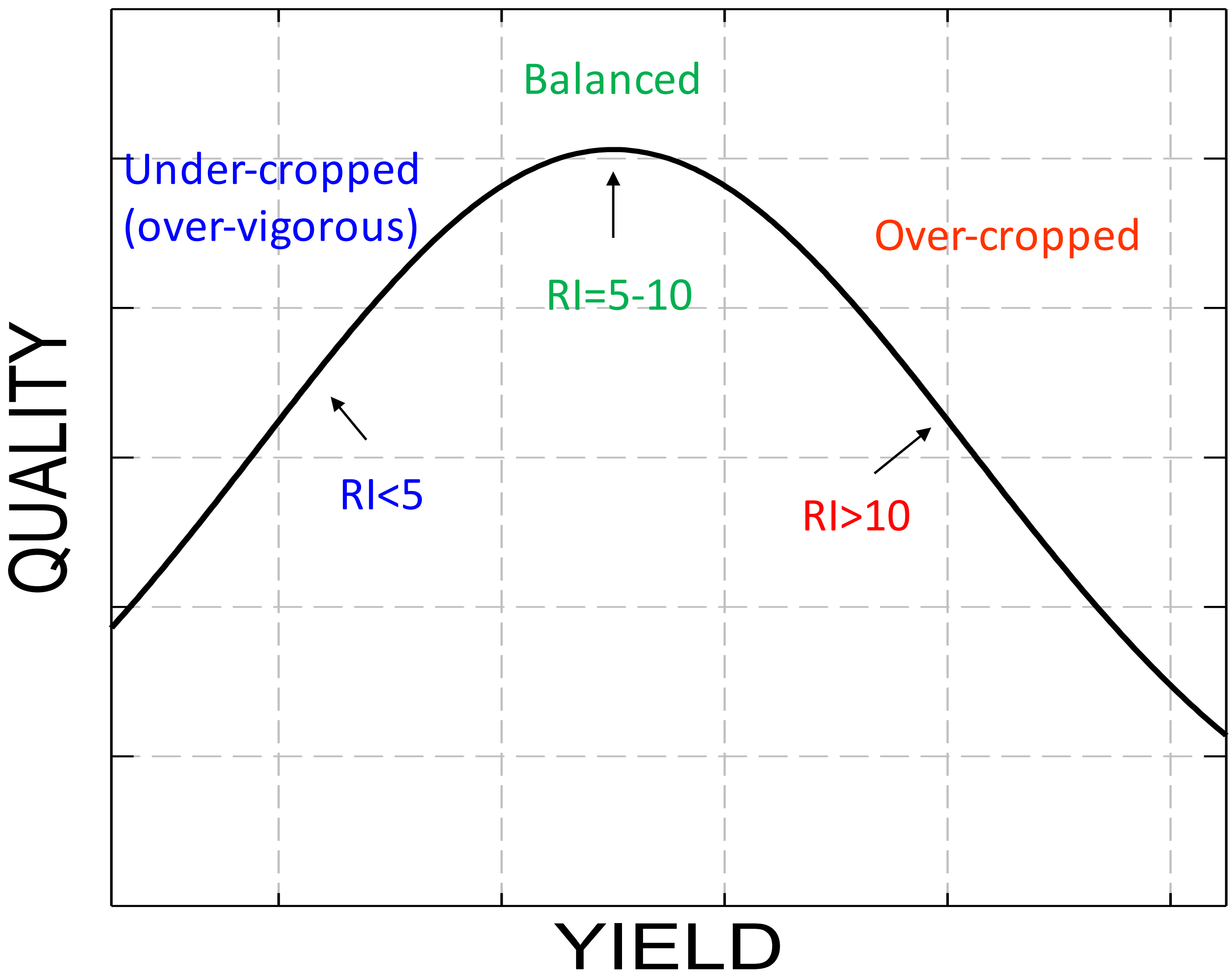




Vine Balance & Crop Load

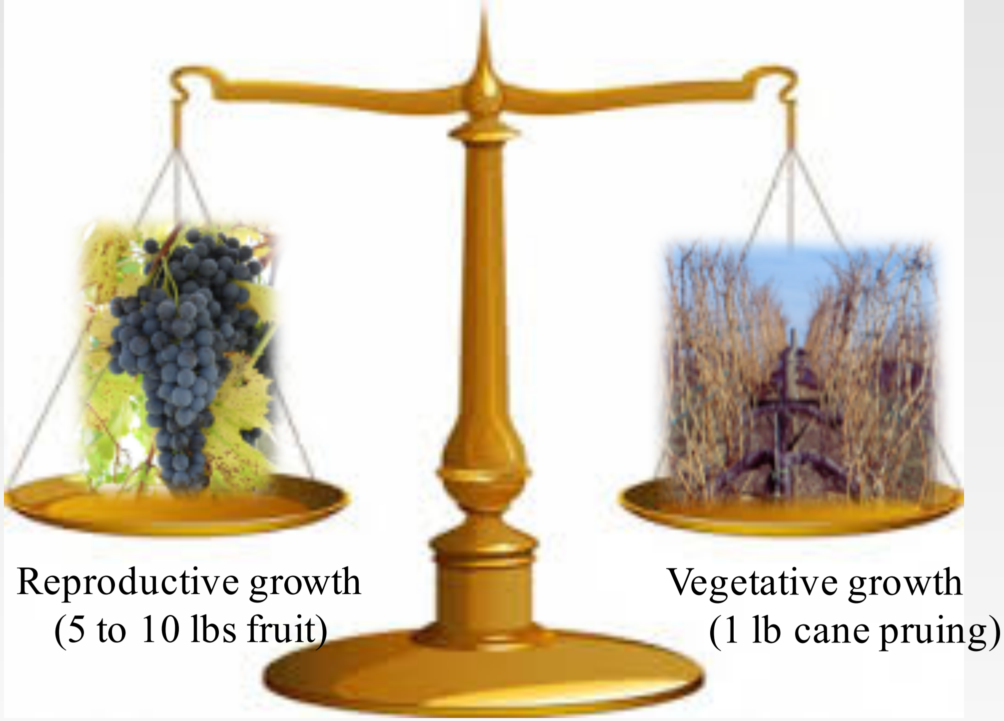
- What is vine balance?
- How do I know my vines are balanced?
- Is it when vines produce quality wines?
- **Crop load:** ratio (reproductive growth / vegetative growth) also called Ravaz Index (RI)
- **Ravaz Index** = Crop weight/Pruning weight
- **RI = 5-10: Ideal** – for every 1 lb of pruning weight, vine has the capacity to produce 5 to 10 lbs of fruit ➔ ***Balanced*** vine
- **RI > 10: Over-cropped**: high crop level, vine can't ripen fruit
- **RI < 5: Under-cropped (or over vigorous)**: low crop level, poor fruit quality, economic loss

The 3 Scenarios of Vine Balance:



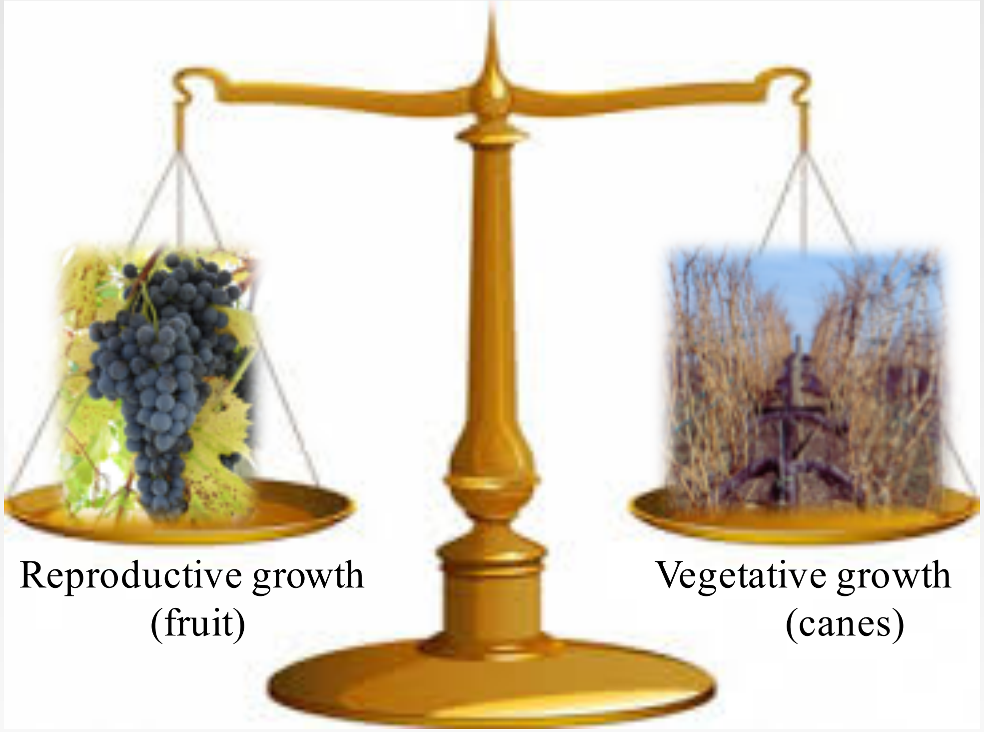
Vine Balance & Crop Load (cont’d)

- *Balanced* vines have *optimum* crop load:
  - Not overcropped (high yield)
  - Not undercropped (high vigor)
  - Optimum fruit ripening before frost
  - Optimum cold acclimation before winter
  - Healthy vines
- *Crop load* varies with grape type:
  - Vinifera: 5-10
  - Hybrids: 10-28



Vine Balance & Crop Load (cont'd)

- Crop load: requires 2 measurements
- **Yield or crop weight**: lbs per vine or tons per acre
- **Pruning weight (PW)**: lbs per vine or per foot of cordon
- **PW = 0.2-0.4** lb/ft: **ideal**
- **PW > 0.4** lb/ft: **high vigor**
- **PW < 0.2** lb/ft: **low vigor**



Crop Load Measurement

Crop weight (Year X)

Pruning weight (Year X)

Factors Affecting Wine Quality & Vine Health

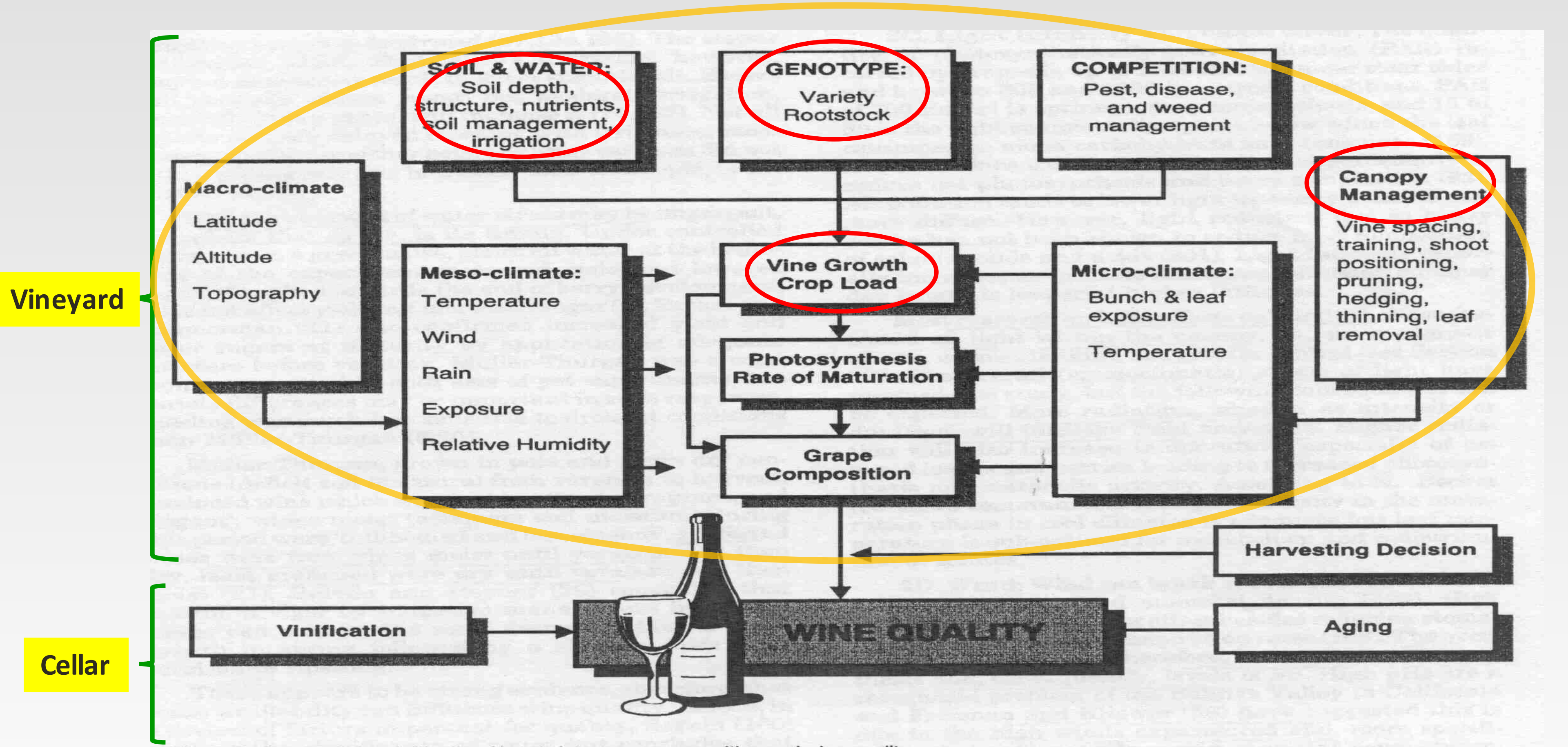
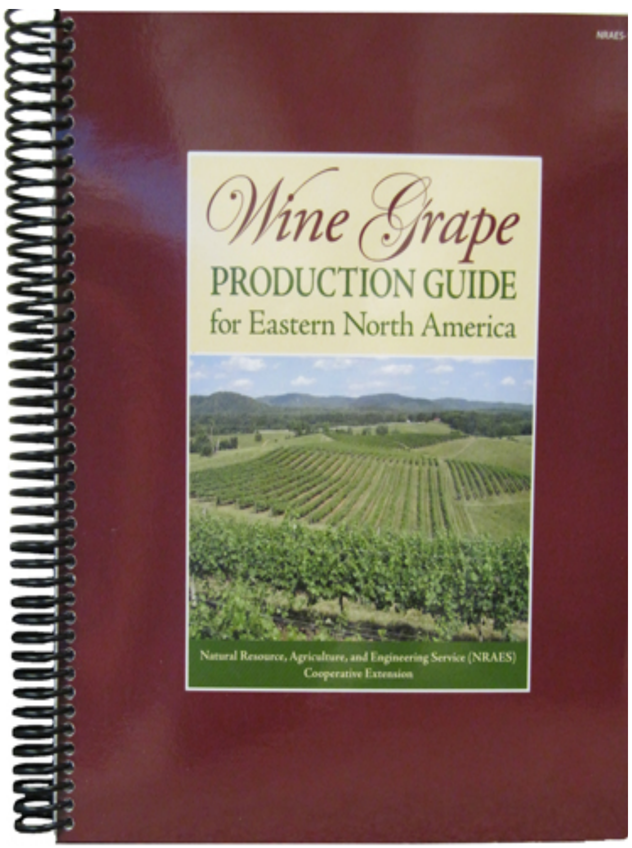


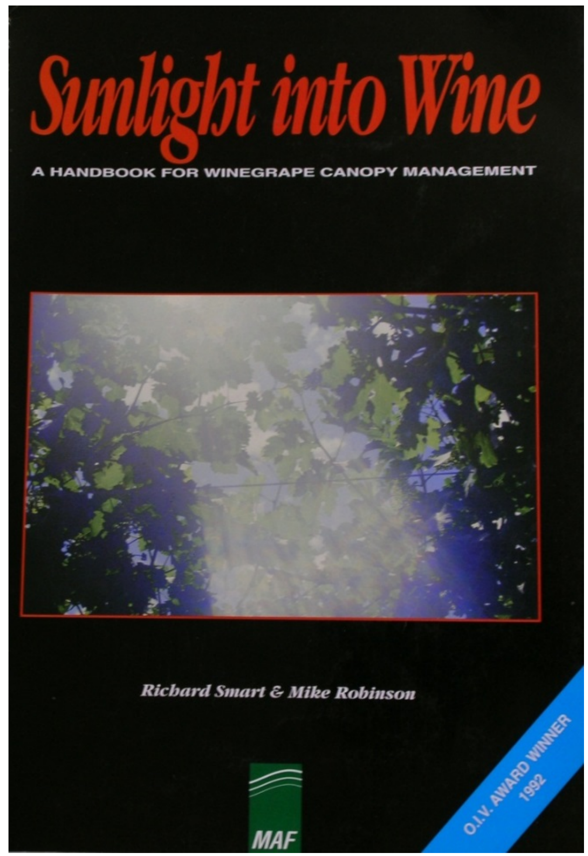
Fig. 2. Environmental and viticultural inputs into grape composition and wine quality.

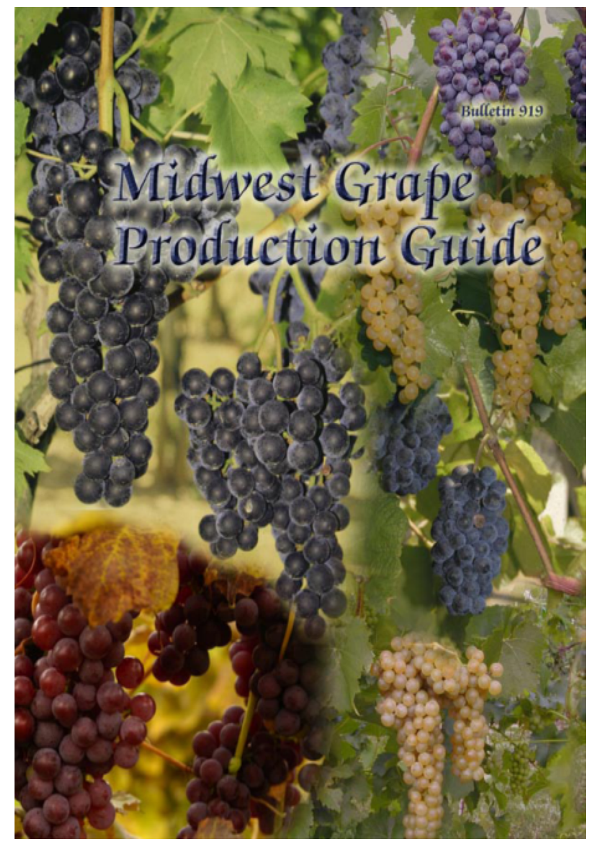
(Jackson & Lombard 1993)

Canopy Management

Canopy Management Resources







Canopy Management -Why?

- Optimize sunlight interception
- Improve canopy microclimate
- Maintain balance between shoot growth and fruit production

Signs of Problem Canopies

- Shaded and yellow leaves
- Shaded fruit
- High fruit acidity, pH and K
- Low fruit sugars, and color
- Low fruit flavors
- Wines w/ vegetative character
- High incidence of bunch rot

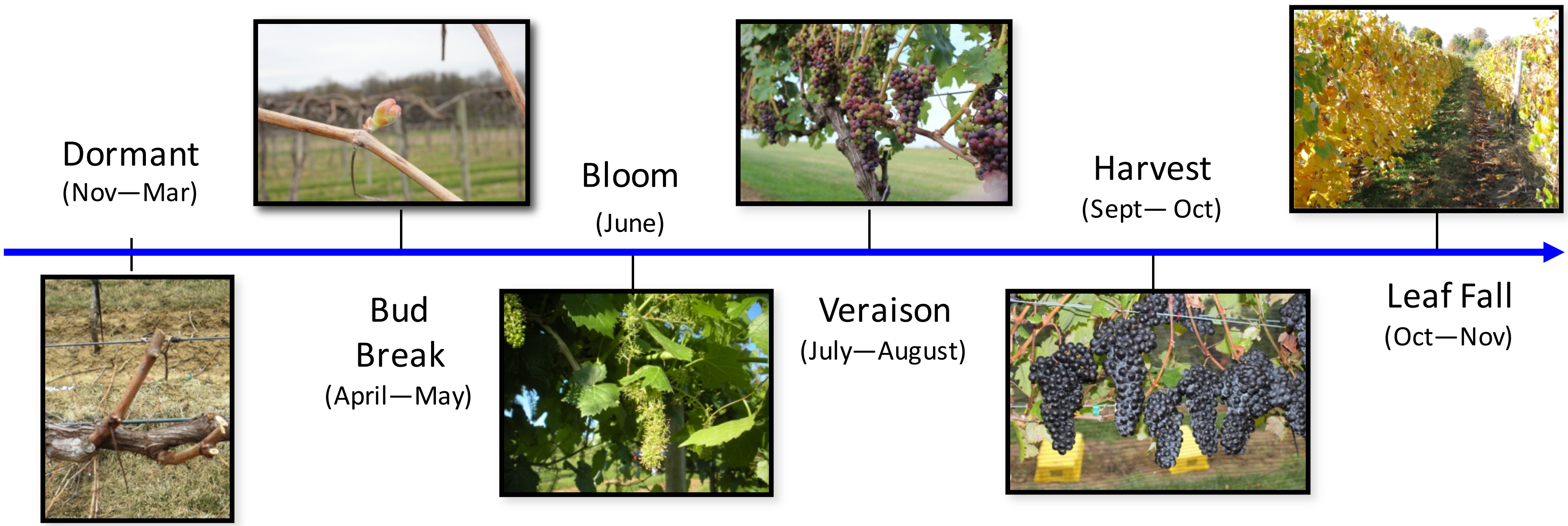
Benefits of Canopy Management

- Improved vine balance
- Improved fruit (wine) quality
- Improved winter hardiness
- Reduced disease incidence

- Increased bud fruitfulness
- Reduced cost (if mechanized)

Steps of Canopy Management:

1) dormant pruning, 2) shoot thinning, 3) shoot positioning, 4) leaf removal, 5) cluster thinning, 6) hedging



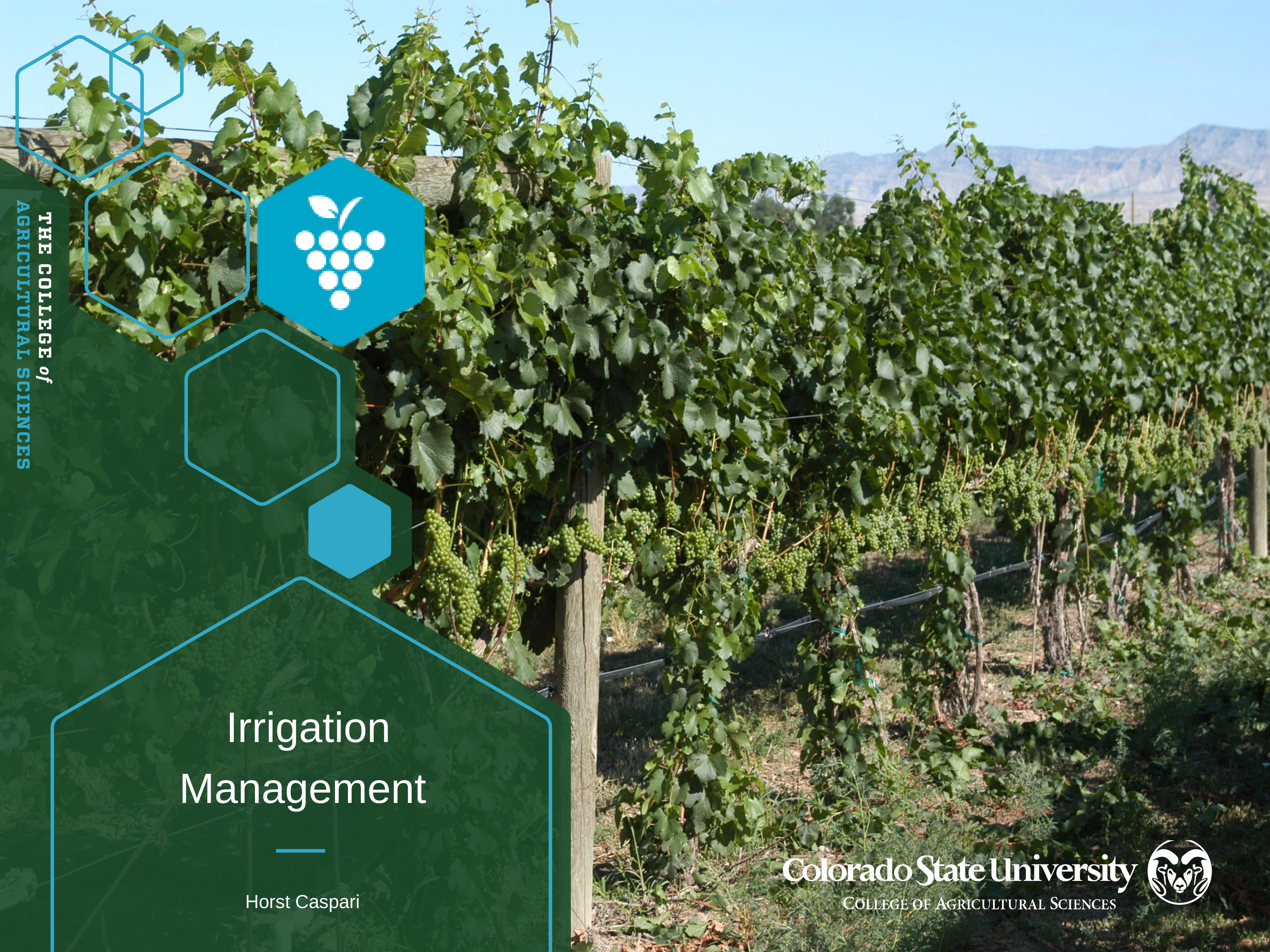
Canopy Management Videos:

Dormant pruning:

https://ohiograpeweb.cfaes.ohio-state.edu/video

All 5 CM practices:

https://ohiograpeweb.cfaes.ohio-state.edu/video



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Irrigation Management

Horst Caspari

Colorado State University
College of Agricultural Sciences

Factors Affecting Wine Quality & Vine Health

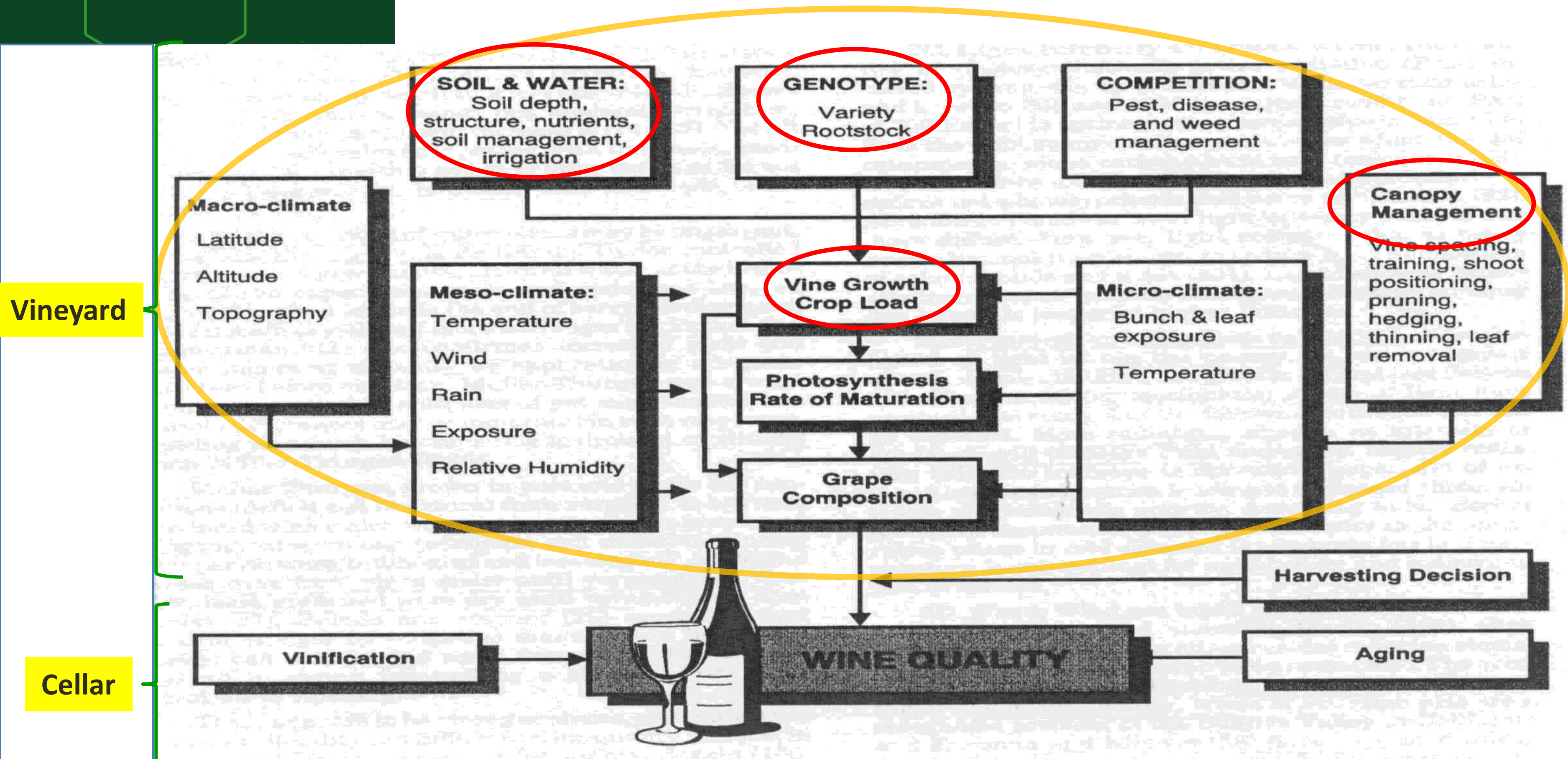

Fig. 2. Environmental and viticultural inputs into grape composition and wine quality.

Introduction

Irrigation is quite simple. All you have to do is answer two simple questions:

When to irrigate?

How much water to apply?

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Introduction

To answer those questions one needs to know

- how much water do grape vines use/need?

- how much water can be supplied from the soil?

Irrigation – further questions

- Why?
- How?

Irrigation – How?

Types of irrigation

- Furrow
- Sprinklers
- Micro-sprinklers
- Drip

- Overhead irrigation
- Under vine irrigation
  - Subsurface drip

Irrigation – Why?

What are we trying to achieve with irrigation?

- Replace the water that has been used by the crop (lost to evapo-transpiration (ET_c))
- Use irrigation as a management tool to achieve a desired outcome

Irrigation – How much?

What determines plant water use?

- Climate
- Plant development
- Plant size (leaf area)
- Plant species
- (Soil)

Irrigation – How much?

How can we determine how much water a plant has used?

- Model ET_c (Crop evapotranspiration)
- Measure plant water use
  - Directly
  - Indirectly

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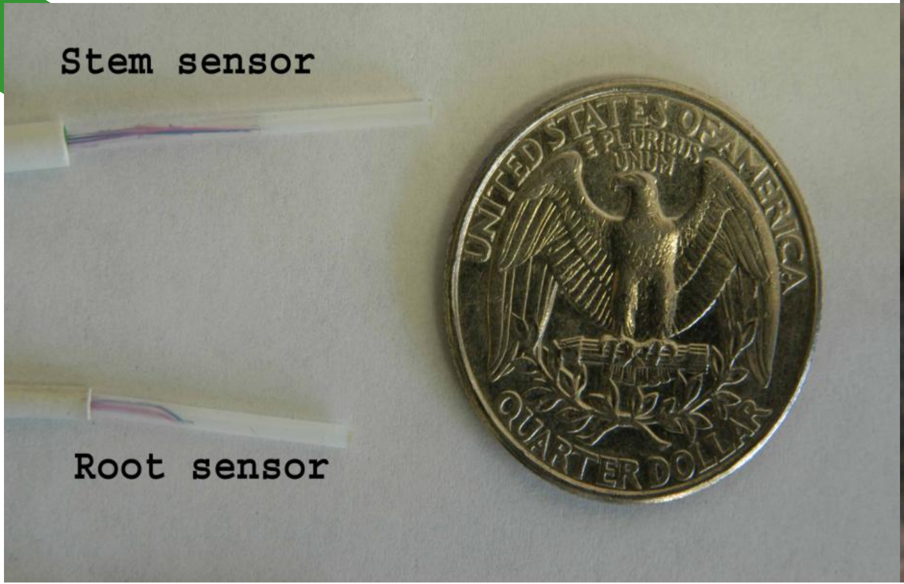
Direct measurement of vine water use

Determine water use of grape vines under the climatic conditions of Western Colorado

Measurements

- Vine water use
  - Sap flow
  - Heat-pulse (Tmax)



Heat-pulse sensors in stem of grape vine

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Materials and Methods

In 2004

- Cabernet Sauvignon
  - Planted in 1984, 8’ x 12’ (454 vines per acre)
  - VSP
  - Furrow irrigated
  - 2 vines, 4 stems

In 2005

- Merlot
  - Planted in 1992, 5’ x 10’ (871 vines per acre)
  - VSP
  - Drip irrigated
  - 4 vines (single stems)

Materials and Methods

Heat-pulse technique using Tmax

- Pulse fired every 30 minutes
- Installed on 14 July 2004 (DOY 196)
- Installed on 23 June 2005 (DOY 174)

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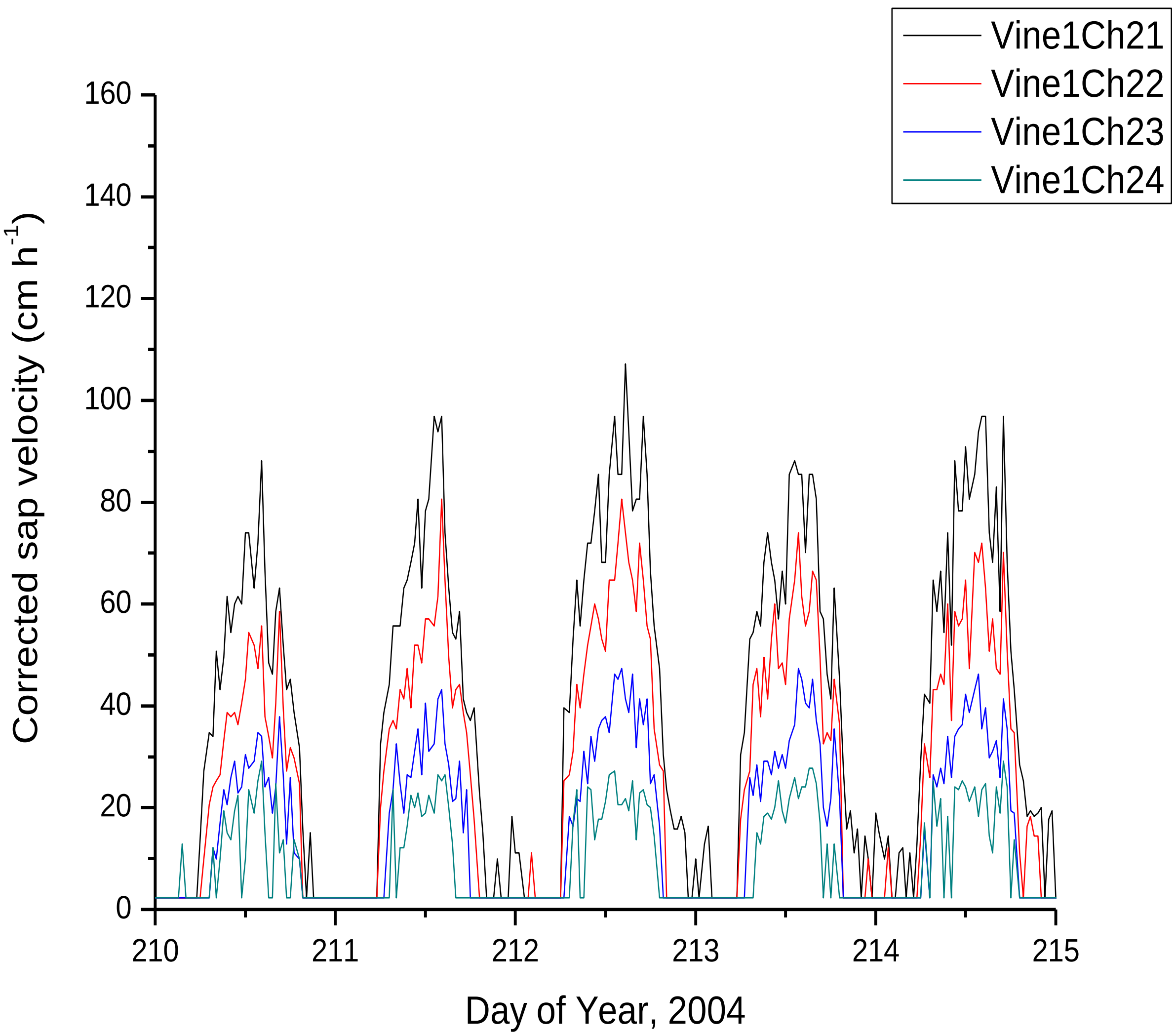
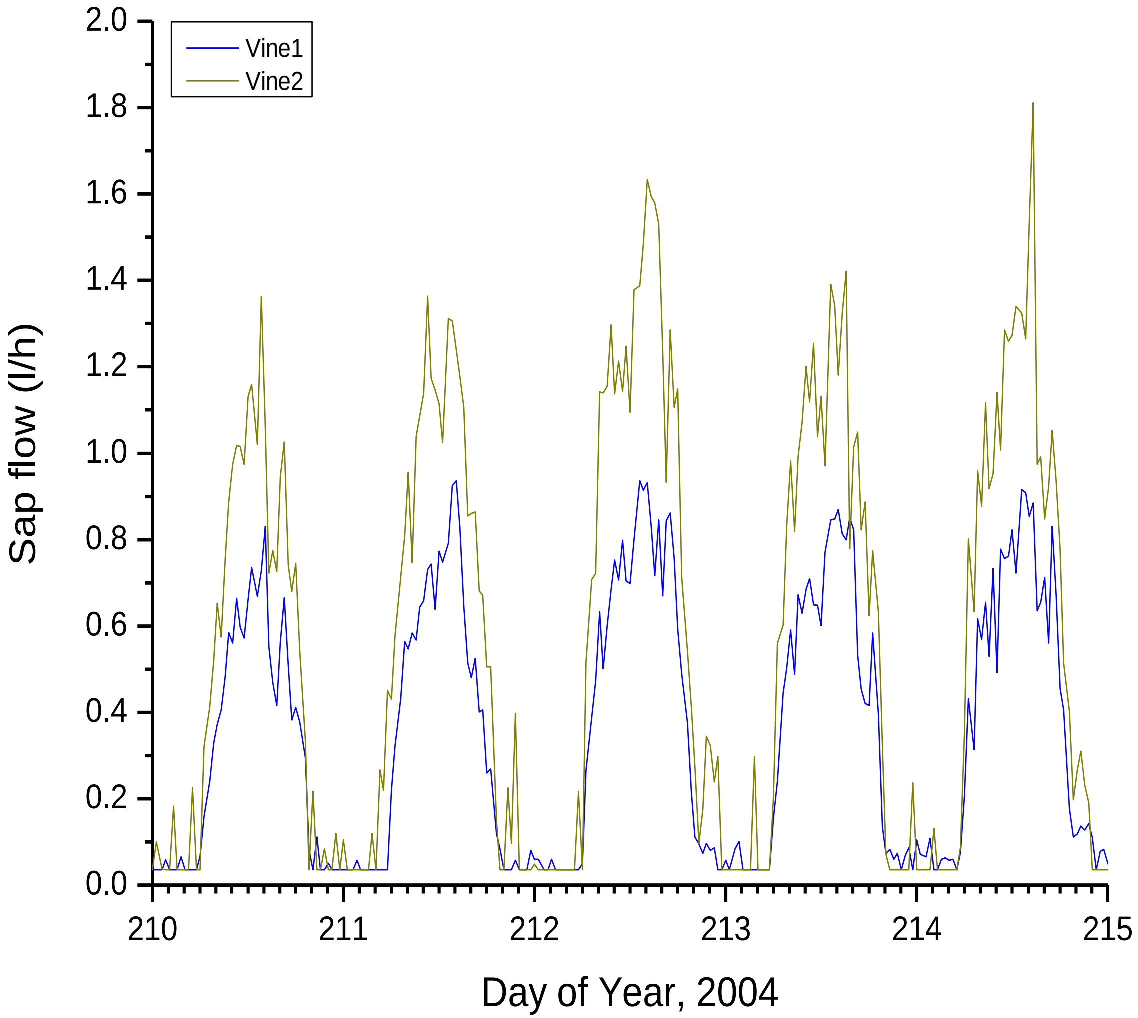
Results

A look at sap velocities inside a grape vine stem



Results

From sap velocity to sap flow



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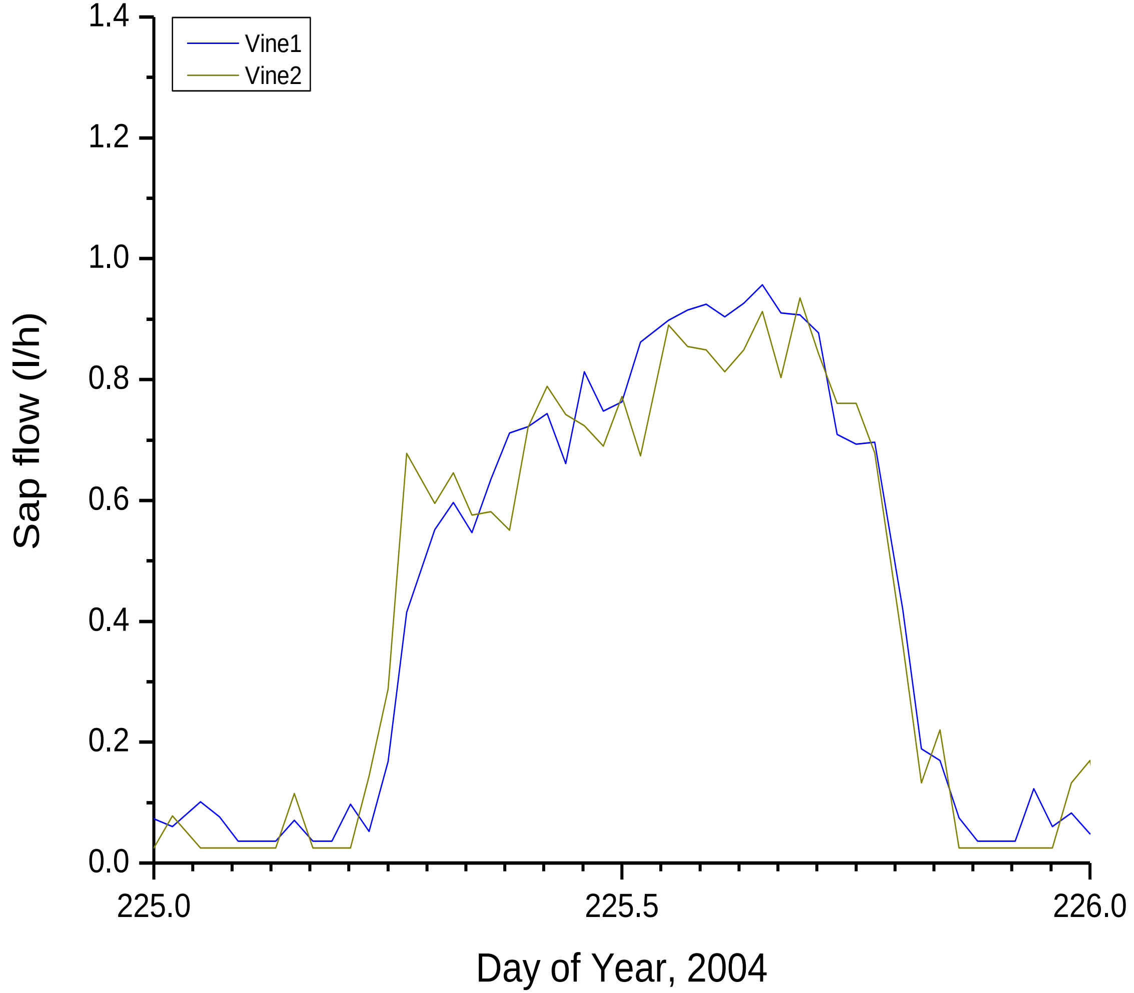
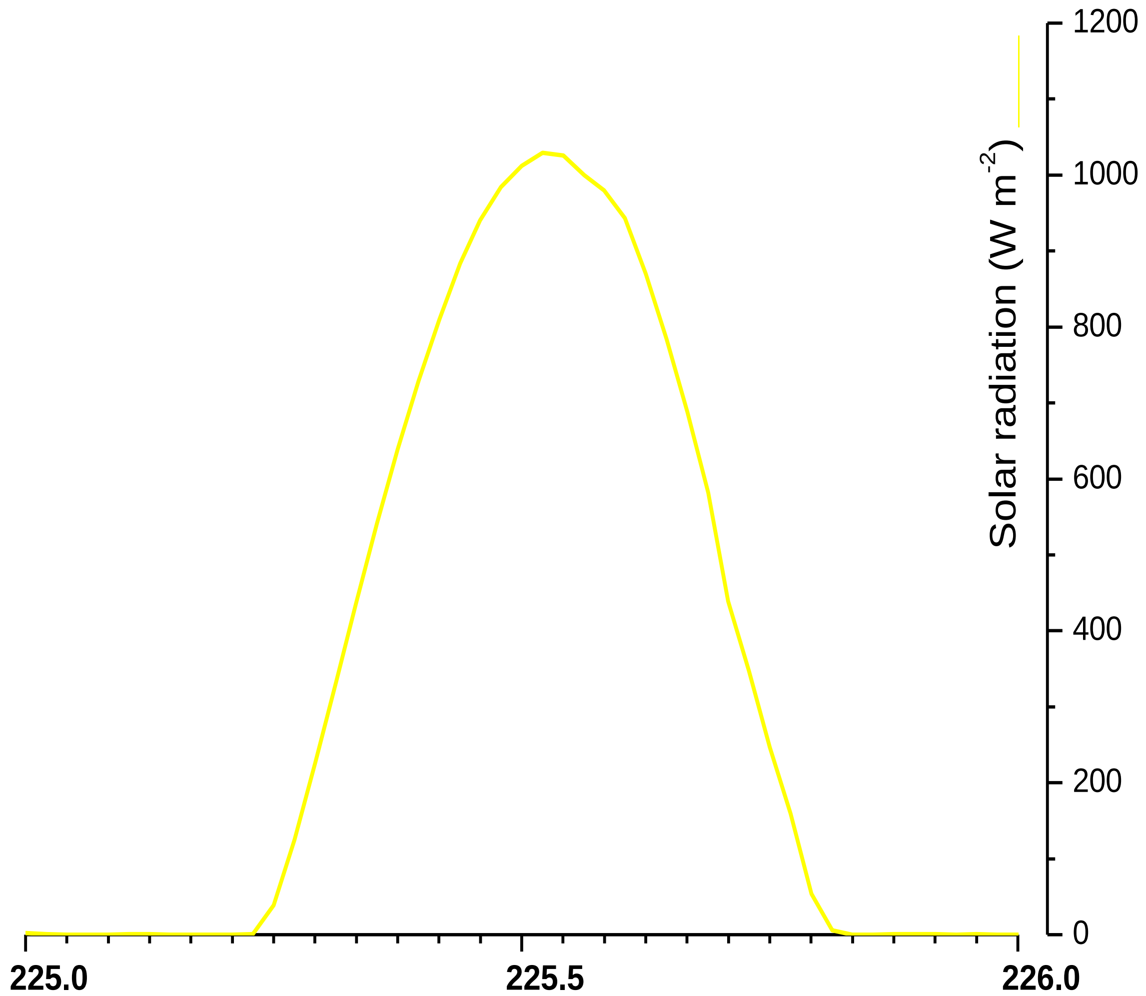
Results

A typical daily sap flow profile



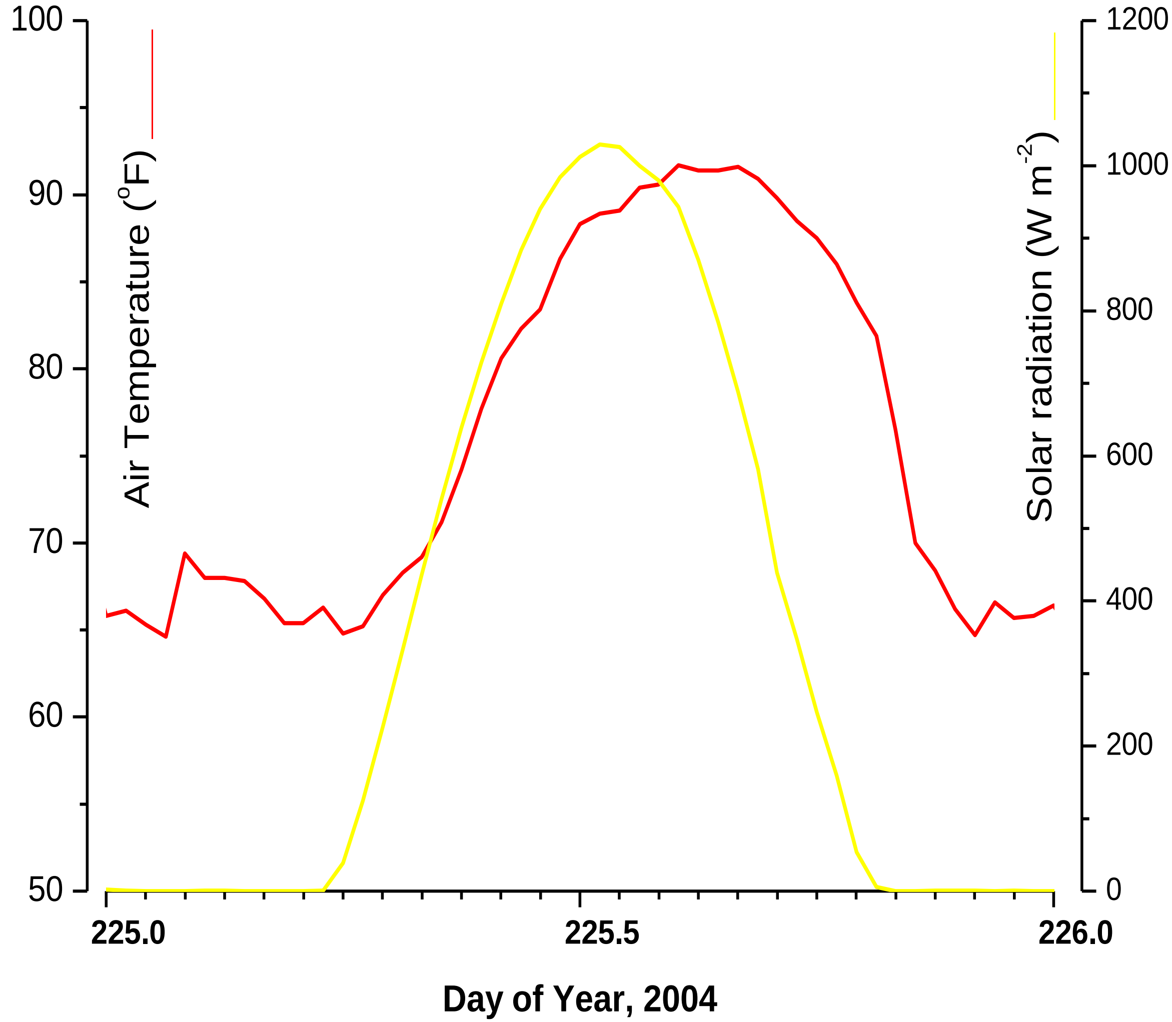
Results

Why does sap flow not peak at solar noon?



Results

Daily maximum temperature is around 4 – 5 pm



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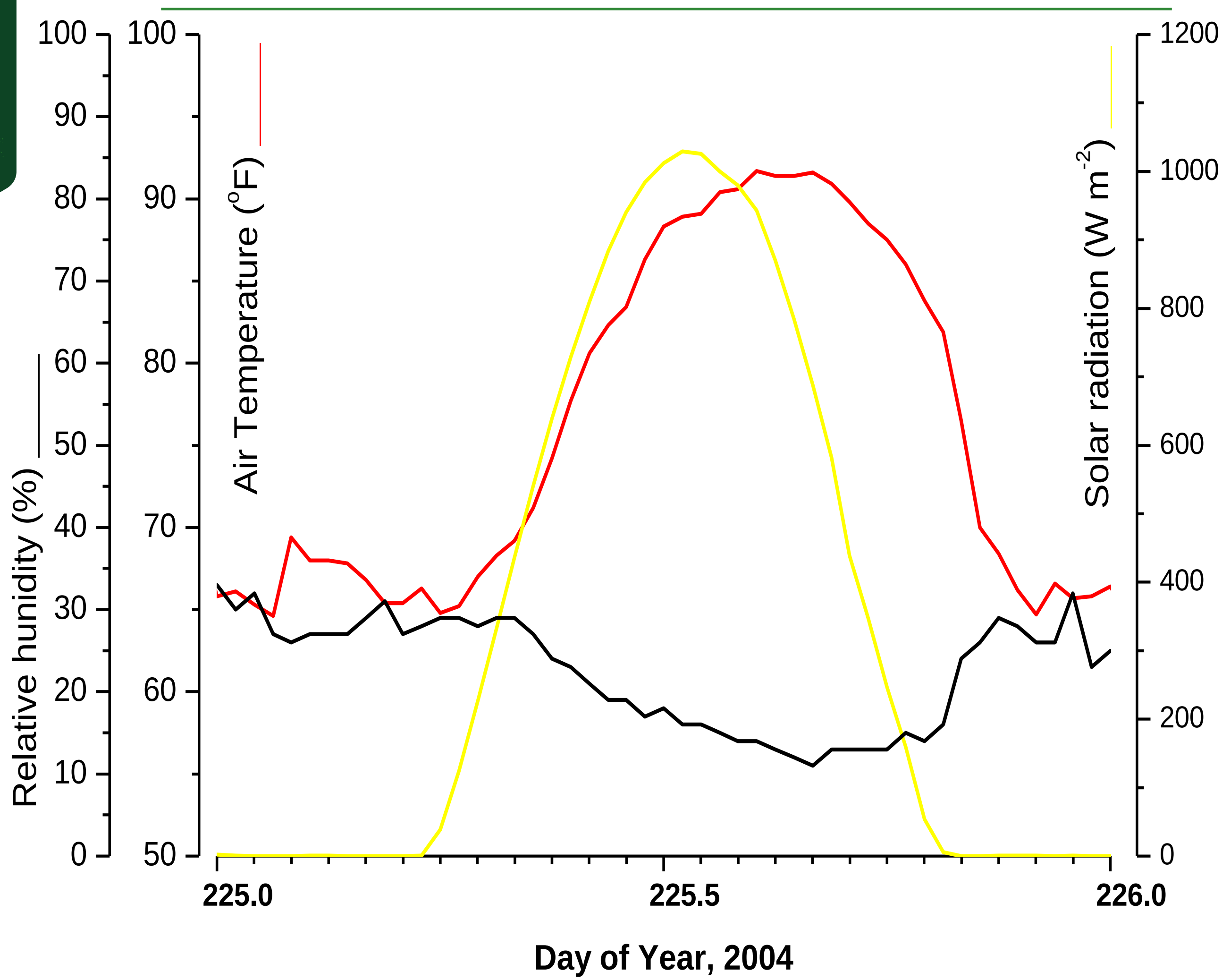
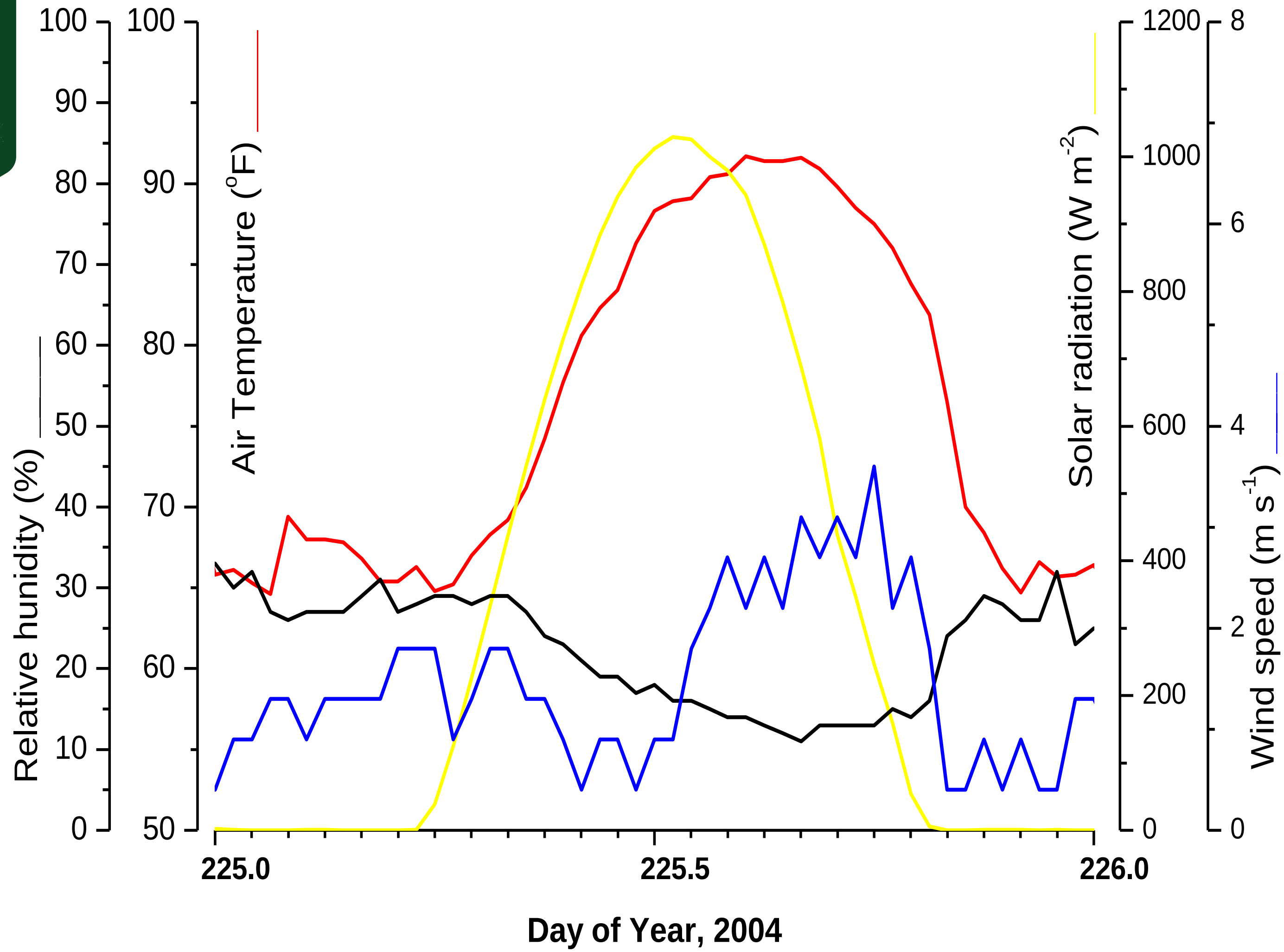
Results

Relative humidity is lowest around 4 – 5 pm



Results

Wind speed increased in the afternoon



Results

Why does sap flow not peak at solar noon?

• Temperature is highest in mid-late afternoon.

• Relative humidity is lowest in mid to late afternoon.

• Canopy light interception of VSP trellis with North-South row orientation increases after solar noon!

Results

Why does sap flow not peak at solar noon?

- Who cares? It is purely academic anyways!

- Maybe not.

- A crude, but simple way to test for vine water stress is to touch fully sun-exposed leaves late in the afternoon and determine their temperatures.

Results

Why does sap flow not peak at solar noon?

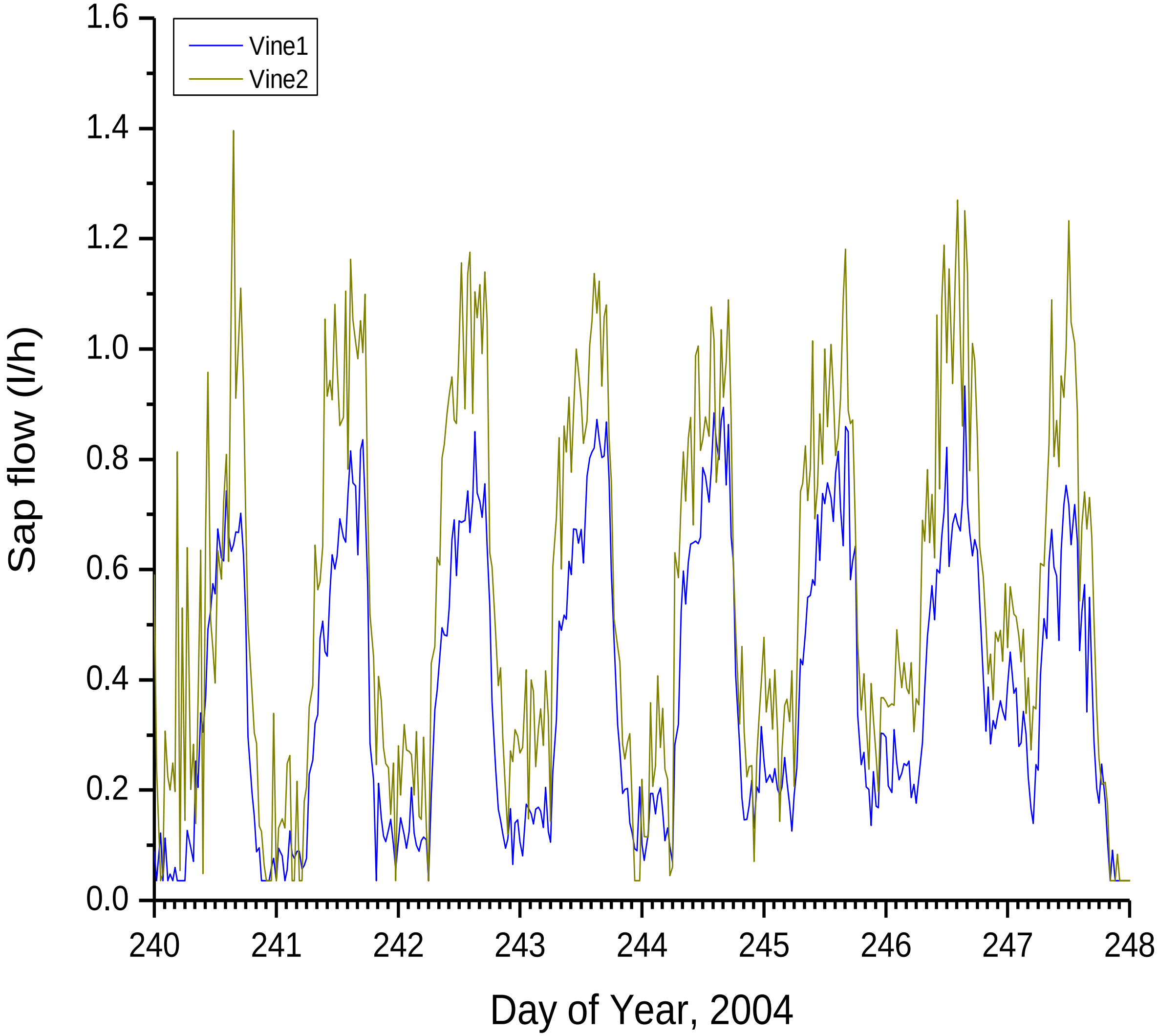
• If the leaves feel "cool" (near or below ambient temperature) then the leaves are transpiring rapidly and there is no shortage of water.

• If the leaves feel "hot" (well above ambient) then the leaves are likely not transpiring at maximum rate, suggesting water stress.

• The leaf temperature can be an indicator of water stress, but should not be used as the only means to assess vine water status.

Results

Effect of nocturnal wind on sap flow



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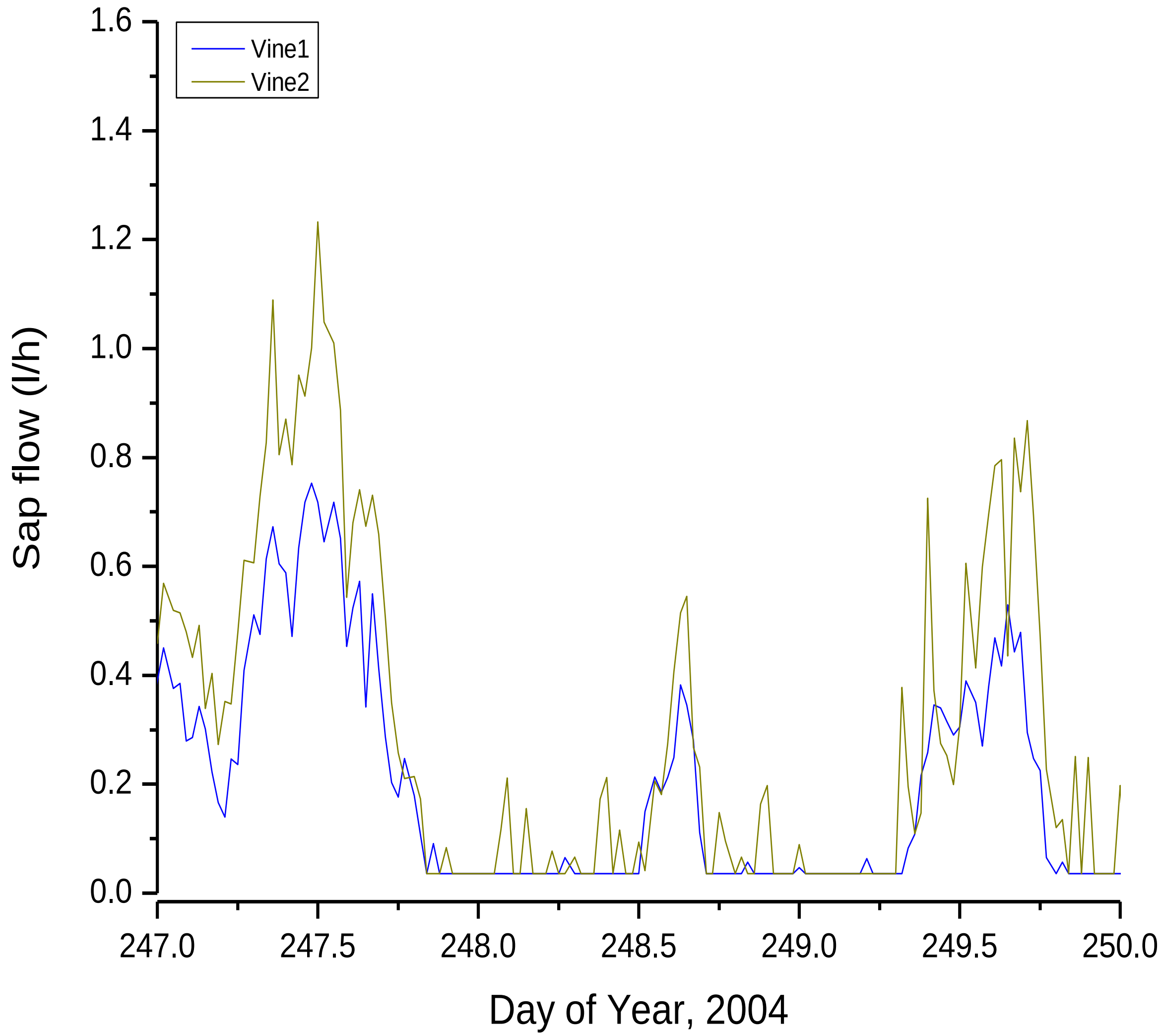
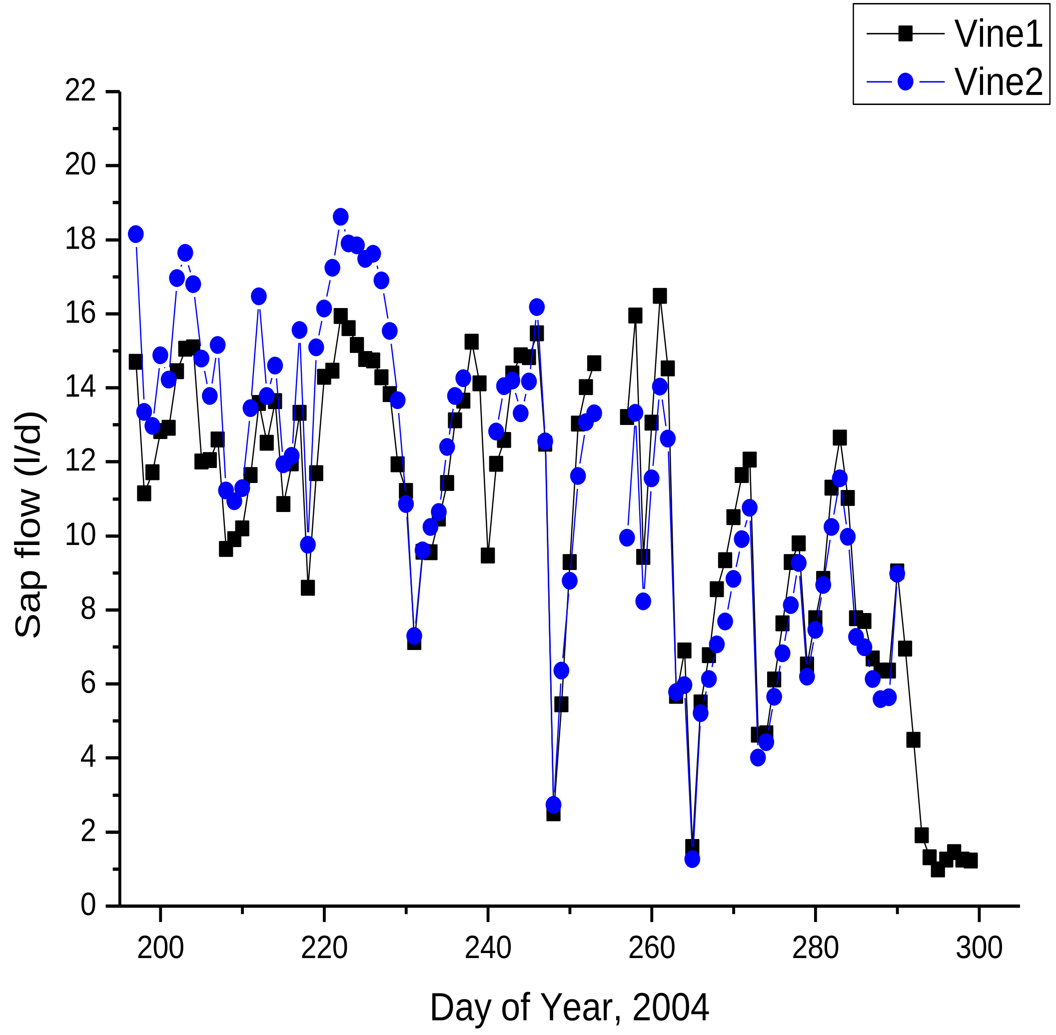
Results

Effect of rain / leaf wetness on sap flow



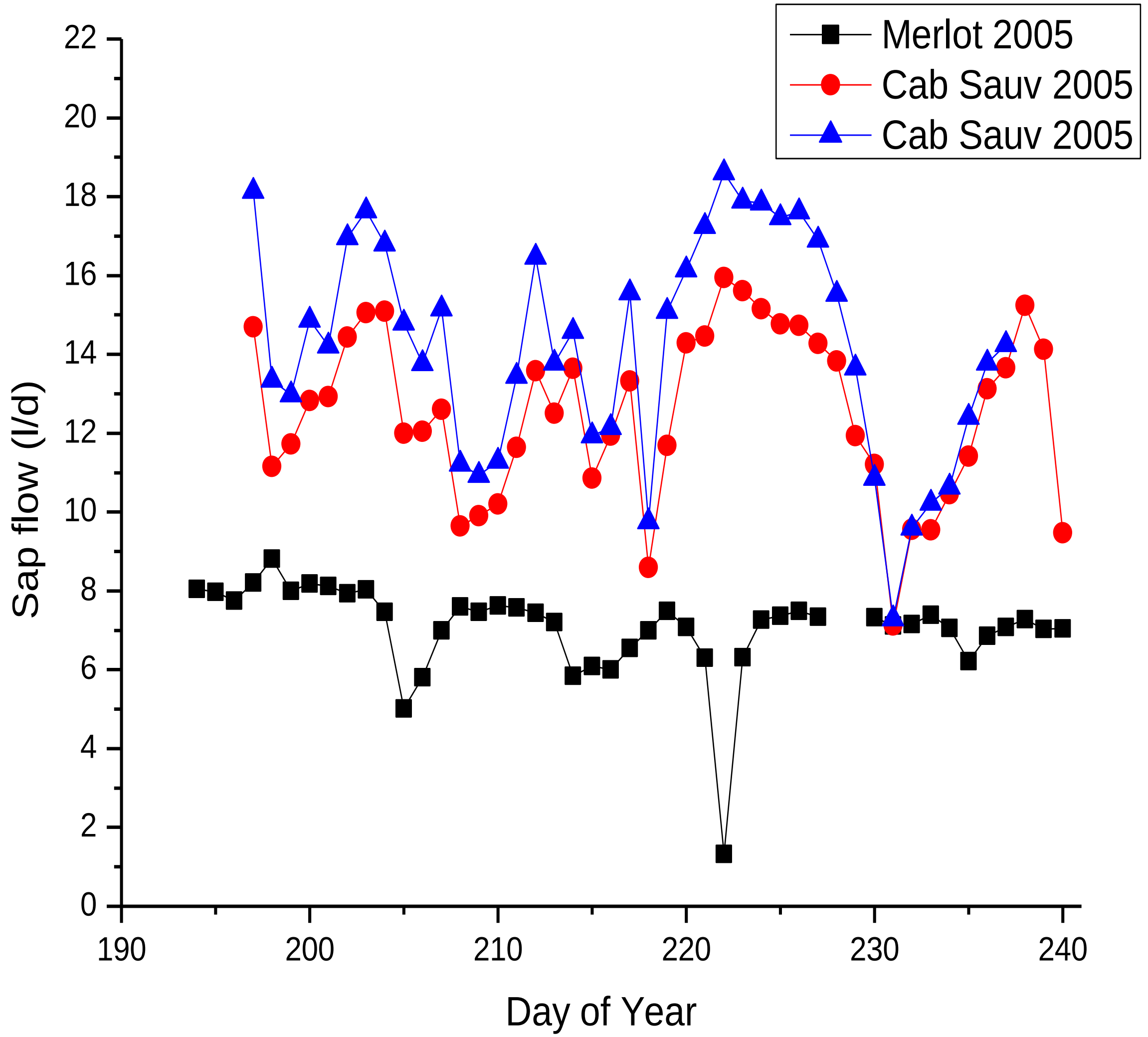
Results

Total daily sap flow over time



Results

Daily sap flow over time – comparison of 2004 vs 2005



Water use in mid summer

- In 2004, ~5 gal per vine per day
- In 2005, ~2.5 gal per vine per day

However, due to differences in planting densities between years, water use per acre was the same at ~0.1” per day.

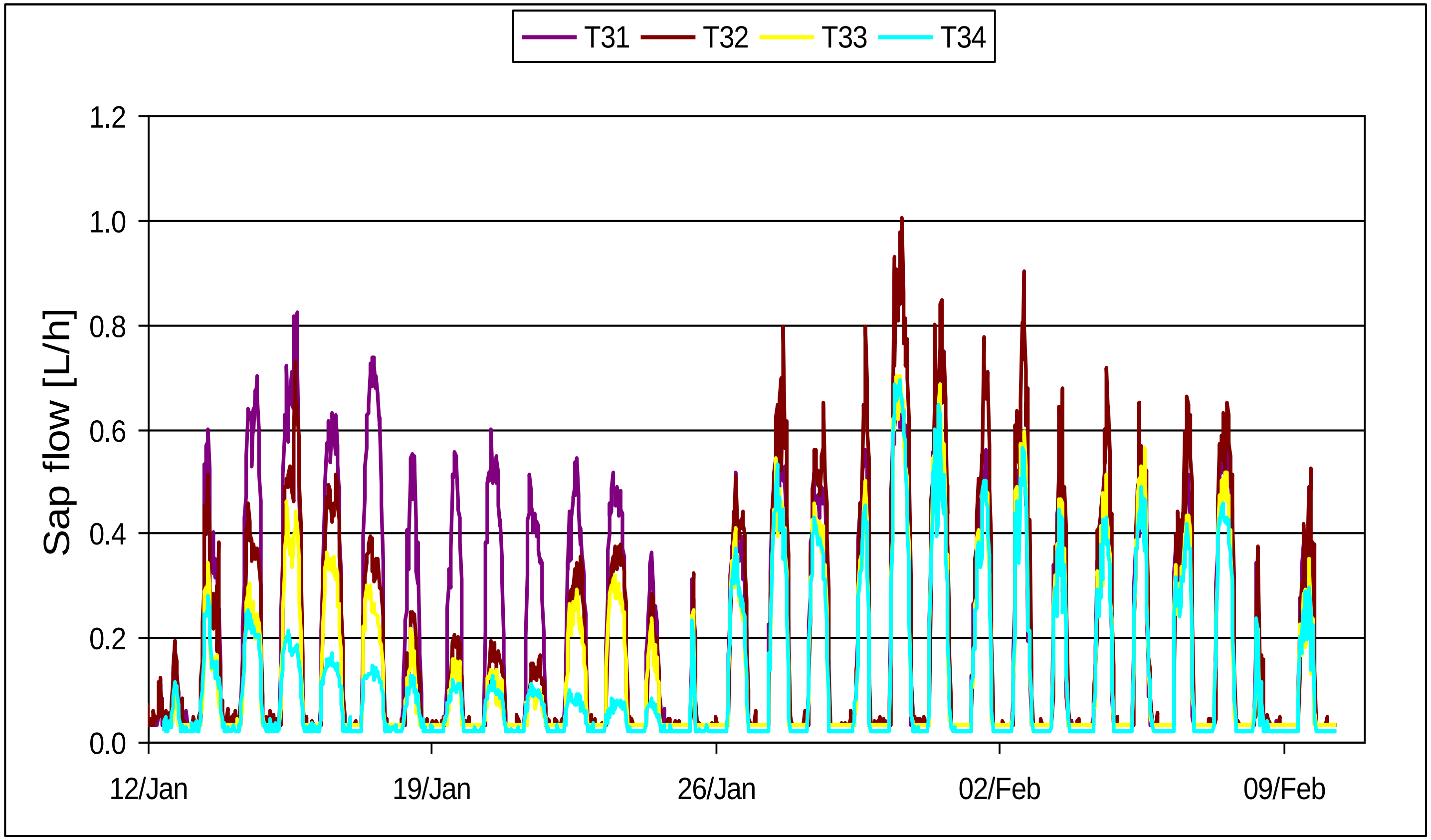
Water use versus water needs

- How much water do grape vines use?
- How much water do grape vines need?

Water use versus water needs

Vines using water relative to the irrigation input.

T31 – 100% T32 – 60% T33 – 40% T34 – 20 %

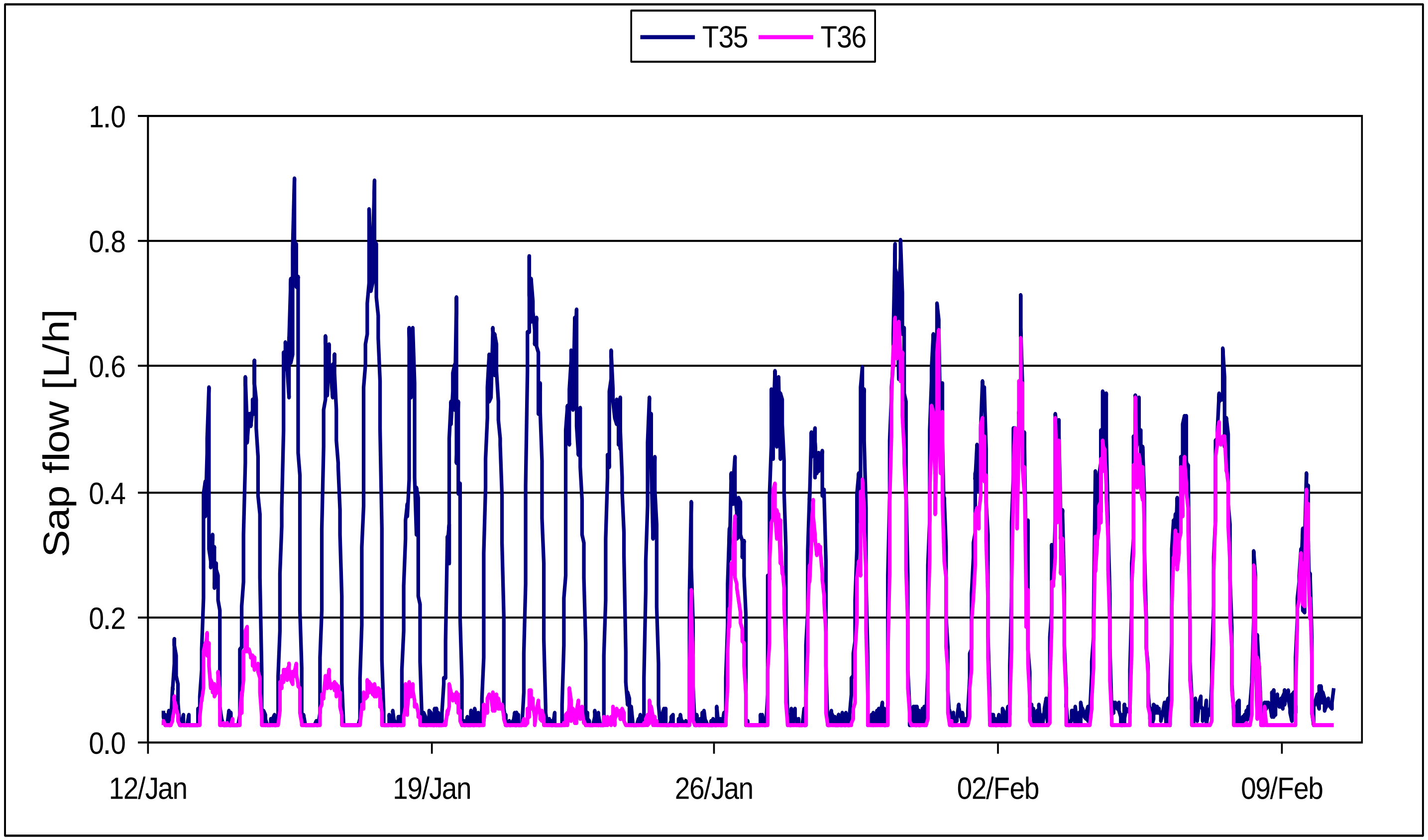


Note: Major rainfall event on 25 Jan

Sauvignon blanc, Marlborough, New Zealand (data from S. Green)

Water use versus water needs

Vines using water relative to the irrigation input.
T35 – PRD60%   T36 – mulch (no irrigation)



Note: Major rainfall event on 25 Jan
Sauvignon blanc, Marlborough, New Zealand (data from S. Green)

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Water use versus water needs

- Vines can use large volumes of water if available

- However, we can force them to restrict their water use to the volume that is applied via irrigation.

- How little is enough?

Water use of grape vines

What determines vine water use?

- Climate
- Plant development
- Plant size (leaf area)

What determines vineyard water use?

- All of the above
- Trellis type
- Plant density
- Soil management

Influence of trellis and row spacing

Trellis	row spacing	peak k_c
VSP	6’	0.82
VSP	7’	0.71
VSP	8’	0.62
VSP	9’	0.55
VSP	10’	0.49
Lyre	9’	0.83
GDC	12’	0.75
HD (VSP)	1 x 1 m	0.91

Source: Williams, 2001

Estimating water needs

- ET_o for July and August: 8.4” and 7.3”
- VSP trellis with 5’ x 10’ vine x row spacing
- Peak k_c = 0.49
- Estimated vine water use:
  - July 8.4” x 0.49 = 4.1” (~4.2 gal/vine/d)
  - August 7.3” x 0.49 = 3.6” (~3.6 gal/vine/d)

Estimating water needs

Williams (2001) reported that irrigation at approximately 80 % of full ET maximised berry size for raisin and table grapes.

Given that we generally do NOT want to maximise berry size of wine grapes, it appears that we can reduce the crop coefficient by more than 20 % from the values above.

Where to find ET information

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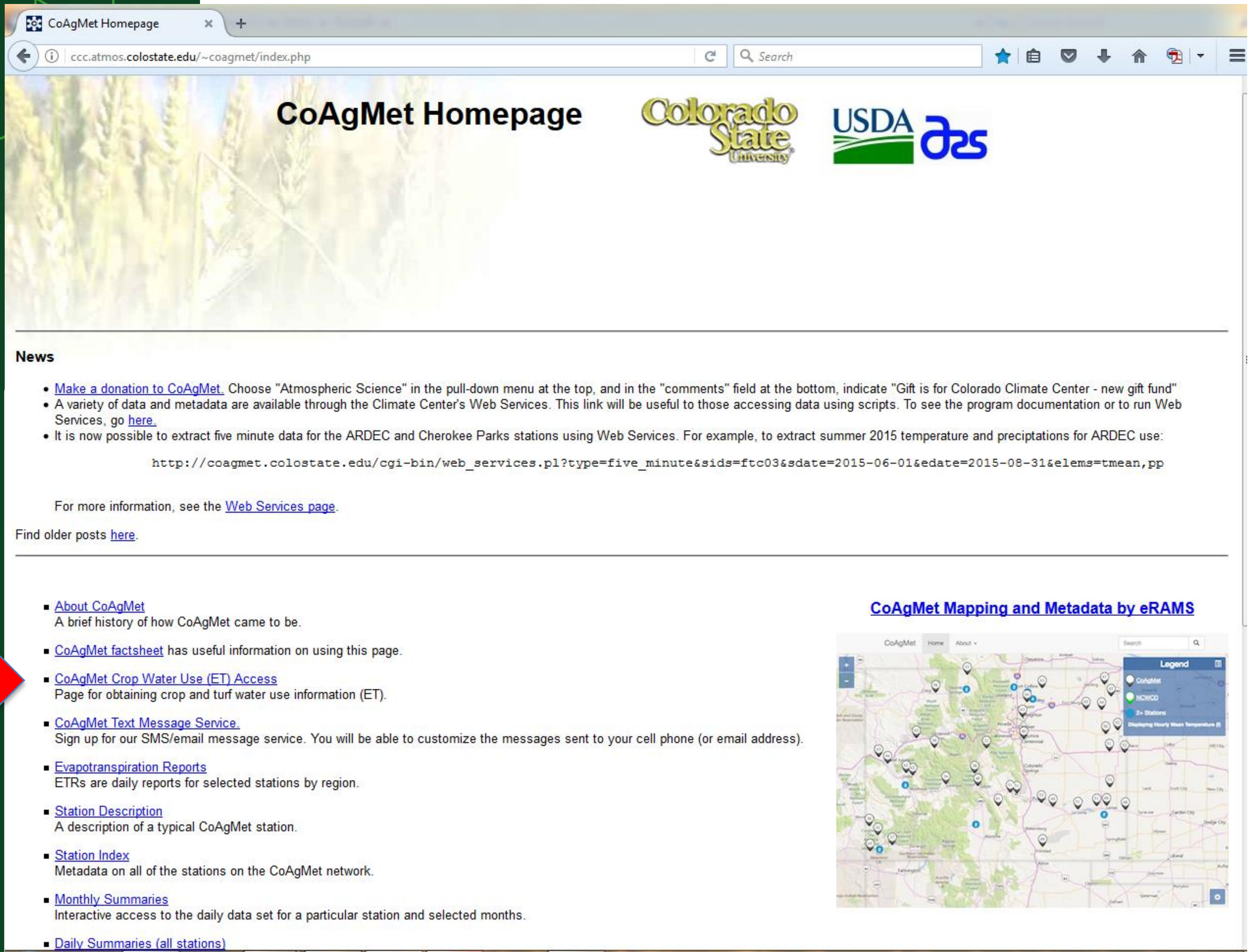

CoAgMet Homepage

ccc.atmos.colostate.edu/~coagmet/index.php

CoAgMet Homepage

Colorado State University

USDA ars

News

- Make a donation to CoAgMet. Choose "Atmospheric Science" in the pull-down menu at the top, and in the "comments" field at the bottom, indicate "Gift is for Colorado Climate Center - new gift fund"
- A variety of data and metadata are available through the Climate Center's Web Services. This link will be useful to those accessing data using scripts. To see the program documentation or to run Web Services, go here.
- It is now possible to extract five minute data for the ARDEC and Cherokee Parks stations using Web Services. For example, to extract summer 2015 temperature and preciptations for ARDEC use:

```
http://coagmet.colostate.edu/cgi-bin/web_services.pl?type=five_minute&sids=ftc03&sdate=2015-06-01&edate=2015-08-31&elems=tmean,pp
```

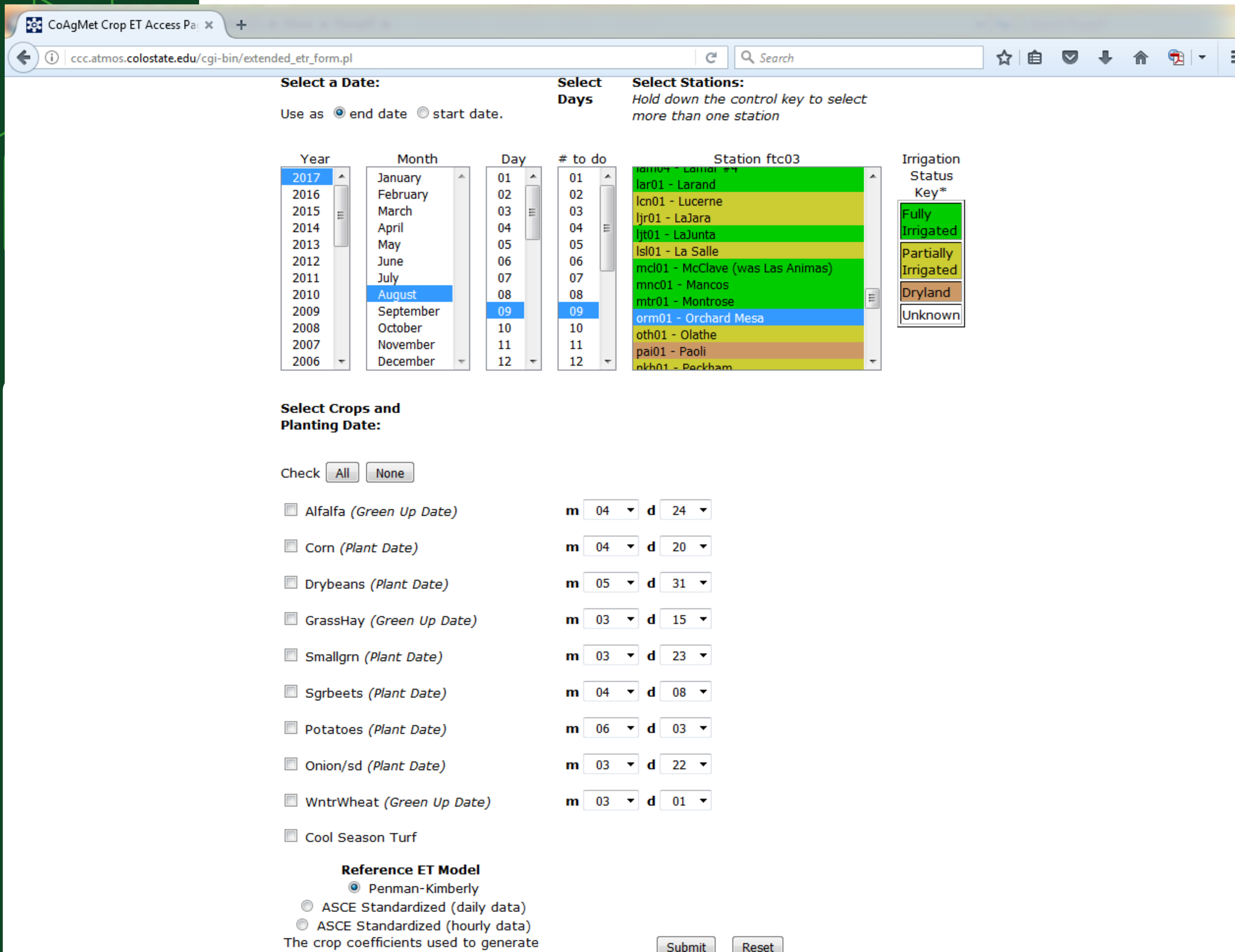
For more information, see the Web Services page.

Find older posts here.

- About CoAgMet
  A brief history of how CoAgMet came to be.
- CoAgMet factsheet has useful information on using this page.
- CoAgMet Crop Water Use (ET) Access
  Page for obtaining crop and turf water use information (ET).
- CoAgMet Text Message Service.
  Sign up for our SMS/email message service. You will be able to customize the messages sent to your cell phone (or email address).
- Evapotranspiration Reports
  ETRs are daily reports for selected stations by region.
- Station Description
  A description of a typical CoAgMet station.
- Station Index
  Metadata on all of the stations on the CoAgMet network.
- Monthly Summaries
  Interactive access to the daily data set for a particular station and selected months.
- Daily Summaries (all stations)

CoAgMet Mapping and Metadata by eRAMS

CoAgMet ET page



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CoAgMet ET report

Colorado State Home Page
USDA/ARS Home Page

CoAgMet Extended Crop Evapotranspiration

Station:Orchard Mesa
Location:Orchard Mesa
Elevation:4600
Longitude:108.46
Latitude:39.042

Crop Evapotranspiration in Inches

Date	RefET	Precip
08/01/2017	0.34	0.00
08/02/2017	0.39	0.00
08/03/2017	0.37	0.00
08/04/2017	0.37	0.09
08/05/2017	0.31	0.01
08/06/2017	0.31	0.00
08/07/2017	0.22	0.00
08/08/2017	0.29	0.01
08/09/2017	0.30	0.01
Sum	2.90	0.12
Average	0.32	0.01

Return to the CoAgMet ETR Summary Access.

Return to the CoAgMet Homepage.

Estimating water needs

- ET_o for 1-9 August: 2.9”
- VSP trellis with 5’ x 10’ vine x row spacing
- Peak k_c = 0.49
- Estimated vine water use (ET_o x k_c):
  - 2.9” x 0.49 = 1.42”
  - 1.42” = 38,586 gallons/acre
  - ~4.9 gal/vine/d

Irrigation – further questions

- Do we irrigate vines?
- Do we irrigate vineyards?

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Drip-irrigated vines
dry alleyway

Sprinkler-irrigated vineyard
actively growing cover crop

Irrigation – further questions

- What about young vines?

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Water use of young grape vines

- Potted 2-year-old Noiret vines
- Two shoots per vine, trained to a V-shape
- All lateral shoots removed in late June
- Node and mature leaf number per shoot determined every 2 weeks

Water use of young grape vines

- Pots weighed 2-3 times a week
- “Water use” calculated from weight changes
- “Water use” includes vine transpiration and soil evaporation

Water use of young grape vines

- 1 July 2015
- Shoot length about 1.3 m

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Water use of young grape vines

- 31 July 2015
- Shoot length ~2.4 m

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Water use of young grape vines

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- 2 Sep 2015
- Shoot length ~3.6 m

Water use of young grape vines

- 28 Oct 2015
- Shoot length ~4.0 m

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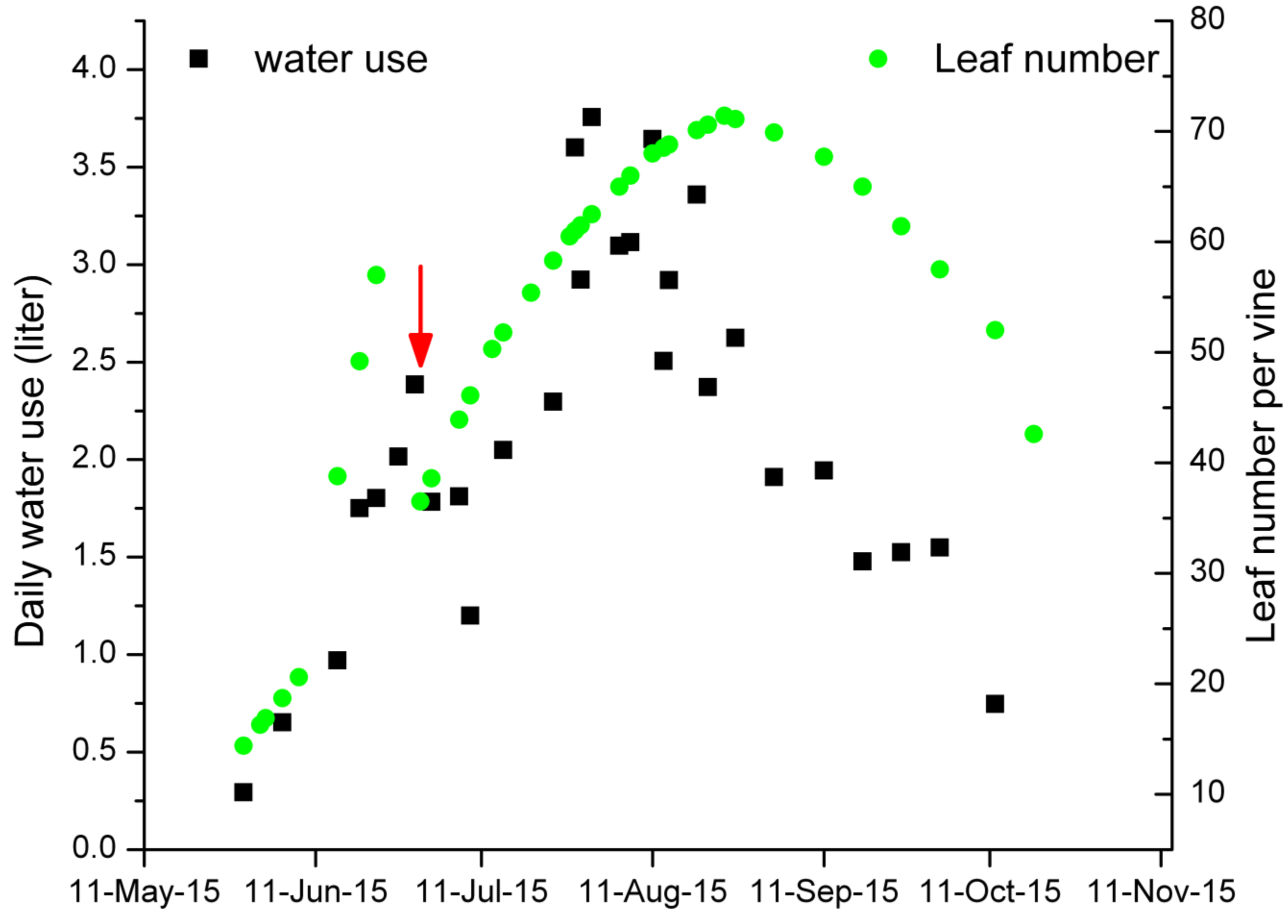
Water use of young grape vines

- Exceptional shoot growth!
- Shoot growth was 2-3 times that of similar-aged vines in the vineyard

Water use of young grape vines



Seasonal development of leaf number and water use of potted Noiret vines. Red arrow indicates time when laterals were removed.

Water use of young grape vines

- Early-season water use tightly linked to leaf area development
- Peak water use in late July / early August
- Maximum water use was 3.8 l/day
- Daily vine water use exceeded 3 l/day for approximately one month (late July to late August)

Water use of young grape vines

• After its peak in late July water use gradually declined despite continued increases in leaf area until mid September

• This trend matches that of mature vines. In 2004, water use of mature Cabernet Sauvignon vines peaked in early August, then gradually declined throughout the rest of the growing season.

Take home messages

- Early-season water use is tightly linked to leaf area development.
- Vine water use peaks in late July / early August, then gradually declines.
- Water use is related to vine size (canopy size and canopy orientation).

Take home messages

- Peak water use of young vines with exceptional growth was ~1 gallon/day.
- Peak water use of mature vines spaced at 8’ in row was ~4.5 gallon/day.
- Peak water use of mature vines spaced at 5’ in row was ~2.5 gallon/day.

Take home messages

- Water use ≠ Water needs

- Vine water use ≠ Vineyard water use
  - Drip-irrigated Chardonnay vines with a crested wheatgrass cover crop at WCRC-OM received 12.8“ of irrigation in 2016.

  - Sprinkler-irrigated Chardonnay vines with grass, legume, or grass-legume cover crops at WCRC-OM received 31.3“ of irrigation.

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Questions?

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Colorado State University
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Ph: (970) 434-3264
horst.caspari@colostate.edu

Best Viticultural Practices for Premium Wines from Healthy Vines

Imed Dami

11 August 2017

Grand Junction, CO

Factors Affecting Wine Quality & Vine Health

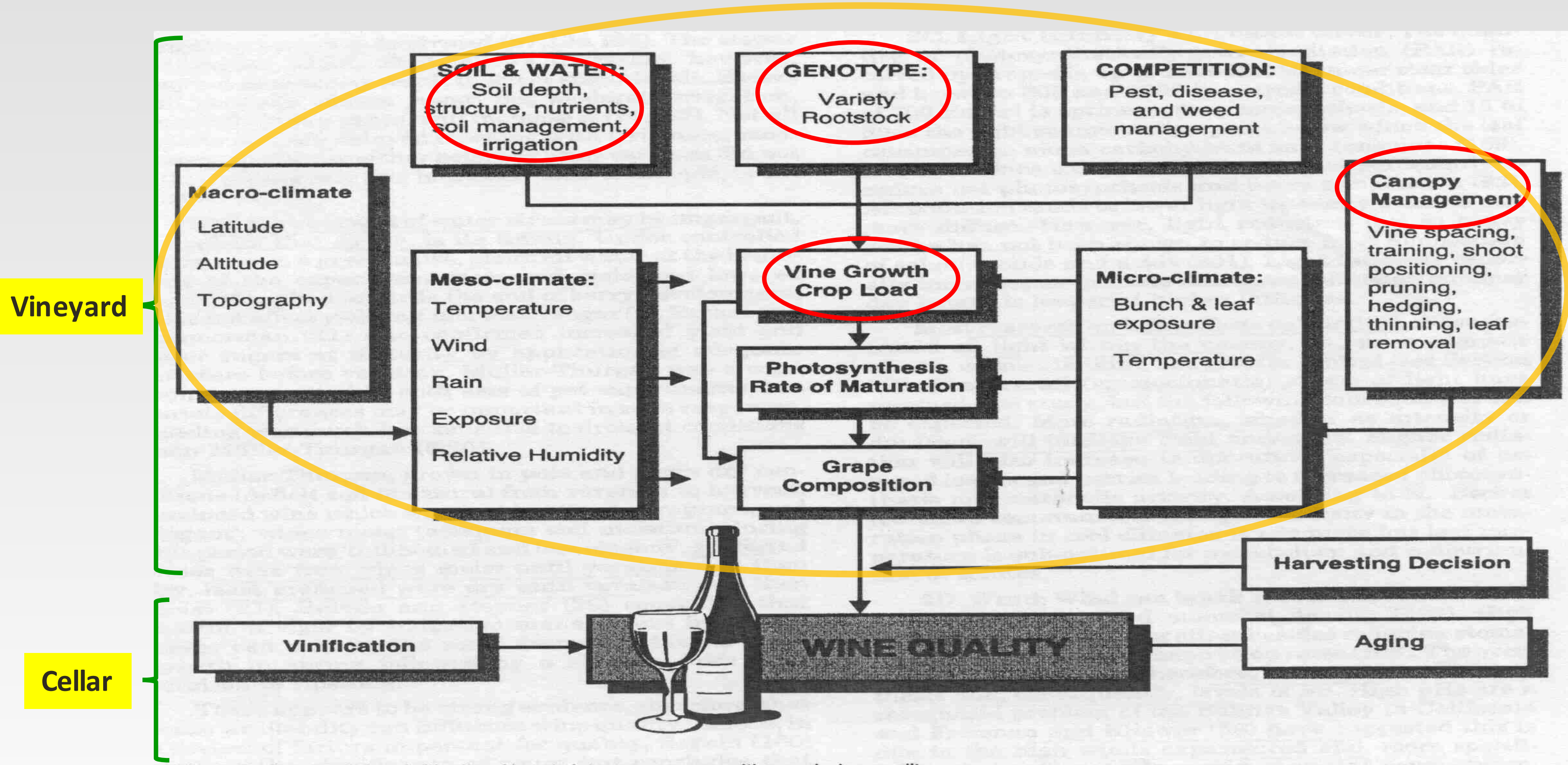


Fig. 2. Environmental and viticultural inputs into grape composition and wine quality.

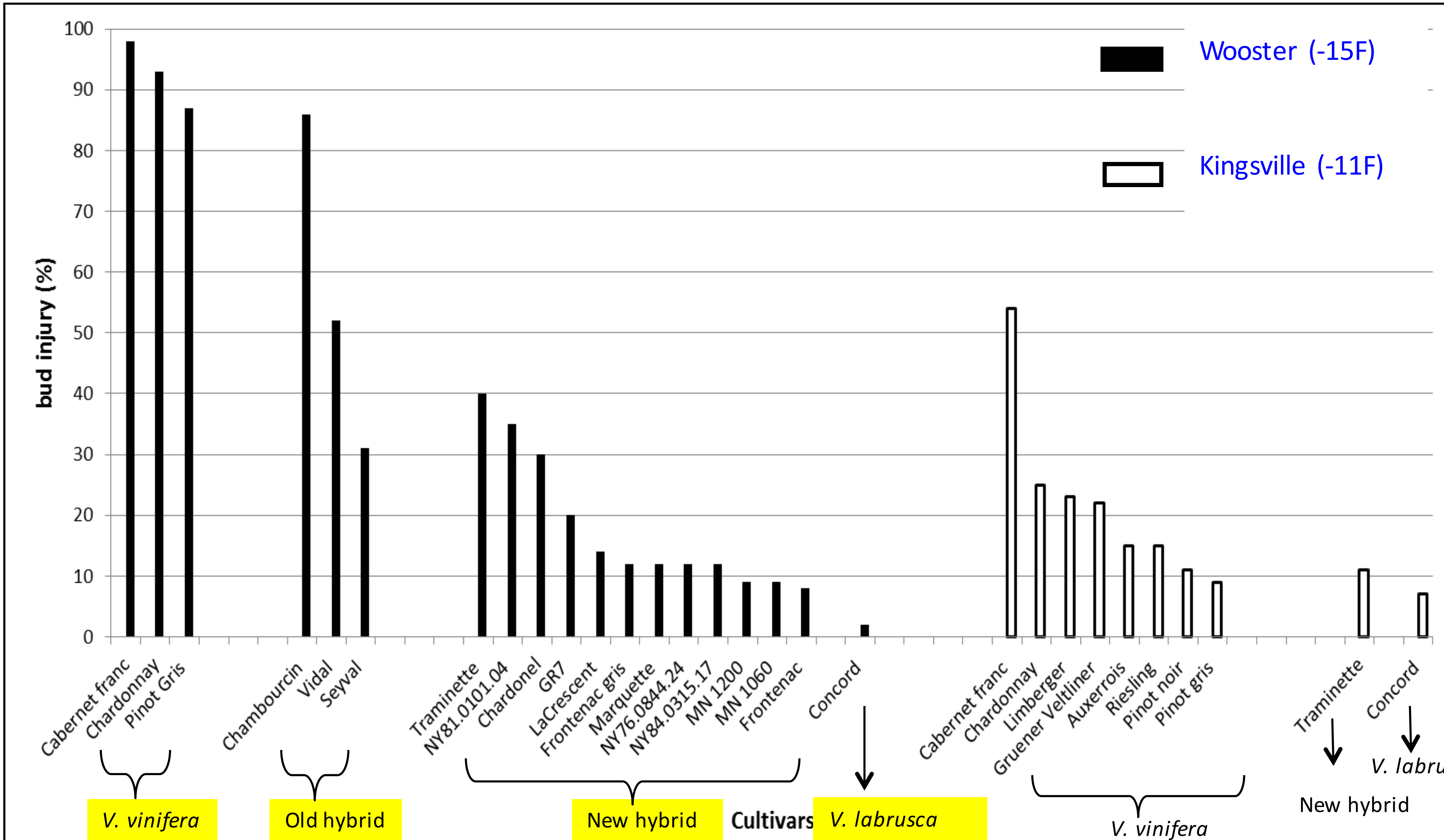
(Jackson & Lombard 1993)

Vinifera vs. Hybrids

- ***Vitis vinifera*:** one species/cross of varieties from same species
- **Hybrid:** product of a crossing of two or more *Vitis* species

	Vinifera	Hybrid
Growth	Upward	Procumbent (downward)
Training system	Low cordon - VSP	High cordon, GDC
Fruit zone	36-42"	60-72"
Vigor	Less	More
Yield	Less	More
Crop Load	5-10	10-28
Diseases	Most susceptible	Less susceptible
Phylloxera (root)	Susceptible (grafting)	Less susceptible
Cold hardiness	Most sensitive	More cold hardy

Primary Bud Injury after 2009 Freezing Event



(Dami et al. AJEV 2012)

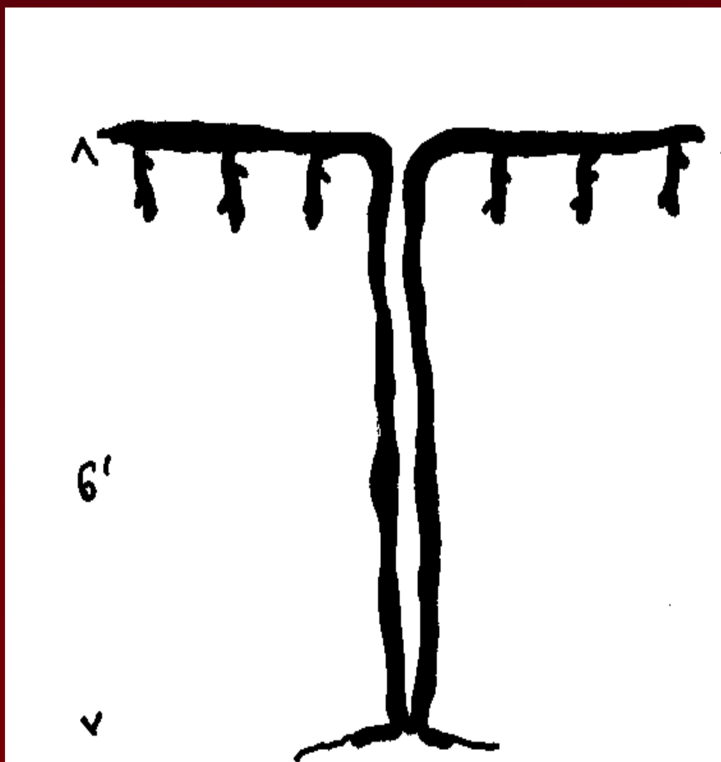
Released Wine Grape Varieties

Year	Variety name	Crosses	Wine	Source
1948	Ruby Cabernet	vinifera x vinifera	Red	University of California
1972	Cayuga White	Multiple species	White	Cornell University
1985	Melody	Multiple species	White	Cornell University
1990	Chardonel	Multiple species	White	Cornell University
1996	Traminette	Multiple species	White	Cornell University
1996	Frontenac	Multiple species	Red	University of Minnesota
2002	La Crescent	Multiple species	White	University of Minnesota
2003	GR 7	Multiple species	Red	Cornell University
2006	Corot noir, Noiret	Multiple species	Red	Cornell University
2006	Marquette	Multiple species	Red	University of Minnesota
2013	Aromella, Arandell	Multiple species	White	Cornell University
2017	Itasca	Multiple species	White	University of Minnesota

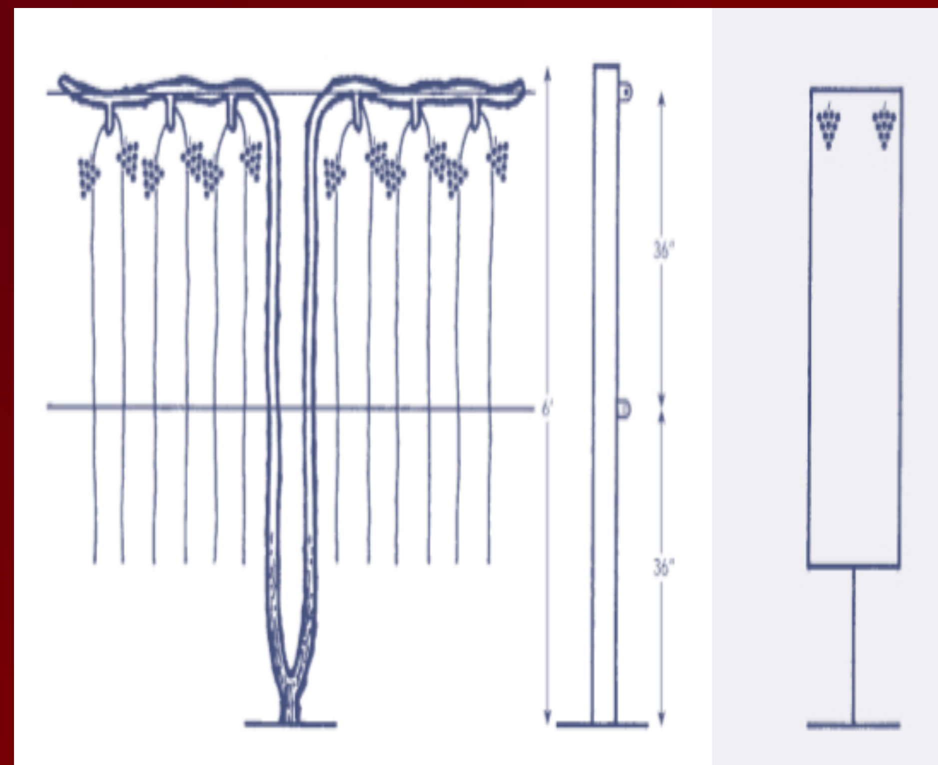
Training of Hybrids

Research has shown High-Cordon training outperformed Low-Cordon (VSP)(Chambourcin, Chardonel, Frontenac, Marquette, Noiret, Norton, Traminette, Vidal, Vignoles)

High Cordon / Single High Wire

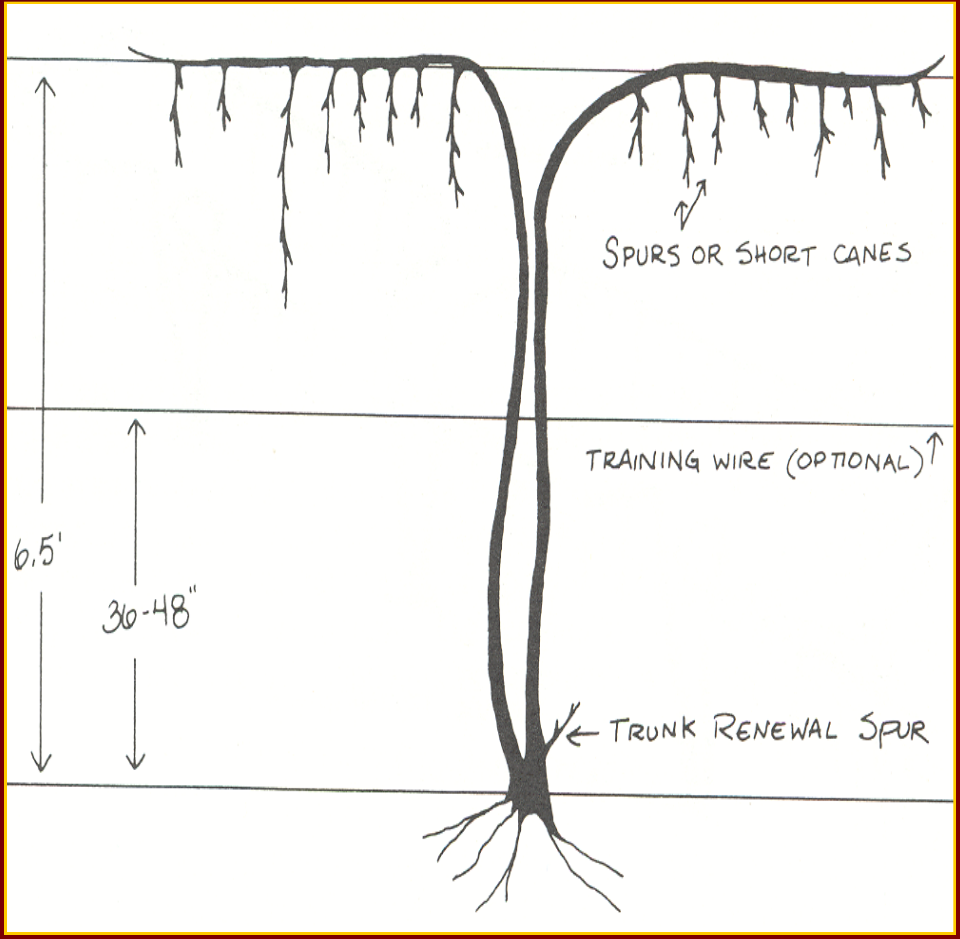


Winter- Pruned



Fall- Not Pruned

High-Cordon Training System



High Cordon Training

2 trunks
2 cordons
established

Spring 2nd year

Winter 3rd+ year

2 trunks
2 cordons
Spurs established

Crop Control

- For (most) *Vitis vinifera*, crop control is accomplished by **balance pruning**
- For many hybrids, balance pruning alone does not control crop yield
- Hybrids require "**balanced cropping**" = pruning + cluster thinning
- Chambourcin is productive: fruitful count and non-count buds → balance pruning was not known

Crop Load Study - Chambourcin

Identify the **optimum** crop load: "*optimum vine size that is sustainable and corresponds to optimum yield and fruit quality with minimum cold injury*" (Dami et al. 2006)

Objectives:

Determine the effect of pruning and Cluster thinning on:

- Growth (vine size)
- Yield
- Fruit composition
- Cold hardiness

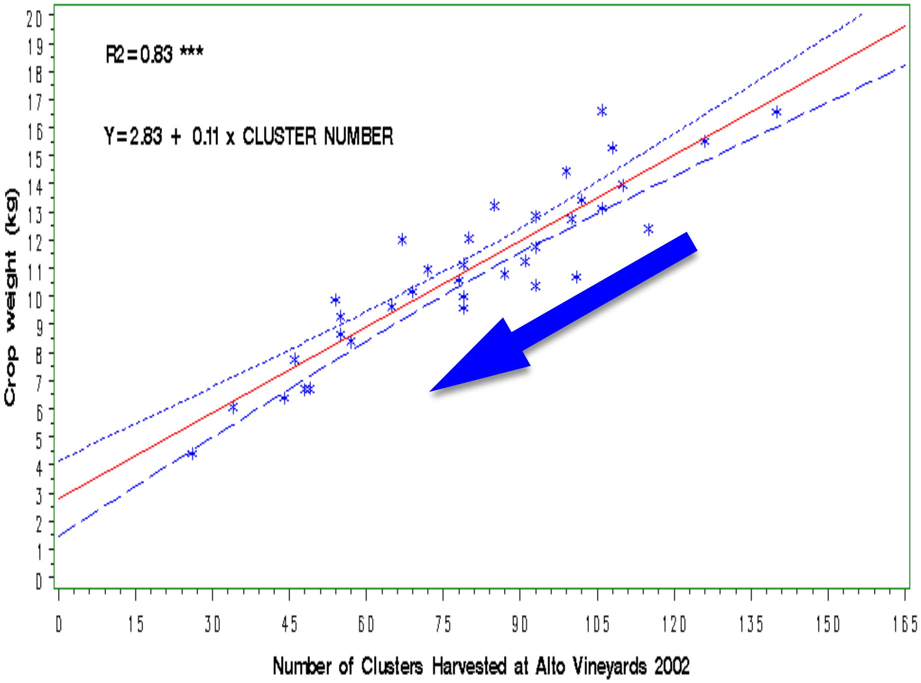
Results (8 years and 2 states)

- **Balanced pruning** had little or no effect on any of the variables measured

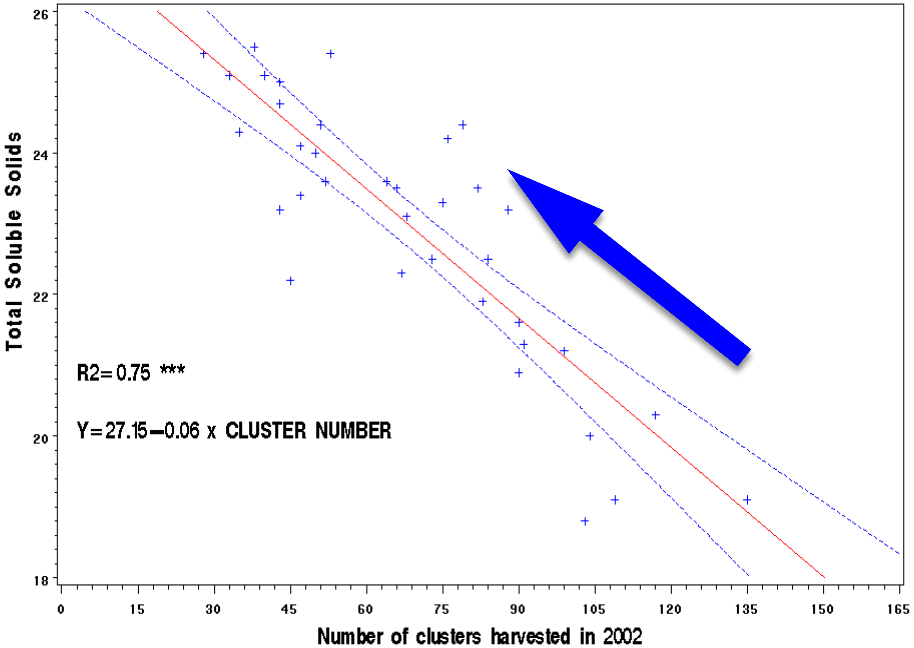
- **Cluster thinning** had significant effect on most measured parameters in Chambourcin

Cluster Thinning vs. Yield & Brix

Yield



Brix



Effect of Cluster Thinning on **Fruit** Composition 5-Year Summary (2000-2004)

Target clusters	Crop load (CL)	CL assessment	Brix	pH	TA (g/L)
10	10	Optimum/ideal	21.3	3.27	11.2
20	23	Over-cropped	20.5	3.23	10.7
30	25	Over-cropped	20.1	3.20	10.7
Linear	***		*	*	ns

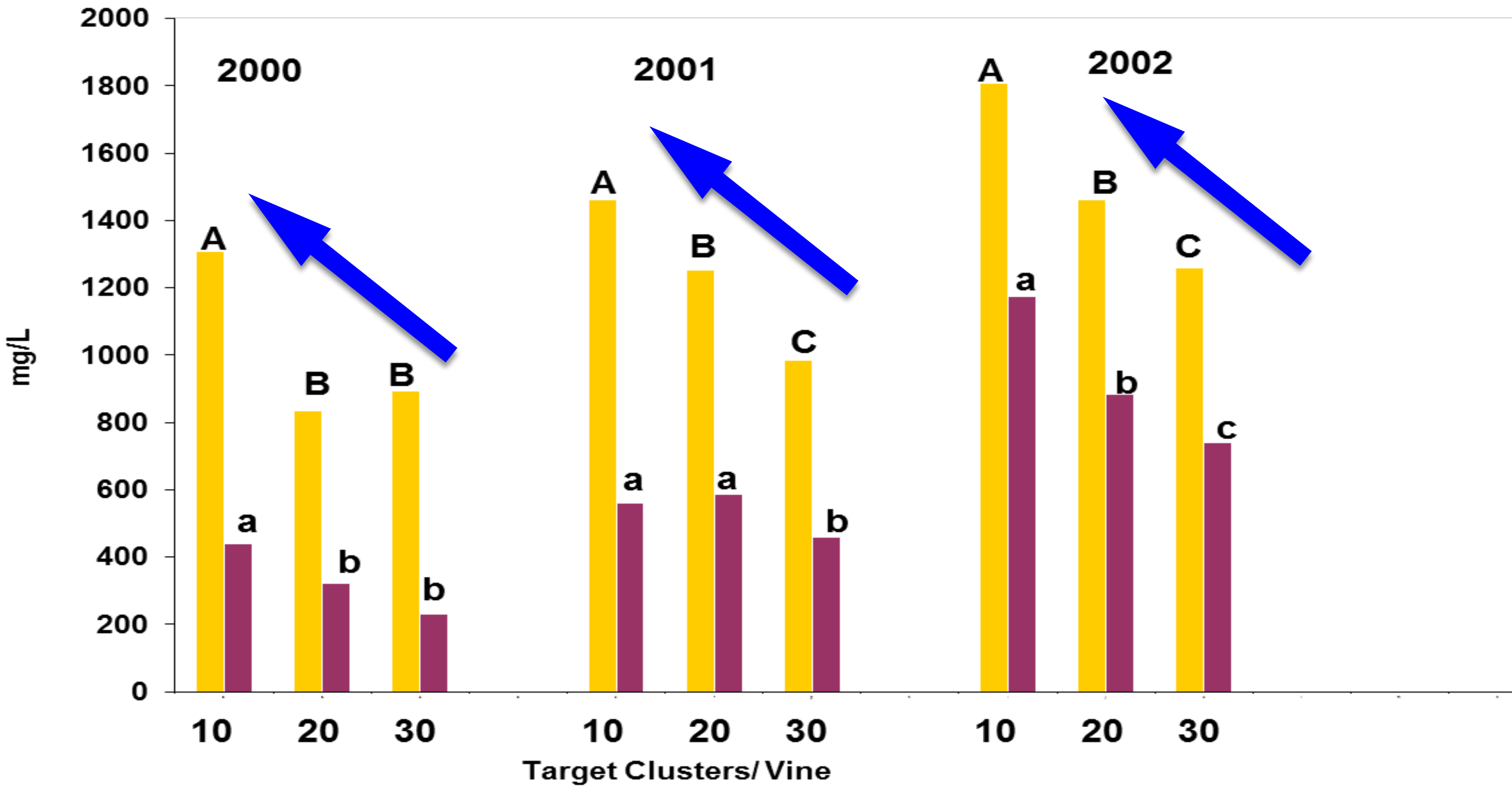
Effect of Cluster Thinning on **Fruit** Composition Year 2005

Target clusters	Harvest date	Brix	pH	TA (g/L)	Malic acid (mg/L)	Anthocyanins (mg/L)	Total phenols (mg/g fw)
10	6 Oct	22.4	3.45	12.6	403	1733	4.37
20	19 Oct	22.4	3.43	10.7	322	1301	3.63
30	19 Oct	22.1	3.42	10.6	325	1228	3.39
Linear		ns	*	**	**	**	**

Cluster Thinning & Wine Quality in Chambourcin

Ohio Study

Anthocyanins and Total Phenolics of Chambourcin Wines

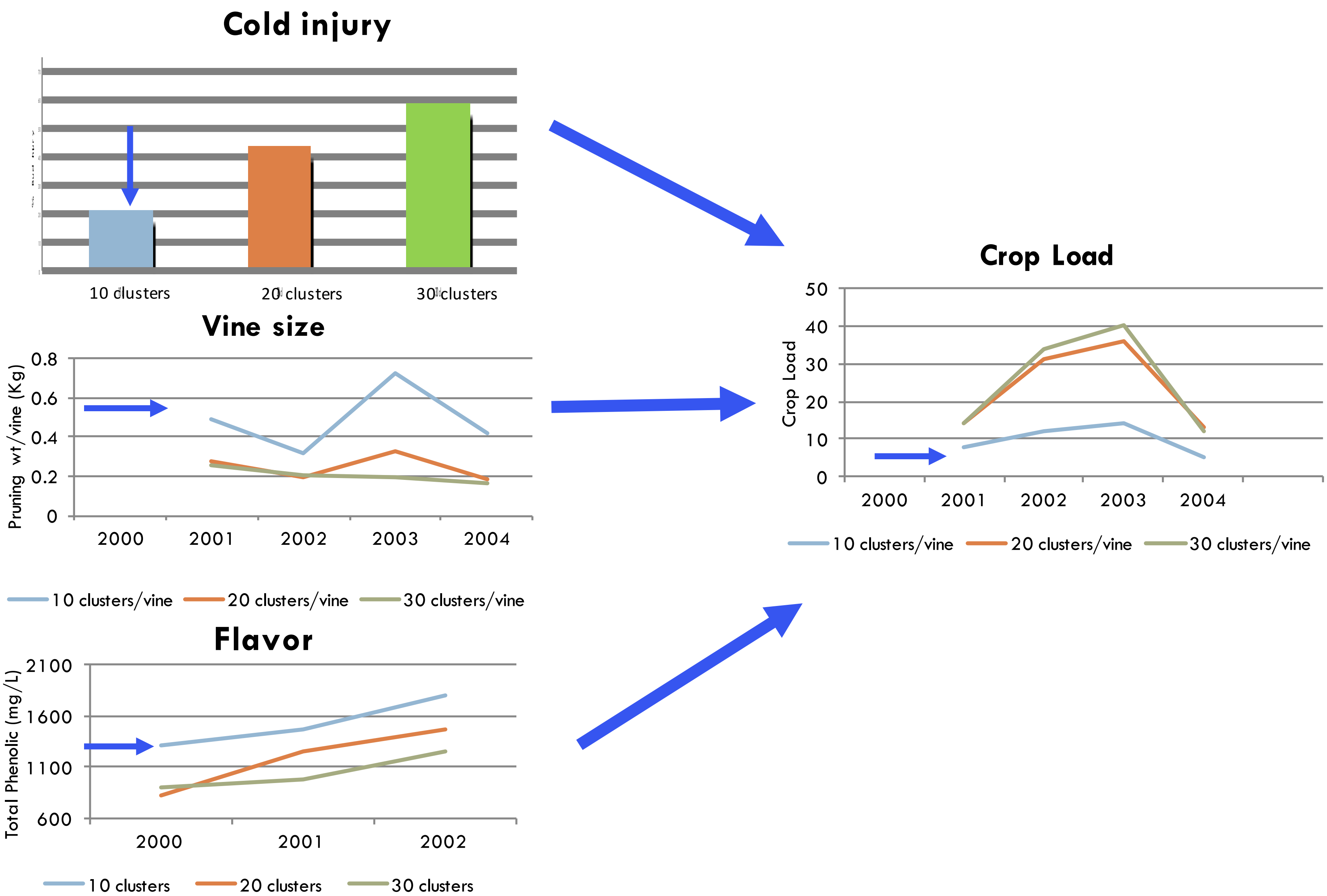


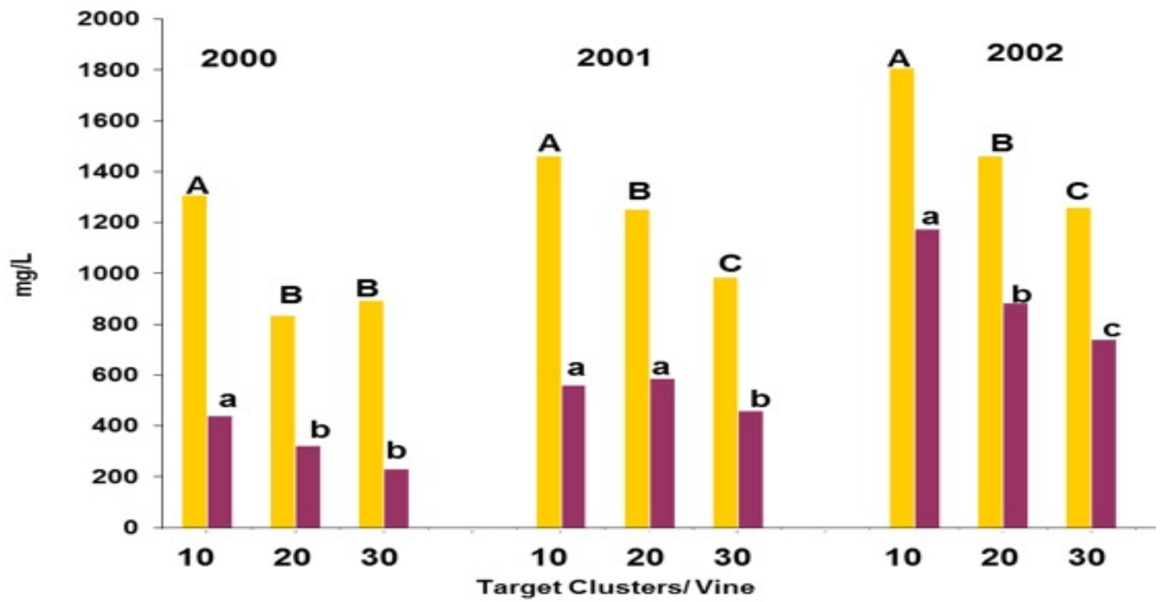
(Prajitna et al. AJEV. 2007)

Cluster Thinning & Cold Hardiness (N. Ohio)

Target clusters/vine	Actual clusters/vine	Shoots/vine	%Bud injury at 0 °F
10	14	22	22
20	23	22	44
30	32	21	60
Linear	***	NS	*

*Goal: Identify the **optimum** crop load (10-14): Vine size that is sustainable and corresponds to optimum yield and fruit quality with minimum cold injury.*

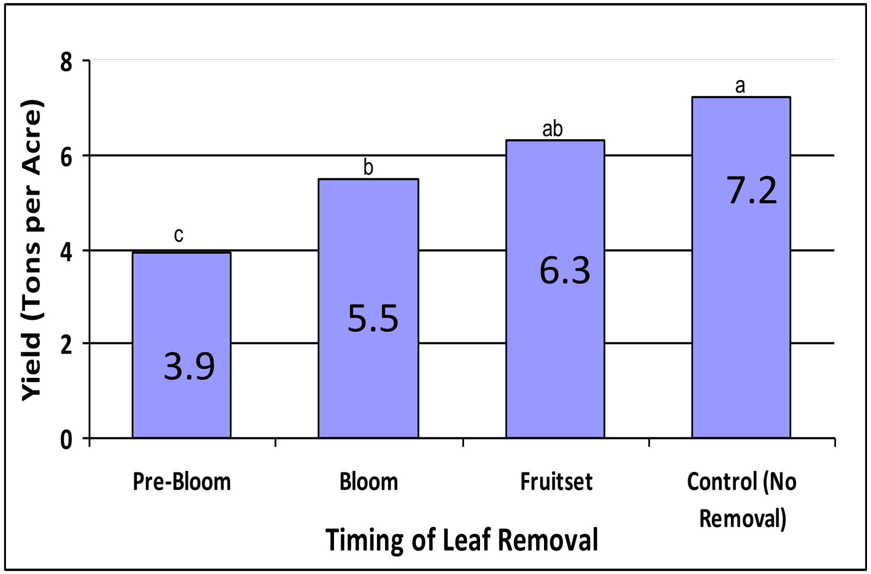




Year	Harvest Date	FFD	GDD-harvest	Coldest Temp(°F)
2000	18 Oct	165	2662	-7
2001	10 Oct	161	2795	4
2002	1 Oct	145	3046	4
2003	6 Oct	158	2639	-12
2004	12 Oct	166	2727	-8
Mean	9 Oct	~160	~2800	-4F

Early Leaf Removal Works: Similar to Cluster Thinning!

Chambourcin



PB leaf removal equivalent to cluster thinning

Cabernet franc

Mechanical comparable to manual leaf removal

Chalfant & Dami 2011

Take Home Message

In addition to pruning, **cluster thinning** of Chambourcin is a **MUST** practice that:

- **Maintains** vine **balance:**
  - Pruning = 15 nodes per lb (or 4-5 buds/ft)
  - Pruning weight ≥ 0.2 lb/ft cordon length
  - Cluster thinning = 1 cluster /shoot
  - "Optimum" CL varied with location:
    - N. Ohio (short/cool season) = 10 (5-14)
    - S. Illinois (long/warm season)= 14 (10-16)
    - Optimum growing season: FFD ≥ 170; GDD ≥ 3000

- **Increases** winter **hardiness**
- **Shortens** ripening **season**
- **Improves** basic **fruit** chemistry & **wine** flavor attributes


Thank you!

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Vine Nutrition

Horst Caspari

Colorado State University
College of Agricultural Sciences

Factors Affecting Wine Quality & Vine Health

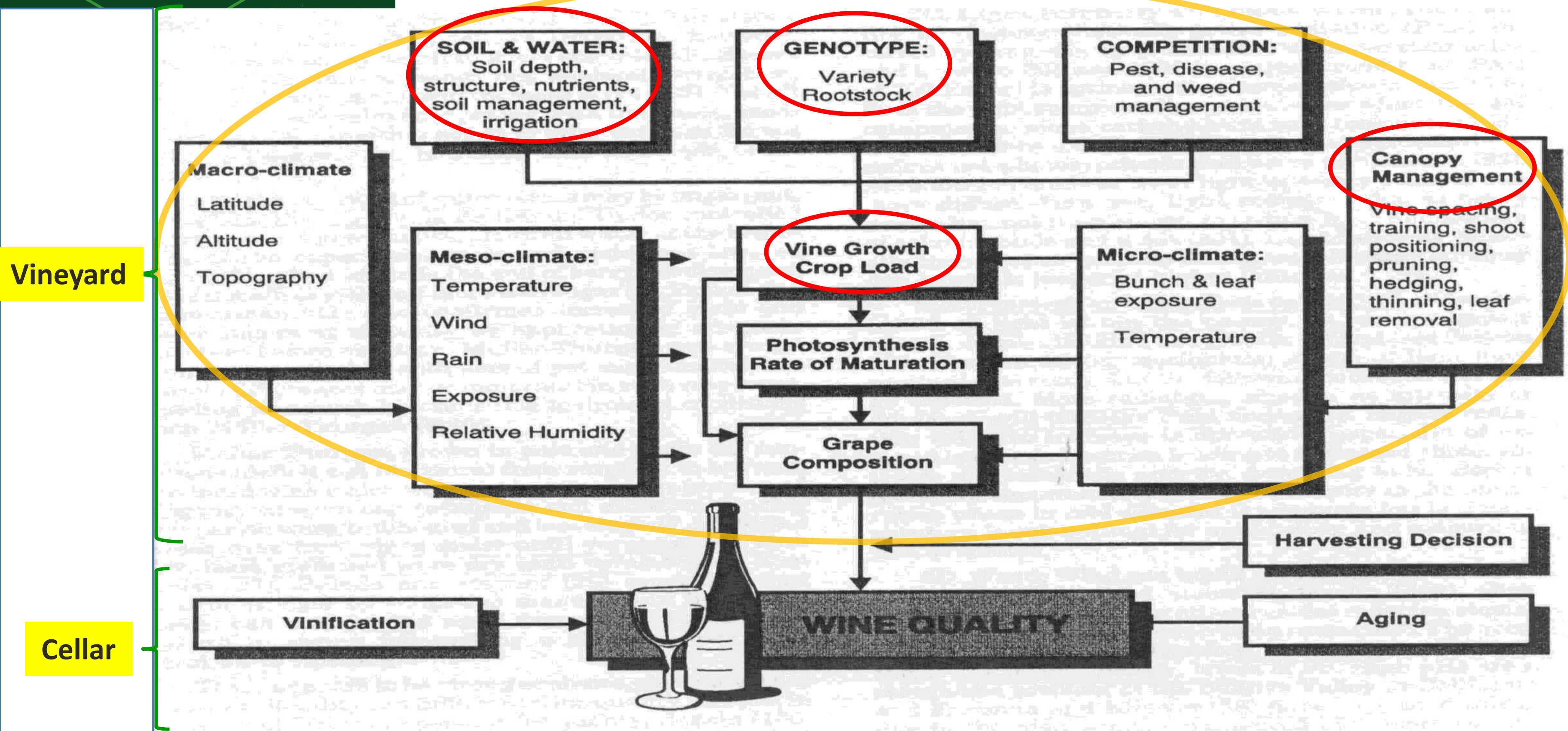


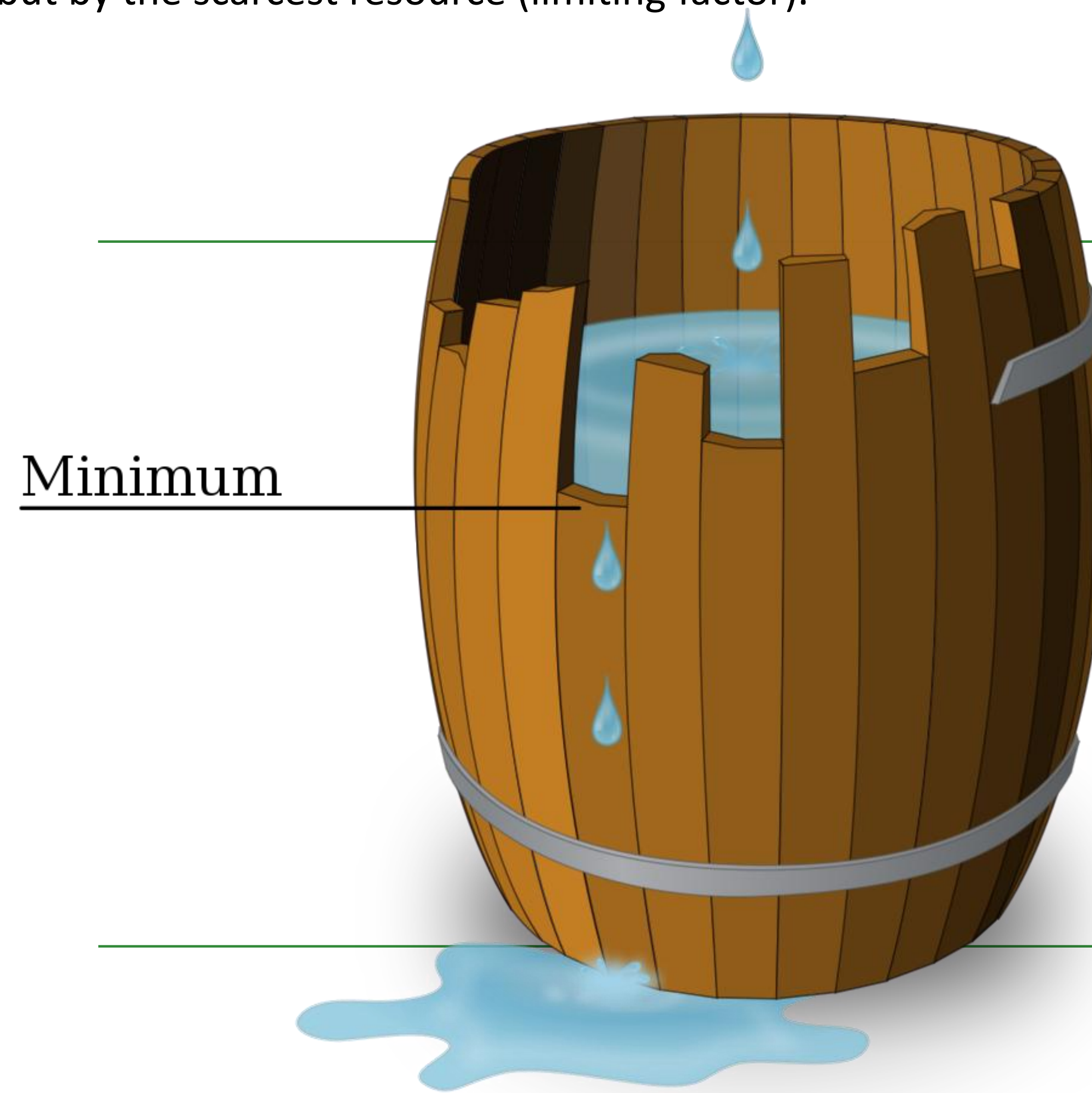
Fig. 2. Environmental and viticultural inputs into grape composition and wine quality.

Vine nutrition

- Why do we need to pay attention to the vines' nutrient status?

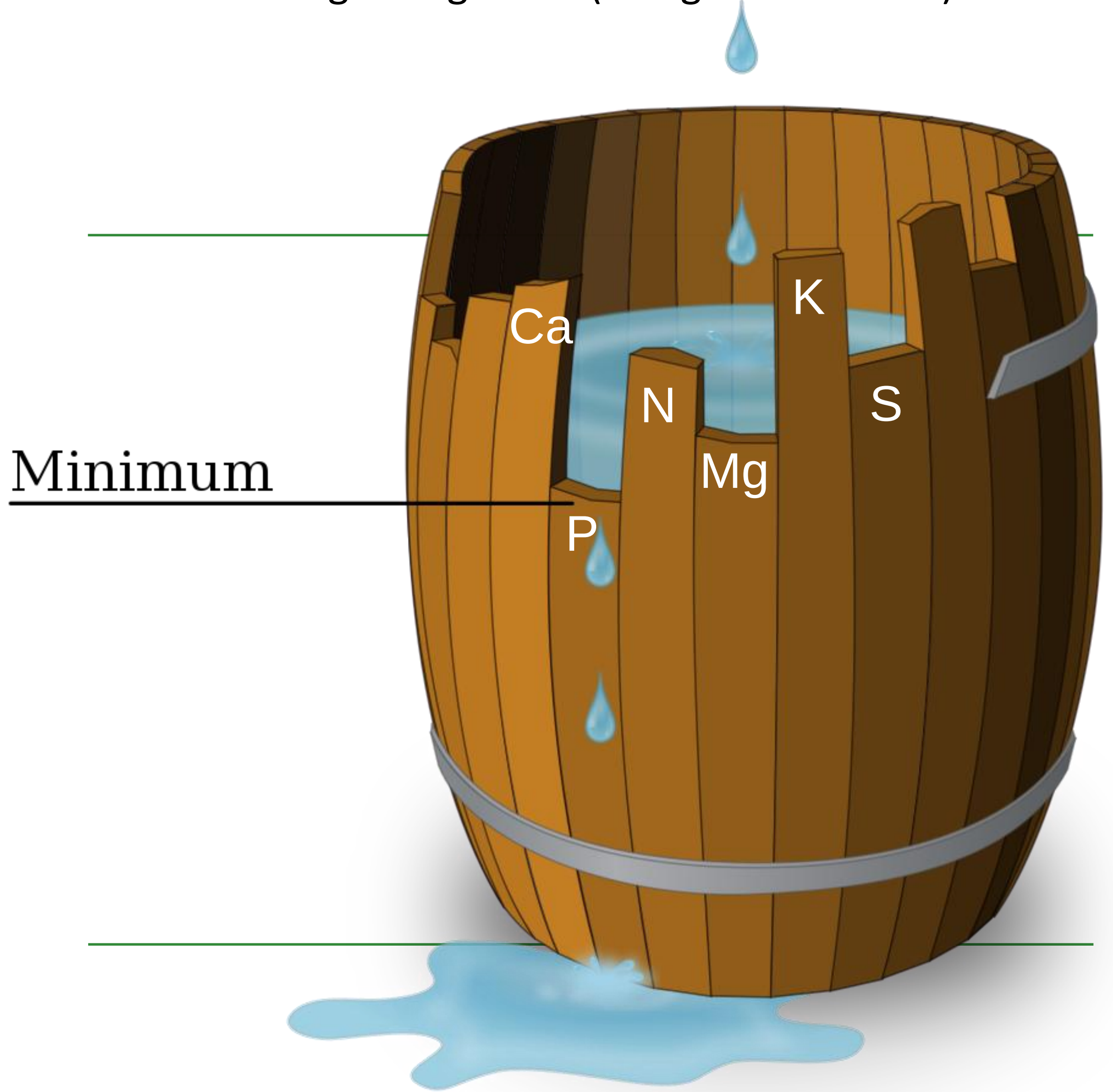
Sprengel's (Liebig's) Law of the Minimum

Growth is controlled not by the total amount of resources available, but by the scarcest resource (limiting factor).



Sprengel's (Liebig's) Law of the Minimum

In the example, the lowest stave is "P", indicating that phosphorus is the factor limiting vine growth (filling of the barrel).



Know your vineyard nutrient needs

Essential plant nutrients
Soil pH & nutrient availability
Soil vs. tissue sampling & testing
Treating for micronutrient deficiencies

Essential plant nutrients

<u>Essential</u>: Plant can not complete its life cycle without these nutrients

C - Carbon
H - Hydrogen
O - Oxygen

<u>Macro</u>

N - Nitrogen
P - Phosphorus
K - Potassium
S - Sulfur
Ca - Calcium
Mg - Magnesium

<u>Micro</u>

Fe - Iron
Mn - Manganese
Cu - Copper
Zn - Zinc
B - Boron
Cl - Chloride
Mo - Molybdenum

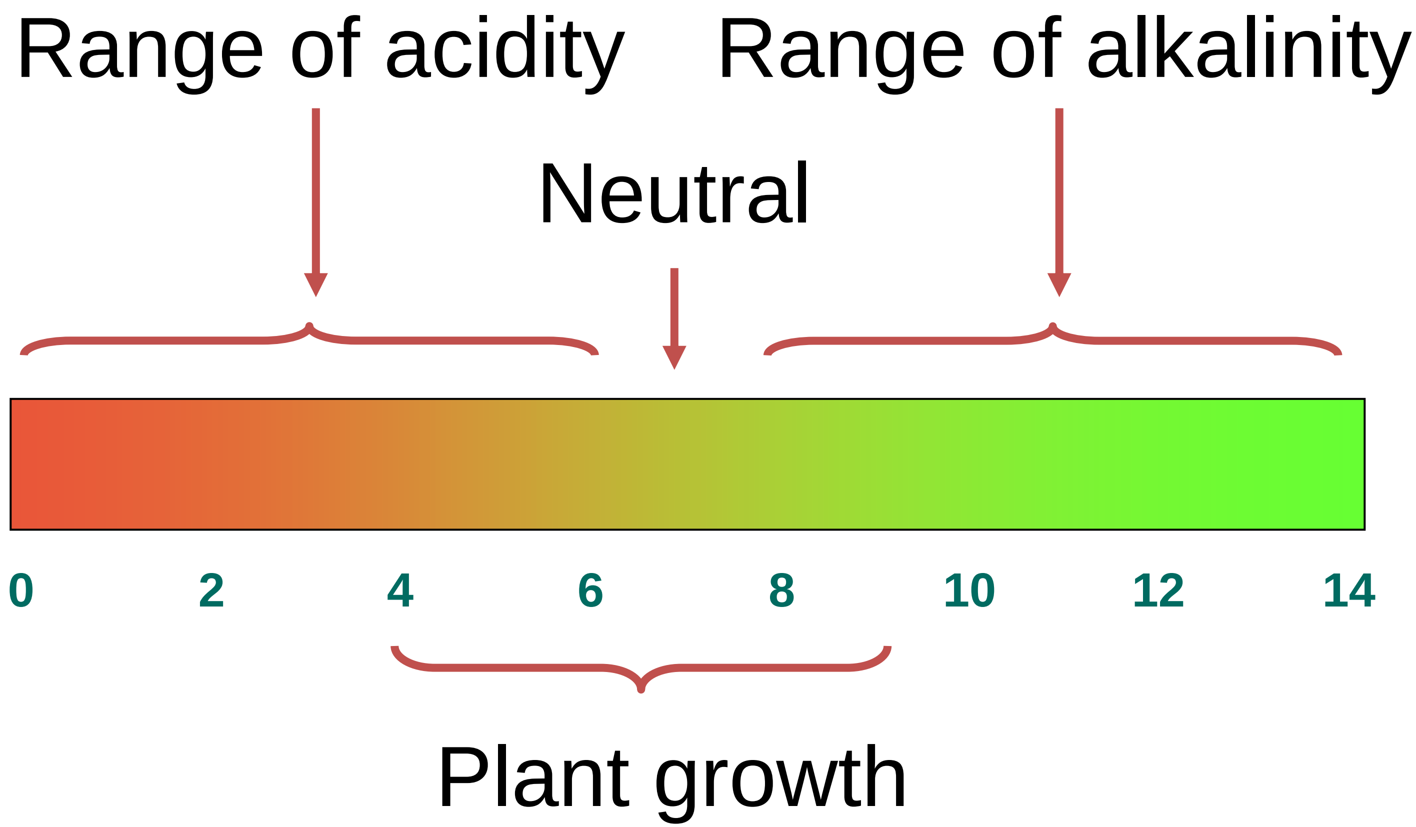
The pH scale

pH is a measure of ACIDITY or ALKALINITY

ACIDITY = H^+ (Hydrogen)

ALKALINITY = OH^- (Hydroxide)

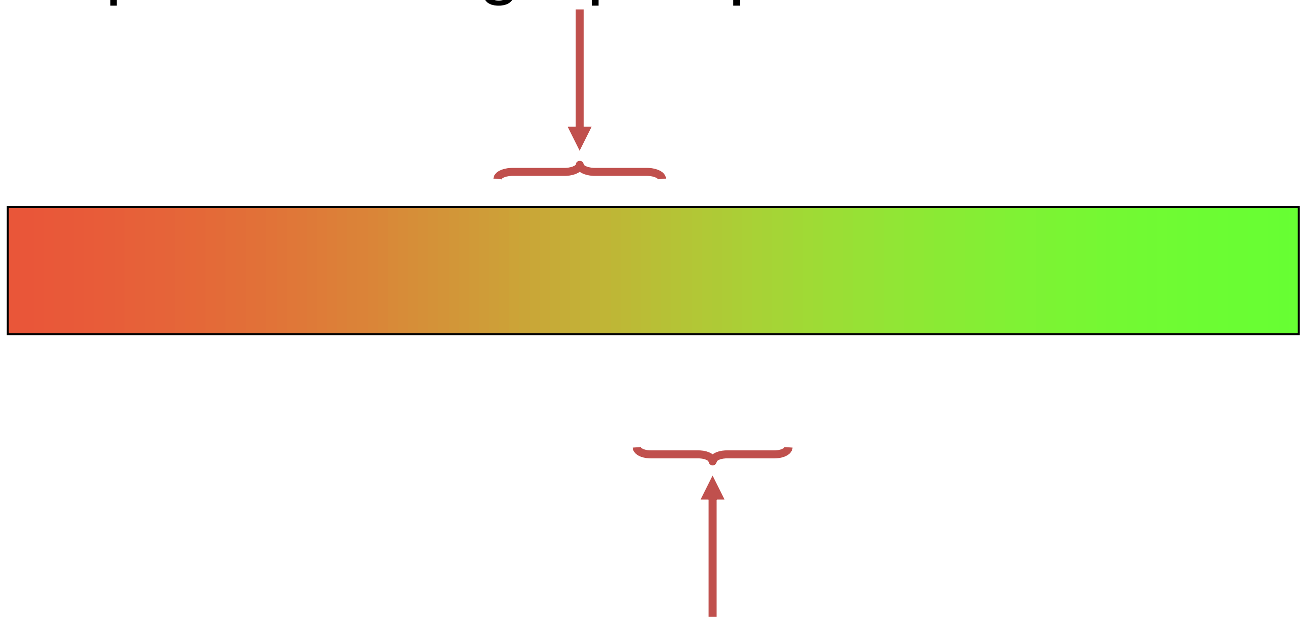
The pH scale



*Each pH unit is 10 times more acid or alkaline than the next unit

Soil pH

Optimum for grapes pH 5.8-6.8



Most Western Colorado soils pH 7-8.5

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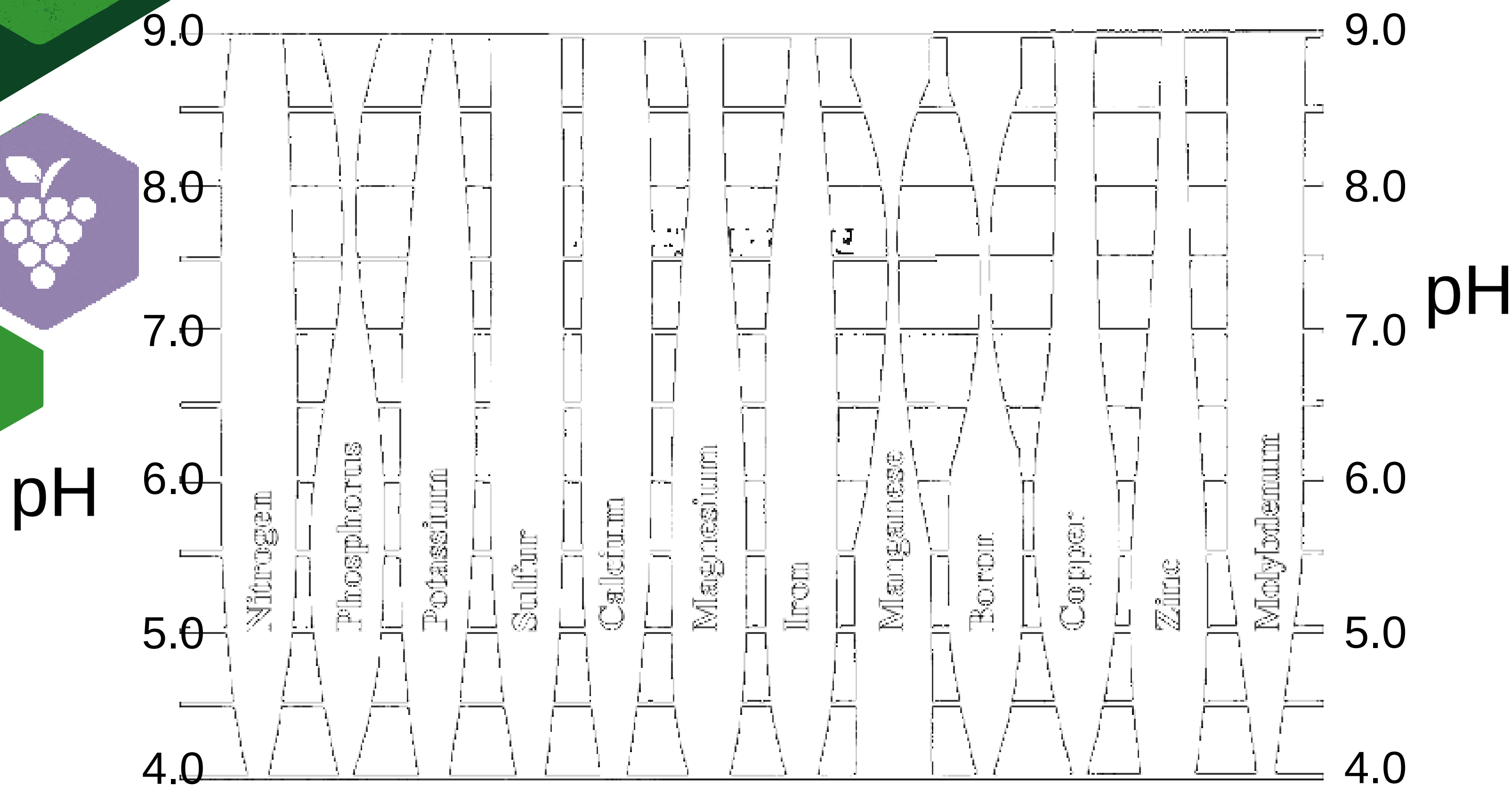
Effects of pH on nutrient availability

The thicker the bar,
the more available the nutrient



Soil or tissue sample – which one should I do?

BOTH

- Soil sampling is a MUST prior to planting
  - Consider soil sampling every 5 years
- Tissue sampling is an ongoing, annual tool

When to take tissue samples

- Whenever there is a deficiency
- At bloom
- Pre-veraison
- At veraison
- After harvest
- During dormancy

  (not a standard practice, but sometimes used in research)

Which tissue to sample

Tissues to choose from:

- Leaves
  - Petioles
  - Blades

} The standard

- Fruit
- Shoots
- Wood
  - Trunks/cordons
  - Roots

Which tissue to sample

- At bloom --- Petiole, Laminae
- At veraison --- Petiole, Laminae
- At harvest --- Fruit
- After harvest --- Laminae
- During dormancy --- Wood

Sample report – petiole at bloom

Report Number
05-194-9034

Lab No:
194184

http://www.allabs.com

A&L Analytical Laboratories, Inc.
2790 Whitten Rd. Memphis, TN 38133 • Phone (901) 213-2400 • Fax (901) 213-2440

The One Source.

PLANT ANALYSIS

Customer Account Number : **08991**

Send To : CSU
3168 B 1/2 ROAD
GRAND JUNCTION CO 81503

Grower : WCRC-OM
ATTN. DR. CASPARI
3168 B1/2 RD
GRAND JUNCTION, CO 81503

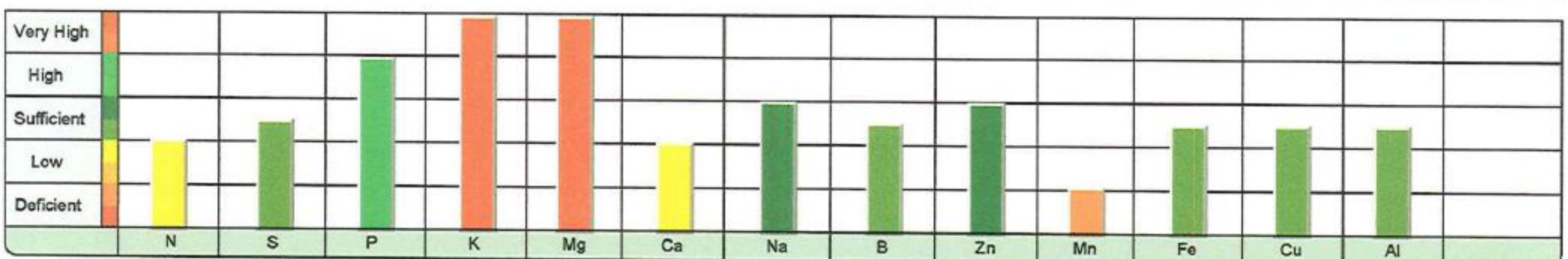
Report Date : 7/15/2005
Page 1 of 7

Blk 10, Chardonnay, healthy

Sample Id : **P05033** Crop : **Grape, Wine*** Growth Stage : **Full-bloom**

	Nitrogen %	Sulfur %	Phosphorus %	Potassium %	Magnesium %	Calcium %	Sodium %	Boron ppm	Zinc ppm	Manganese ppm	Iron ppm	Copper ppm	Aluminum ppm
Analysis	1.85	0.33	0.56	3.43	0.91	1.86	0.15	41	96	24	67	17	32
Normal Range	2.00	0.25	0.28	1.30	0.25	2.00	0.00	25	25	30	60	5	0
	2.29	0.49	0.39	1.49	0.49	2.49	0.19	70	100	300	175	50	300

	N/S	N/K	P/S	P/Zn	K/Mg	K/Mn	Ca/B	Fe/Mn
Actual Ratio	5.6	0.5	1.7	58.3	3.8	1,429.2	453.7	2.8
Expected Ratio	5.8	1.5	0.9	53.6	3.8	84.5	472.7	0.7



Comments :

02015) THESE PLANTS ARE LOW OR DEFICIENT IN NITROGEN. THIS CONDITION COULD BE DUE TO INADEQUATE NITROGEN FERTILIZATION, POOR DRAINAGE, EXCESSIVE RAINFALL OR LEACHING.

02022) THESE PLANTS ARE LOW OR DEFICIENT IN CALCIUM. POSSIBLE CAUSES INCLUDE LOW SOIL PH OR EXCESS SOIL POTASSIUM.

02025) THESE PLANTS ARE LOW OR DEFICIENT IN MANGANESE. LOW SOIL MANGANESE AVAILABILITY COULD BE CAUSED BY HIGH SOIL PH, HIGH SOIL ORGANIC MATTER, POOR DRAINAGE OR HIGH SOIL IRON.

02092) MANGANESE MAY BE FOLIAR APPLIED AT 1 TO 2 LBS PER ACRE. IF A CHELATED MATERIAL IS USED, APPLY ACCORDING TO MANUFACTURER SPECIFICATIONS. REPEATED APPLICATIONS MAY BE NECESSARY.

Report – petiole at 100 % bloom

FRUIT GROWERS LABORATORY, INC.

ANALYTICAL CHEMISTS

June 2, 2000

FGL Growers
P.O. Box 272
853 Corporation Street
Santa Paula, CA 93061-0272

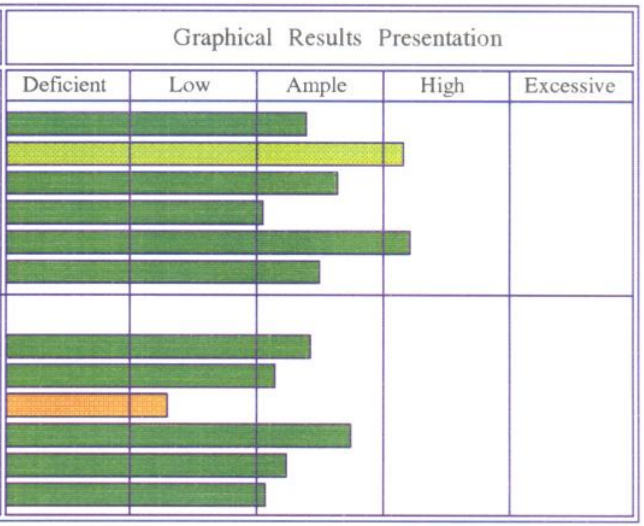
Lab ID : SP 12346-01
Customer ID : 2-1

Sampled On : May 30, 2000
Sampled By : Mark Cortez
Received On : May 31, 2000
Age : 100% Bloom
Meth. Irrg. : Drip

Description : SA - 1
Project : Sample Report

MERLOT PLANT TISSUE ANALYSIS

Test Description	Result		Optimum Range
Macro Nutrients			
Total Nitrogen	3.9	%	3.5 - 4.5
Nitrate-Nitrogen*	1330	ppm	500 - 1200
Phosphorus*	0.65	%	0.2 - 0.9
Potassium*	1.75	%	1.5 - 6.0
Calcium*	3.43	%	1.0 - 3.0
Magnesium*	0.95	%	0.4 - 1.5
Micro Nutrients			
Zinc*	230	ppm	26 - 500
Manganese*	173	ppm	25 - 1000
Iron*	33	ppm	40 - 500
Copper*	28	ppm	7 - 35
Boron*	46.8	ppm	30 - 100
Sodium*	0.02	%	0.01 - 0.15



* Analyses performed on the Petiole.

Publication # 4087 printed October 1978. Grapevine Nutrition and Fertilization, and #1879 Soil and Plant Tissue Testing in California, April 1976, Division of Agricultural Sciences, University of California.

Multi-year report – petiole at bloom

FRUIT GROWERS LABORATORY, INC.

Analytical Chemists

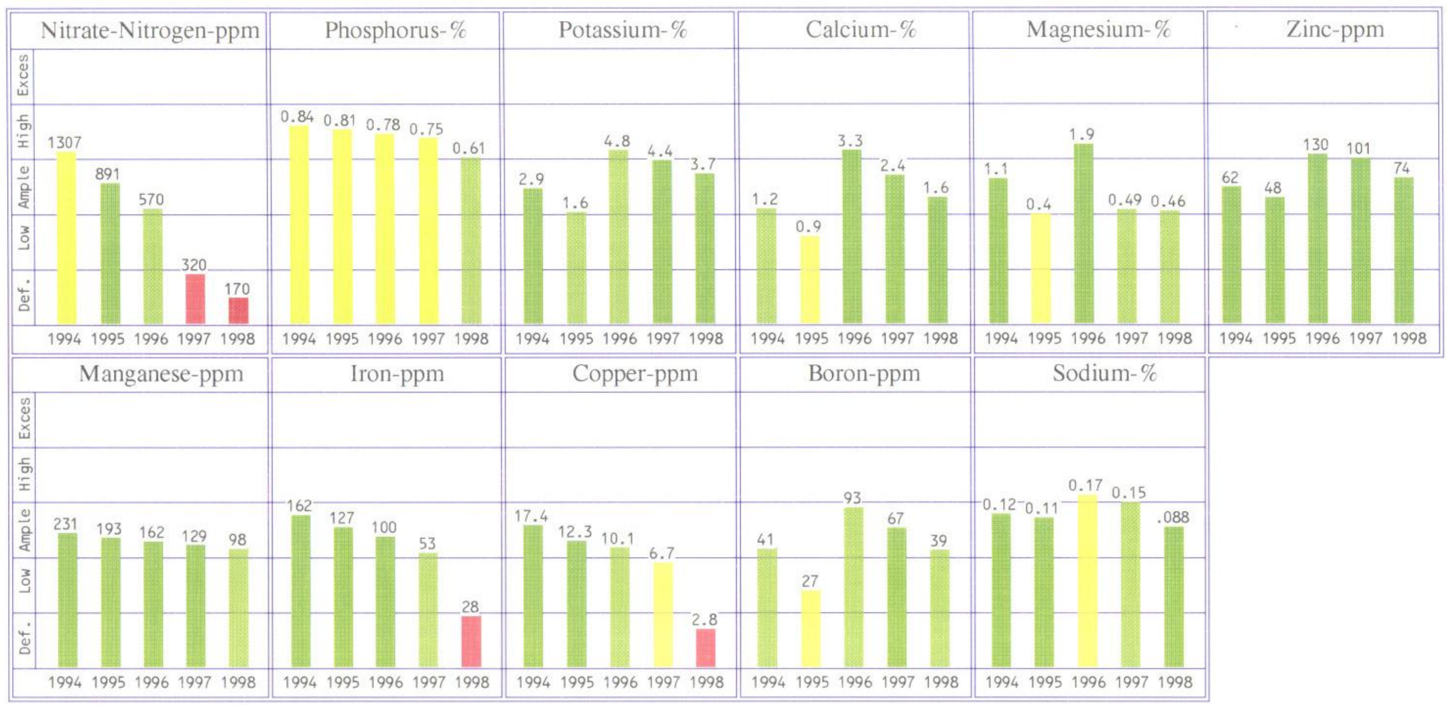
GRAPE PETIOLE DATA: 1994-1998

May 20, 1998

Fruit Growers Laboratory, Inc.

Sample: SA-02 Syrah for SAMPLE REPORT

Sampled on 05/16/1998 by FGL, Inc.



Good: :Problem

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

Def. => Deficient Exces => Excessive

Corporate Offices & Laboratory
P.O. Box 272 / 853 Corporation Street
Santa Paula, CA 93061-0272
TEL: (805) 659-0910
FAX: (805) 525-4172

Office & Laboratory
2500 Stagecoach Road
Stockton, CA 95215
TEL: (209) 942-0181
FAX: (209) 942-0423

Field Office
Visalia, California
TEL: (559) 734-9473
Mobile: (559) 737-2399
FAX: (559) 734-8435

Sample report – petiole at bloom

A & L WESTERN AGRICULTURAL LABORATORIES

1311 WOODLAND AVE #1 • MODESTO, CALIFORNIA 95351 • (209) 529-4080 • FAX (209) 529-4736

REPORT NUMBER: 07-169-041

SEND TO: CSU WESTERN CO RESEARCH CENTER
3168 B 1/2 RD
GRAND JUNCTION, CO 81503-

CLIENT NO: 9999-D

SUBMITTED BY: HORST CASPARI

GROWER:

DATE OF REPORT: 06/22/07

PLANT ANALYSIS REPORT

PAGE: 1

SAMPLE ID	REPORT OF ANALYSIS IN PERCENT								REPORT OF ANALYSIS IN PARTS PER MILLION							
	Nitrogen N	Sulfur S	Phosphorus P	Potassium K	Magnesium Mg	Calcium Ca	Sodium Na	Chloride Cl	Iron Fe	Aluminum Al	Manganese Mn	Boron B	Copper Cu	Zinc Zn	Nitrate-Nitrogen NO_3-N	
SYNE1	1.40 S	0.29 S	0.98 H	2.44 S	1.11 S	3.56 H	0.18 S		72 S	66 S	54 S	44 S	20 S	57 S		
SYMS2	1.44 S	0.27 S	1.02 E	2.33 S	1.07 S	3.62 H	0.18 S		59 S	64 S	48 S	42 S	19 S	59 S		
SYSE3	1.26 S	0.25 S	0.83 H	2.09 S	0.99 S	3.09 H	0.17 S		41 S	41 S	43 S	38 S	17 S	46 S		
NORMS	1.40	0.13	0.40	2.30	0.70	1.80	0.02		70	90	120	40	15	60		

Sample #	Date	Lab #	Crop	Stage/Part	
SYNE1	06/14	40136	SYRAH	BLM	P
SYMS2	06/14	40137	SYRAH	BLM	P
SYSE3	06/14	40138	SYRAH	BLM	P

DEFINITION OF INTERPRETATION RATINGS

When interpretation of plant analysis results are given, they will be listed as follows:

D or Deficient — Plants should be showing visible symptoms of a nutritional deficiency. Plant growth would definitely be curtailed by an insufficient amount of this element.

L or Low — Plants may be normal in appearance but probably will be responsive to fertilization with this element.

S or Sufficient — Plants contain adequate amounts of this element for maximum yield and are normal in appearance.

H or High — Optimum yields can be expected and plants are normal in appearance. However, concentration of this element is higher than normally expected.

E or Excessive — Plants probably show symptoms of a nutritional disorder or stunted growth. Yields may be reduced significantly by an excessive amount of this element.

Sample report – blade at veraison

A & L WESTERN AGRICULTURAL LABORATORIES

1311 WOODLAND AVE #1 • MODESTO, CALIFORNIA 95351 • (209) 529-4080 • FAX (209) 529-4736

LABORATORIES
AGRICULTURAL + ENVIRONMENTAL + INDUSTRIAL

REPORT NUMBER: 09-236-001

SEND TO: CSU-WESTERN CO RESEARCH CENTER
3168 B 1/2 RD
GRAND JUNCTION, CO 81503-

CLIENT NO: 9999-D

SUBMITTED BY: HORST CASPARI

GROWER:

DATE OF REPORT: 08/26/09

PLANT ANALYSIS REPORT

PAGE: 1

SAMPLE ID	REPORT OF ANALYSIS IN PERCENT								REPORT OF ANALYSIS IN PARTS PER MILLION							
	Nitrogen N	Sulfur S	Phosphorus P	Potassium K	Magnesium Mg	Calcium Ca	Sodium Na	Chloride Cl	Iron Fe	Aluminum Al	Manganese Mn	Boron B	Copper Cu	Zinc Zn	Nitrate-Nitrogen NO_3-N	
CHSE2	2.78 S	0.19 S	0.17 S	0.94 S	0.40 S	1.60 S	0.02 S		93 S	33 S	54 S	46 S	11 S	27 S		
CHSE3	2.92 H	0.22 S	0.19 S	0.97 S	0.44 S	1.78 S	0.02 S		122 S	45 S	53 S	52 S	9 S	28 S		
CHSE4	2.98 H	0.23 S	0.21 S	0.90 S	0.44 S	1.87 S	0.02 S		93 S	45 S	47 S	57 S	13 S	30 S		
NORMS	2.00	0.25	0.25	1.40	0.50	2.30	0.02		120	100	100	50	15	30		

Sample #	Date	Lab #	Crop	Stage/Part
CHSE2	/	41492	CHARDONNAY	VER L
CHSE3	/	41493	CHARDONNAY	VER L
CHSE4	/	41494	CHARDONNAY	VER L

DEFINITION OF INTERPRETATION RATINGS

When interpretation of plant analysis results are given, they will be listed as follows:

- D or Deficient — Plants should be showing visible symptoms of a nutritional deficiency. Plant growth would definitely be curtailed by an insufficient amount of this element.
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- S or Sufficient — Plants contain adequate amounts of this element for maximum yield and are normal in appearance.
- H or High — Optimum yields can be expected and plants are normal in appearance. However, concentration of this element is higher than normally expected.
- E or Excessive — Plants probably show symptoms of a nutritional disorder or stunted growth. Yields may be reduced significantly by an excessive amount of this element.

Interpreting laboratory reports

- Laboratories have different "normal" or "optimal"values
- Example: petiole N at bloom (%)
  - Lab A: 0.7 – 2.0
  - Lab B: 3.5 – 4.5
  - Lab C: 2.0 – 2.29

Interpreting laboratory reports

- “Normal” or “Optimal” values differ between sampling stage (bloom is different to veraison)
- “Normal” or “Optimal” values differ between sampling tissues at the same stage (blade is different to petiole)

Interpreting laboratory reports

- Know your laboratories "Normal" or "Optimal" values
- Pay attention to the stage of vine development when the samples are taken

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Interpreting laboratory reports

- Tell the laboratory which tissue was sampled, and the stage of vine development

- Finally, consider the growth and health of the vines in your vineyard before responding to the tissue analysis results

Treating micro nutrient deficiencies

- There are three options:
  - Treat the soil
  - Treat the plant
  - Treat the soil and the plant

Treating micro nutrient deficiencies

Treat the soil

- Soils in Western Colorado are generally not deficient in micro nutrients (e.g. B, Fe, Mn, Zn)
- However, the high soil pH limits the availability for plant uptake
- Lowering the soil pH thus would increase micro nutrient availability

Treating micro nutrient deficiencies

Treat the soil

- However, most soils are highly buffered (resist change) due to an abundance of Ca & Mg carbonates
- Soil acidification might be a long-term strategy but is not effective when dealing with an in-season deficiency

Treating micro nutrient deficiencies

Treat the soil

- When applying micro nutrients such as Fe to the soil the Fe should be in a chelated fertiliser form

Treating micro nutrient deficiencies

Treat the plant

- Micro nutrients are required in very small amounts
- Foliar applications of micro nutrients directly reach the deficient tissues
- Micro nutrients can be added to other sprays (fungicides, insecticides)

Treating micro nutrient deficiencies

Treat the plant

- Generally, one or two micro nutrient applications are sufficient to correct small deficiencies
- Severe deficiencies may require 2-3 seasonal applications for several years

Treating micro nutrient deficiencies

Fe, Mn, Zn

- Iron (Fe) deficiency is very common in Western Colorado
- Almost always, grape leaves that are deficient in Fe are also deficient in Mn and Zn
- Only applying Fe may overcome the Fe deficiency but will not result in better vine growth as the Mn and Zn deficiencies persist

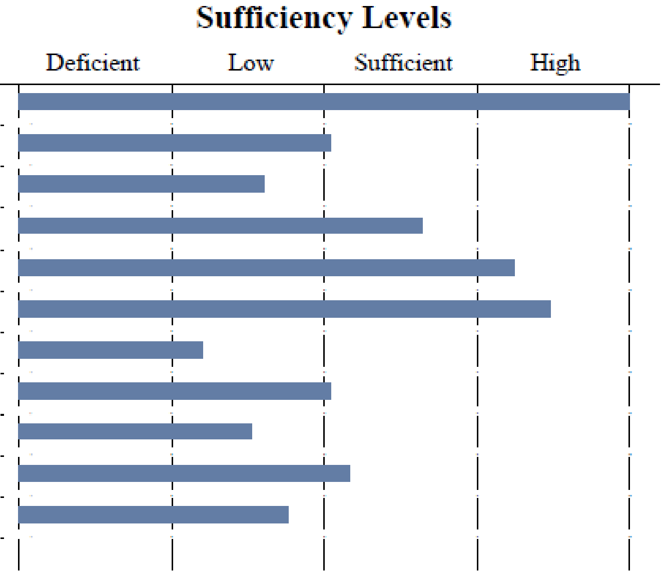
What about phylloxera?

Plant Type : Grape
Stage : PreHarvest

Chardonnay, grass cover crop

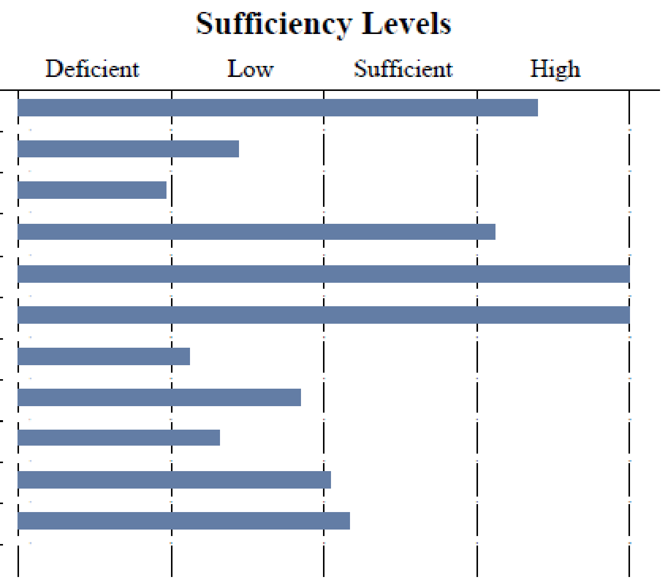
No phylloxera

Element	Result Dry Basis
Nitrogen ,% N	3.03
Phosphorus, % P	0.204
Potassium, % K	0.81
Calcium, % Ca	2.608
Magnesium, % Mg	0.566
Sulfur, % S	0.32
Zinc, ppm Zn	22
Iron, ppm Fe	108
Manganese, ppm Mn	66
Copper, ppm Cu	8.2
Boron, ppm B	34.4
Molybdenum, ppm Mo	0.51



Phylloxera

Element	Result Dry Basis
Nitrogen ,% N	2.41
Phosphorus, % P	0.134
Potassium, % K	0.47
Calcium, % Ca	3.263
Magnesium, % Mg	0.881
Sulfur, % S	0.42
Zinc, ppm Zn	21
Iron, ppm Fe	89
Manganese, ppm Mn	51
Copper, ppm Cu	6.7
Boron, ppm B	49.6
Molybdenum, ppm Mo	0.58



What about phylloxera?

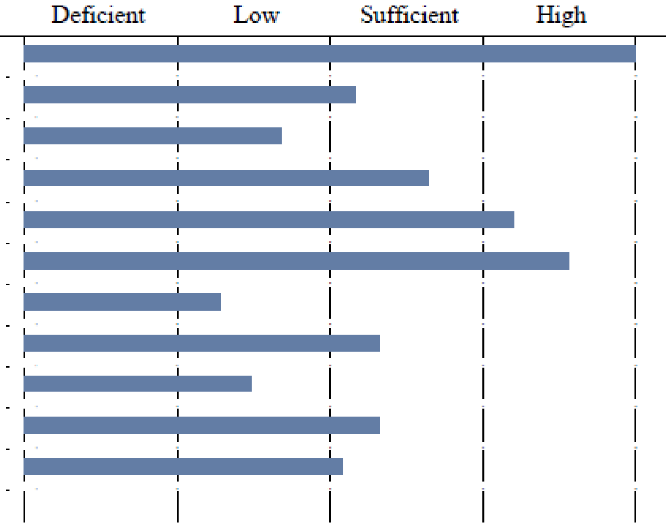
Plant Type : Grape
Stage : PreHarvest

Chardonnay, alfalfa cover crop

No phylloxera

	Result Dry Basis
Nitrogen ,% N	3.17
Phosphorus, % P	0.216
Potassium, % K	0.84
Calcium, % Ca	2.603
Magnesium, % Mg	0.563
Sulfur, % S	0.34
Zinc, ppm Zn	24
Iron, ppm Fe	165
Manganese, ppm Mn	63
Copper, ppm Cu	10.7
Boron, ppm B	44.3
Molybdenum, ppm Mo	0.61

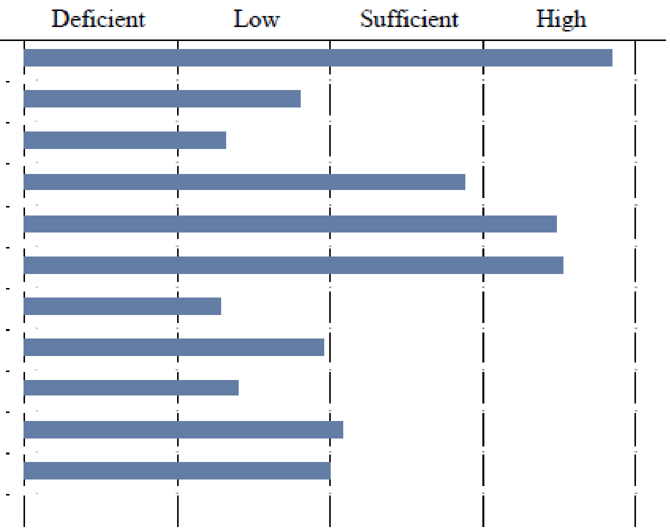
Sufficiency Levels



Phylloxera

	Result Dry Basis
Nitrogen ,% N	2.86
Phosphorus, % P	0.176
Potassium, % K	0.67
Calcium, % Ca	2.855
Magnesium, % Mg	0.650
Sulfur, % S	0.33
Zinc, ppm Zn	24
Iron, ppm Fe	97
Manganese, ppm Mn	57
Copper, ppm Cu	7.3
Boron, ppm B	40.0
Molybdenum, ppm Mo	0.49

Sufficiency Levels



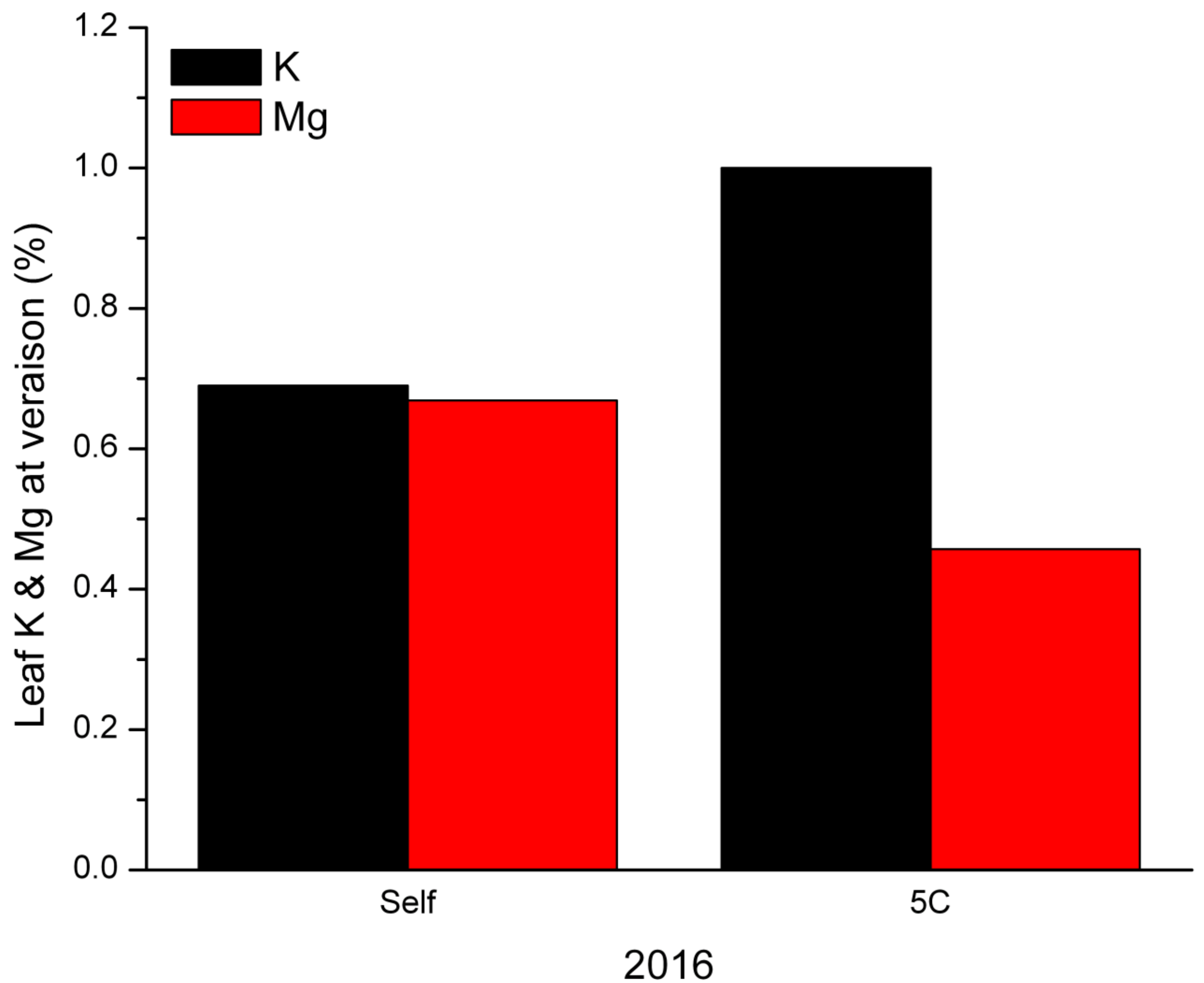
What about phylloxera?

- The most noticeable effect of phylloxera on vine nutrition to date is a reduction in the macro nutrients N, P, and K
- There are no consistent effects of phylloxera on other macro and micro nutrients
- However, it should be noted that vine size is severely reduced

Rootstock effects on vine nutrition

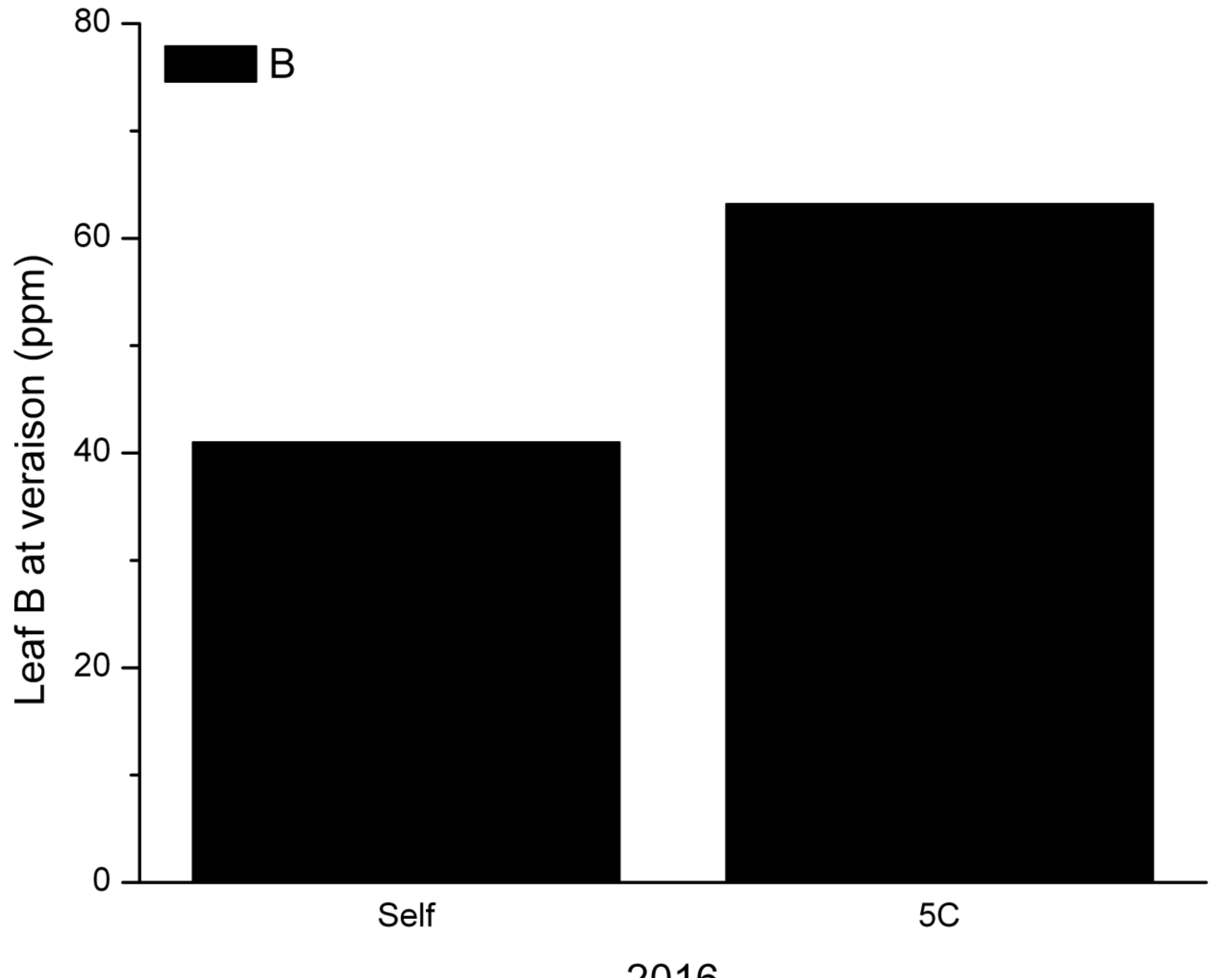
- Some rootstocks increase the uptake of certain nutrients
- In contrast, some rootstocks are more prone to certain nutrient deficiencies and/or nutrient imbalances
  - SO4 & 44-53M – Mg deficiency
  - Salt Creek – Zn deficiency

Rootstock effects on vine nutrition



Higher K, but lower Mg concentration in Chardonnay leaves at veraison with 5C

Rootstock effects on vine nutrition



Higher boron concentration in Chardonnay leaves at veraison with 5C

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Questions?

Dr. Horst Caspari
Department of Horticulture & Landscape Architecture
Colorado State University
Western Colorado Research Center – Orchard Mesa
Grand Junction, CO 81503
Ph: (970) 434-3264
horst.caspari@colostate.edu

Vineyard Site Evaluation Report

OVERVIEW OF VINEYARD SITE REPORT

This report is provided by Virginia Tech's Center for Geospatial Information Technology for the project "Improved grape and wine quality in a challenging environment: An eastern US model for sustainability and economic vitality." The material is based upon research supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2010-51181-21599. Additional support is provided by the Virginia Wine Board. This report is in beta form and is currently under development.

To report errors or problems with this report, send an email to cgitsupport@vt.edu.

*** means that data was unavailable when the report was requested.**

Overview of Site Selection

Geographic Location: 41.0619, -82.033

Area in Acres: 4.54

GRAPE & WINE QUALITY EASTERN U.S. INITIATIVE VirginiaTech Invent the Future® CGIT

TABLE OF CONTENTS

OVERVIEW OF SITE CONDITIONS

Soils

For further information, including details on every soil series in the site, see the in-depth discussion of these parameters on the following pages. A number of soil attributes are recorded as three related values: low, representative, and high. The low and high values denote the typical range of values of that attribute. The representative value denotes the average, or expected value of that attribute.

Attribute	Representative	Low	High
Organic Matter (%)	0.77	-	-
Soil Depth (cm)	151.32	-	-
Available Water Capacity (in./in. soil 30" profile)	0.11	0.09	0.17
Saturated Hydraulic Conductivity (KSat) (inches/hour)	0.07	0.01	0.31
Bulk Density (g/cm3)	1.63	-	-
Soil pH	6.17	-	-

Climate

These precipitation climate conditions are averages based on 30 years of data analyzed by the PRISM Group at Oregon State University. The other climate factors use PRISM layers as a base for calculations completed at Virginia Tech's Center for Geospatial Information Technology.

Attribute	Value
Average Growing Season Temperature	16.63°C, 61.93°F
Average Length of Growing Season	154.0 frost-free days
Annual Precipitation	37.8 in.
Growing Season Precipitation	24.53 in.
Average Growing Season Degree Days	1447.32°C, 2637.17°F
Spring Frost Index	April: 11.88; May: 11.88

Topography

These topographic conditions are determined using the best available public data. Use the in-depth discussion provided on the following pages to further understand how these conditions can effect vineyard production in your area.

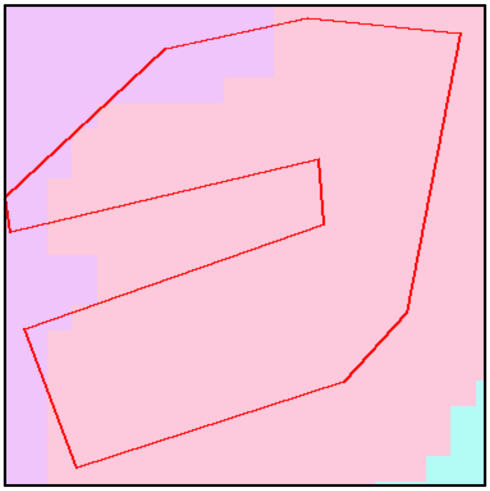
Aspect		
15.56%	0.0%	0.0%
36.67%		0.0%
35.56%	11.11%	1.11%

Attribute	Average	Minimum	Maximum
Slope (%)	5.67	0.23	16.31
Elevation Above Sea Level (ft.)	941.67	920.29	951.75

SOILS AND GEOLOGY

Information

"Soil affects grapevine productivity and wine quality. Confounding influences of vineyard management, climate, varieties and clones, fertilizer and irrigation practices, as well as variation in fruit harvest and winery practices, may easily obscure the more subtle, unique soil contributions to wine quality. Soils cannot be evaluated independently of the other vineyard site considerations, and some compromises in soil quality may be necessary so that the vineyard site selection process does not become too exclusive." - Wolf and Boyer, 2009



Soil Legend

Ellsworth silt loam, 2 to 6 percent slopes	Ellsworth silt loam, 12 to 25 percent slopes, eroded

Site Soil Series

Ellsworth silt loam, 2 to 6 percent slopes (4.14 acres; 91.11% of total area)

Attribute	Representative	Low	High
Organic Matter (%)	0.77	-	-
Soil Depth (cm)	152.0	-	-
Available Water Capacity (cm./cm.)	0.11	0.09	0.17
Saturated Hydraulic Conductivity (Ksat-in./hr.)	0.06	0.01	0.31
Bulk Density (g/cm3)	1.63	-	-
Soil pH (pH)	6.18	-	-

Ellsworth silt loam, 12 to 25 percent slopes, eroded (0.4 acres; 8.89% of total area)

Attribute	Representative	Low	High
Organic Matter (%)	0.83	-	-
Soil Depth (cm)	144.4	-	-
Available Water Capacity (cm./cm.)	0.11	0.09	0.17
Saturated Hydraulic Conductivity (Ksat-in./hr.)	0.12	0.04	0.38
Bulk Density (g/cm3)	1.62	-	-
Soil pH (pH)	6.02	-	-

About Soil Attributes

Organic Matter

Organic matter is generated by the decomposition of plant and animal waste by the communities of soil arthropods and microbial decomposers that it supports. Organic matter improves soil fertility, structure, aeration and drainage. In large quantities, organic matter releases excess Nitrogen that can lead to vigorous vine growth.

Soil Depth (cm)

Deep soil depth acts as a protective buffer against drought as it allows for greater volume of potential soil moisture and ample space for cultivation of large, healthy, perennial root structures.

Available Water Capacity (AWC)

This describes the quantity of water available for uptake by plants after gravitational forces have removed excess water from a saturated soil. The ability of a soil to hold water is a function of soil texture and organic matter content.

Saturated Hydraulic Conductivity (Ksat-in./hr)

Ksat is a measure of the rate at which water moves through a column of saturated soil also described as permeability. Soils with Ksat values above 0.6 inches per hour tend to be better suited for viticultural production.

Bulk Density (g/cm^3)

Bulk density describes the relationship between soil solids and pore space where air and water can be stored in a given volume of soil. Bulk density is a key factor in productive viticulture because bulk densities higher than 1.6 g/cm3 indicate compacted soil, restricted water movement, poor root development and loss of soil aeration.

Soil pH

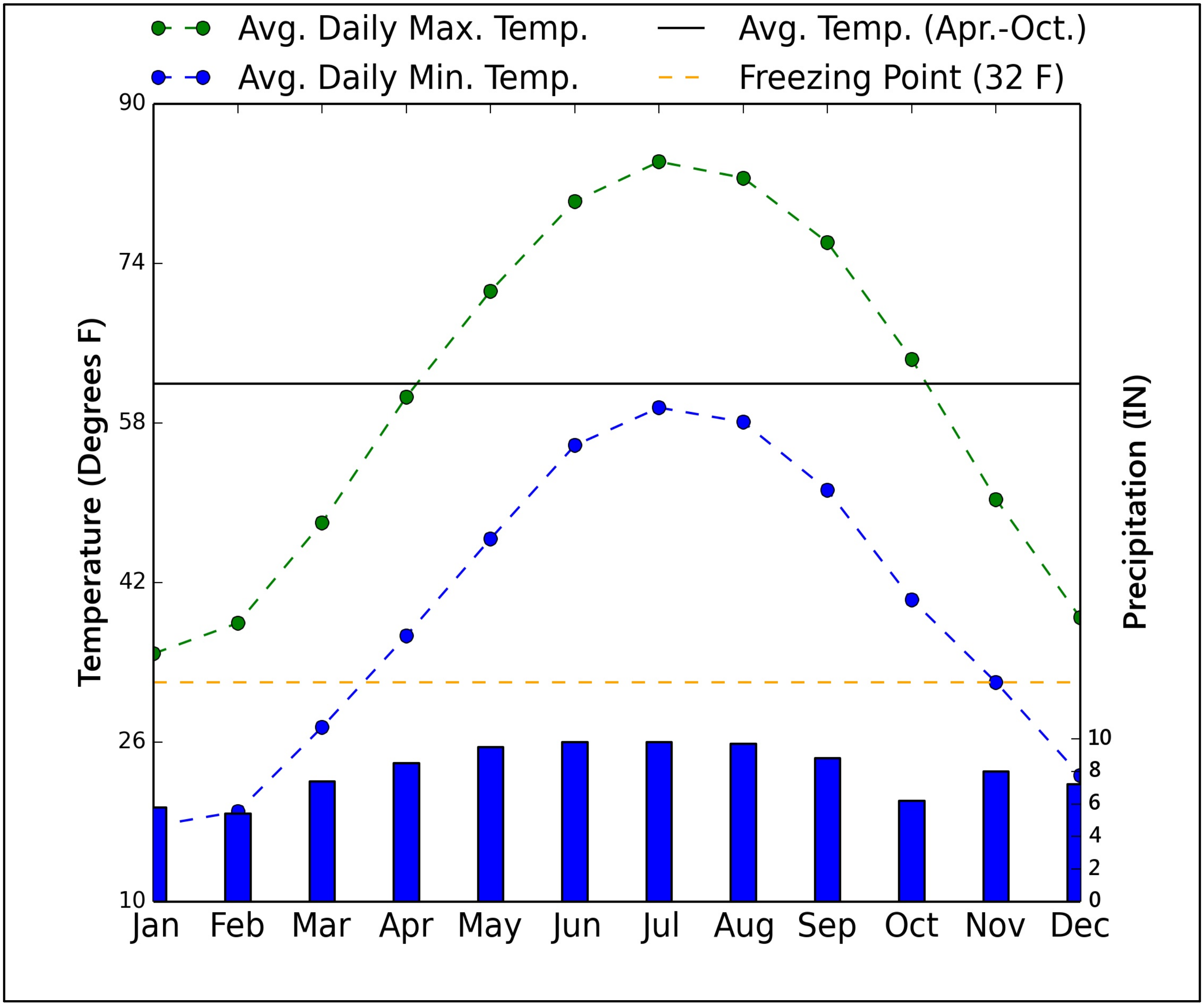
Soil pH is easily amended, but the cost of amendment whether through lime or gypsum applications may be cost prohibitive for some growers if pH is above 7.5 or below 4.0. Appropriate soil pH levels are critical to vine health. Low pH values are especially detrimental to grapevines as Aluminum and Copper are made plant available which can lead to stunted growth and toxicity.

CLIMATE AND WEATHER

Information

"Grapes can be exposed to environmental stresses that can reduce crop quality and yields and injure or kill grapevines. Damaging winter temperatures, spring and fall frosts, extremes of rainfall, and higher than optimal summer temperatures occur with regularity in some regions. Climate refers to the average course of the weather at a given location over a period of years and is measured by temperature, precipitation, wind speed and other meteorological conditions. "Weather" is the state of the atmosphere at a given moment with respect to those same meteorological conditions."- Wolf and Boyer, 2009

Seasonal Temperature Analysis



Growing Season Climate Factors

Attribute	Value
Average Growing Season Temperature (Mean Temp. April - October)	16.63°C, 61.93°F
Average Length of Growing Season	154.0 frost-free days
Annual Precipitation	37.8 in.
Growing Season Precipitation	24.53 in.
Average Growing Season Degree Days (Daily Mean Temp. - Base Temp. 10°C)	1447.32°C, 2637.17°F
Spring Frost Index (Avg. Daily mean Temp. - Avg. Daily Min. Temp.)	April: 11.88; May: 12.42

Determined by number of winters below threshold in a decade.

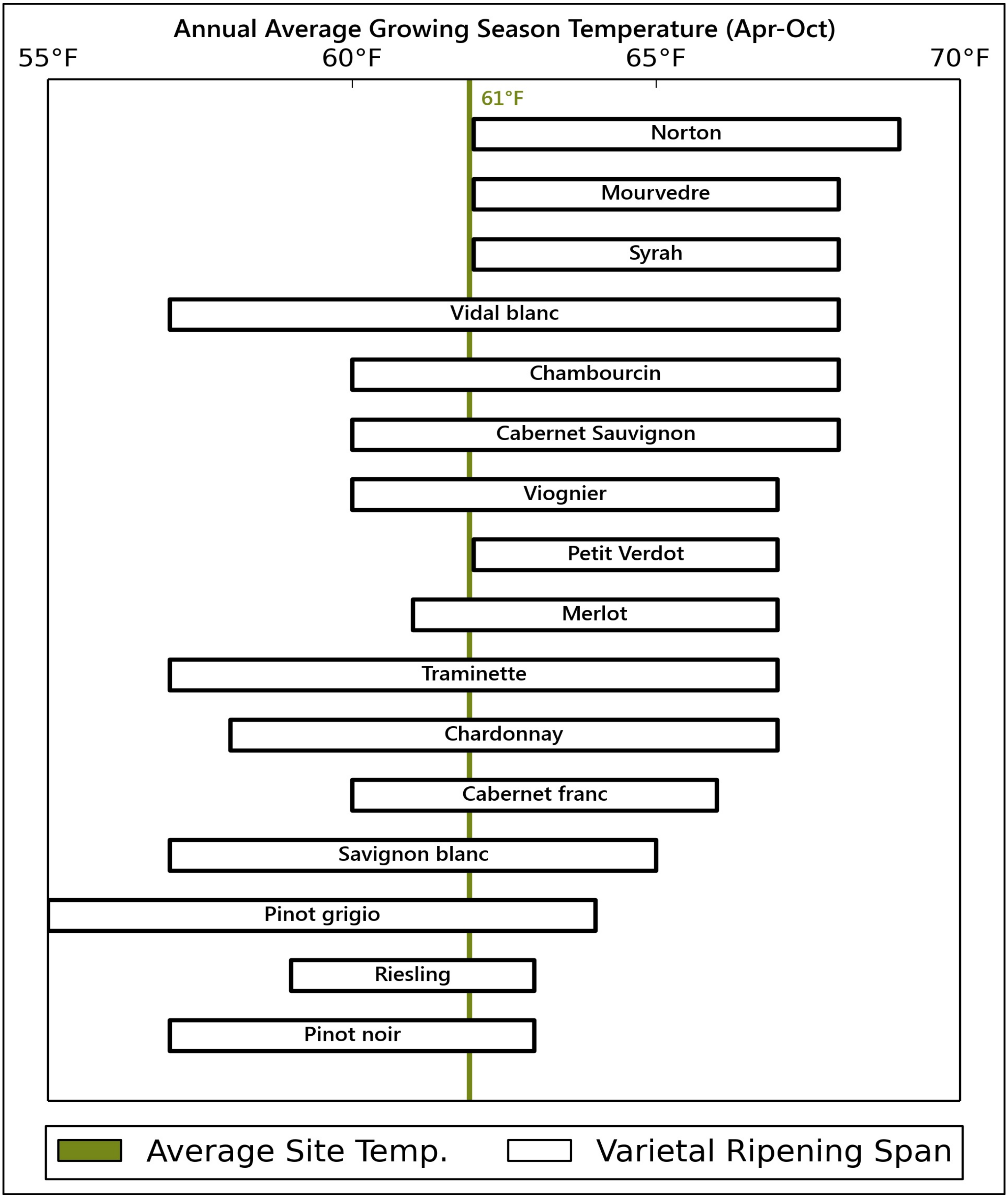
Extreme Low Temperature Risk Factor

The length of the growing season will determine whether grapes will ripen or not. A minimum of 180 frost-free days is recommended.

Grapevines can be injured or killed by winter cold. See chart below for statistics on average number of winters with extreme cold temperatures.

Threshold	5°F	0°F	-5°F	-10°F	-15°F
Winters	8.0	6.0	5.0	2.0	1.0

GRAPEVINE CLIMATE/MATURITY GROUPINGS



TOPOGRAPHY AND SITE FACTORS

Elevation (ft.)

Elevation has a profound influence on the minimum and maximum temperatures in a vineyard, particularly in hilly and mountainous terrain. Because frosts and freezing temperatures can so dramatically reduce vineyard profitability, elevation is one of the most, perhaps the most, important features of vineyard site suitability. The physics of topographic effects on air temperature are well documented (Geiger, 1966) and its horticultural significance generally well appreciated.

Avg.	Min.	Max.
941.67	920.29	951.75

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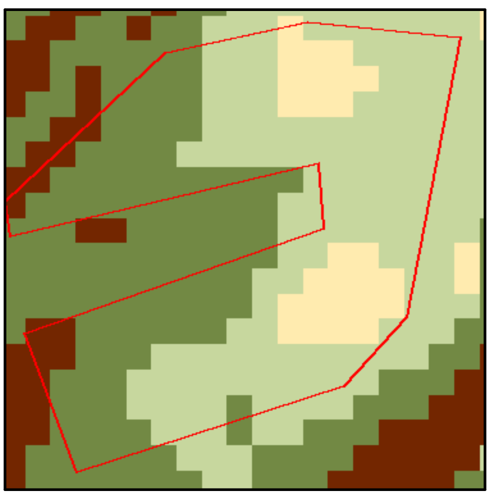
Slope (%)



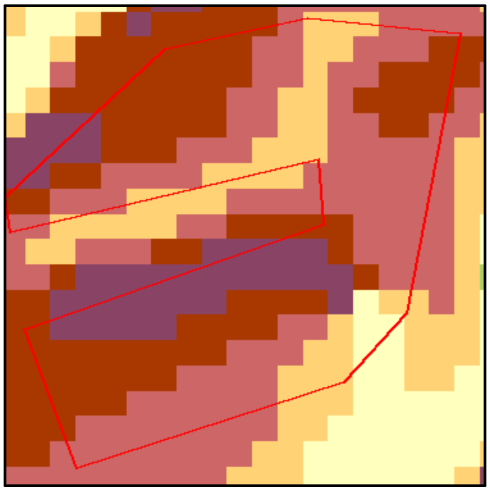
The change in elevation over a horizontal ground distance is expressed here as a percent. Gentle to moderate slopes are best-suited for vineyard production as they protect against damaging frosts (Wolf & Boyer, 2009). Cold air has a higher density than surrounding air, causing it to sink with gravity and move downhill. As a result, vineyards planted on slopes at higher elevations benefit from fluid cold air drainage away from vines and the resulting warm air displacement upwards.

Avg.	Min.	Max.
5.67	0.23	16.31

Flat Land	0% - 2%
Suitable	2% - 5%
Highly Suitable	5% - 15%
Steep Slopes *	> 15%

* Slopes > 15% may require the construction of additional infrastructure.

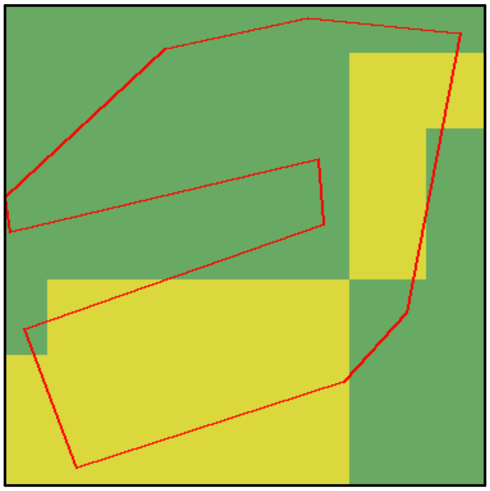
Aspect (°)



Aspect describes the direction a slope faces, which relates to the sun angle and amount of sunlight that reaches the ground. According to Dr. Tony Wolf, Virginia's State Viticultural specialist (p.16), aspect is one of the least influential factors related to a vineyard's overall suitability; however, choosing a site with a favorable aspect can enhance grape taste and facilitate efficient disease and pest management.

Direction	Bearing (°)	Area (%)
Northern	337.5 to 22.5	0.0
Northeastern	22.5 to 67.5	0.0
Eastern	67.5 to 112.5	0.0
Southeastern	112.5 to 157.5	1.11
Southern	157.5 to 202.5	11.11
Southwestern	202.5 to 247.5	35.56
Western	247.5 to 292.5	36.67
Northwestern	292.5 to 337.5	15.56

Land Cover



The Multi-Resolution Land Characteristics Consortium National Landcover Database (NLCD 2011) is a land cover classification that was generated using Landsat imagery.

Open Water	Barren Land
Open Space	Deciduous Forest
Developed-Low Density	Evergreen Forest
Developed-Med. Density	Mixed Forest
Developed-High Density	Shrub/Scrub
Grassland/Herbaceous	Woody Wetlands
Pasture/Hay	Herbaceous Wetlands
Cultivated Crops	

IMPORTANT INFORMATION AND DATA SOURCES

Important Information

This vineyard evaluation report was created automatically by interpreting publicly-available data as it applies to vineyard suitability. The GIS data layers used in this report are generalized and may not capture all details of a specific site. Furthermore, site management practices can significantly alter natural conditions.

Data Sources

Imagery:

Data available from the U.S. Geological Survey.

Soils Data:

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Soil Survey Geographic (SSURGO) Database for all available counties in Connecticut, Delaware, Georgia, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee , Vermont, Virginia, Washington DC, and West Virginia. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed 4/9/2015.

Climate Data:

Daly, C. and Gibson, W., PRISM Group at Oregon State University, 2006, United States Average Monthly or Annual Minimum, Maximum, and Mean Temperature, 1971 - 2000: Corvallis, Oregon, USA, PRISM Group at Oregon State University.

Daly, C. and Gibson, W., PRISM Group at Oregon State University, 2006, United States Average Monthly or Annual Precipitation, 1971 - 2000: Corvallis, Oregon, USA, PRISM Group at Oregon State University.

Daly, C. and Gibson, W., PRISM Group at Oregon State University, 2009, United States Median/Extreme dates of First/Last Freeze in Autumn/Spring: Corvallis, Oregon, USA, PRISM Group at Oregon State University.

National Climatic Data Center, NESDIS, NOAA, U.S. Department of Commerce. U.S. Daily Surface Data (DSI-3200, DSI-3202, DSI-3206, DSI-3210): Asheville, NC, National Climatic Data Center. Available online at http://www7.ncdc .noaa.gov/CDO/dataproduct. Accessed 08/2011.

Contours:

Data available from the U.S. Geological Survey.

Elevation Data:

Data Credit: National Elevation Dataset http://ned.usgs.gov/ Accessed 4/27/2015

Landcover Data:

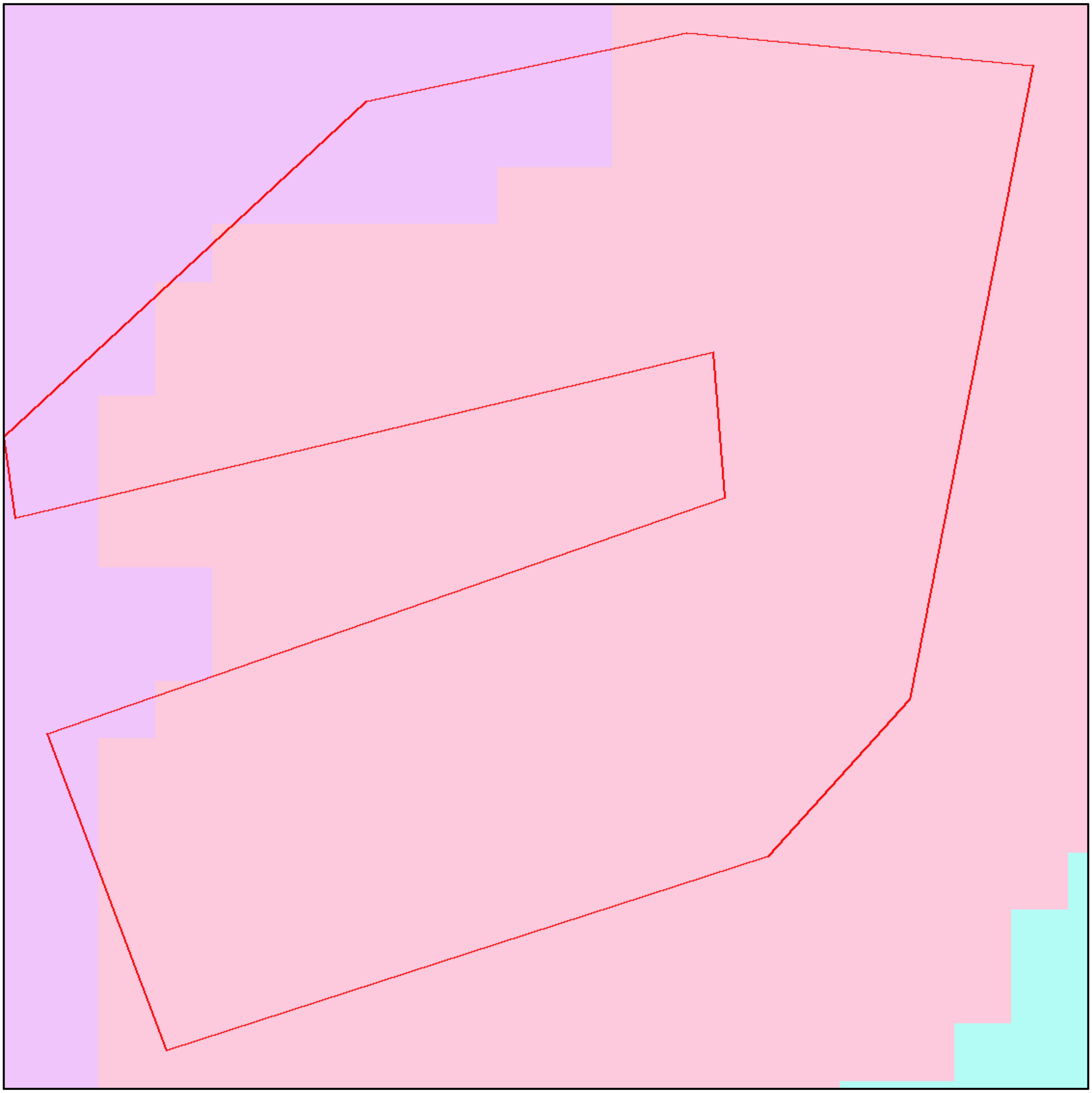
Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354. Accessed 4/2/2015.

Landforms Data:

Originator: USGS Rocky Mountain Geographic Science Center Publication_Date: November 2008 Title: Terrestrial Ecosystems Geospatial_Data_Presentation_Form: raster dataset Data Used: Compound Topographic Index (CTI), EDNA (Elevation Derivative for National Applications), US Geological Survey, http://edna.usgs.gov/edna/datalayers/cti.asp

Appendix I - Aerial Image

Appendix II - Soil



Ellsworth silt loam, 2 to 6 percent slopes	Ellsworth silt loam, 12 to 25 percent slopes, eroded

Appendix III - Elevation

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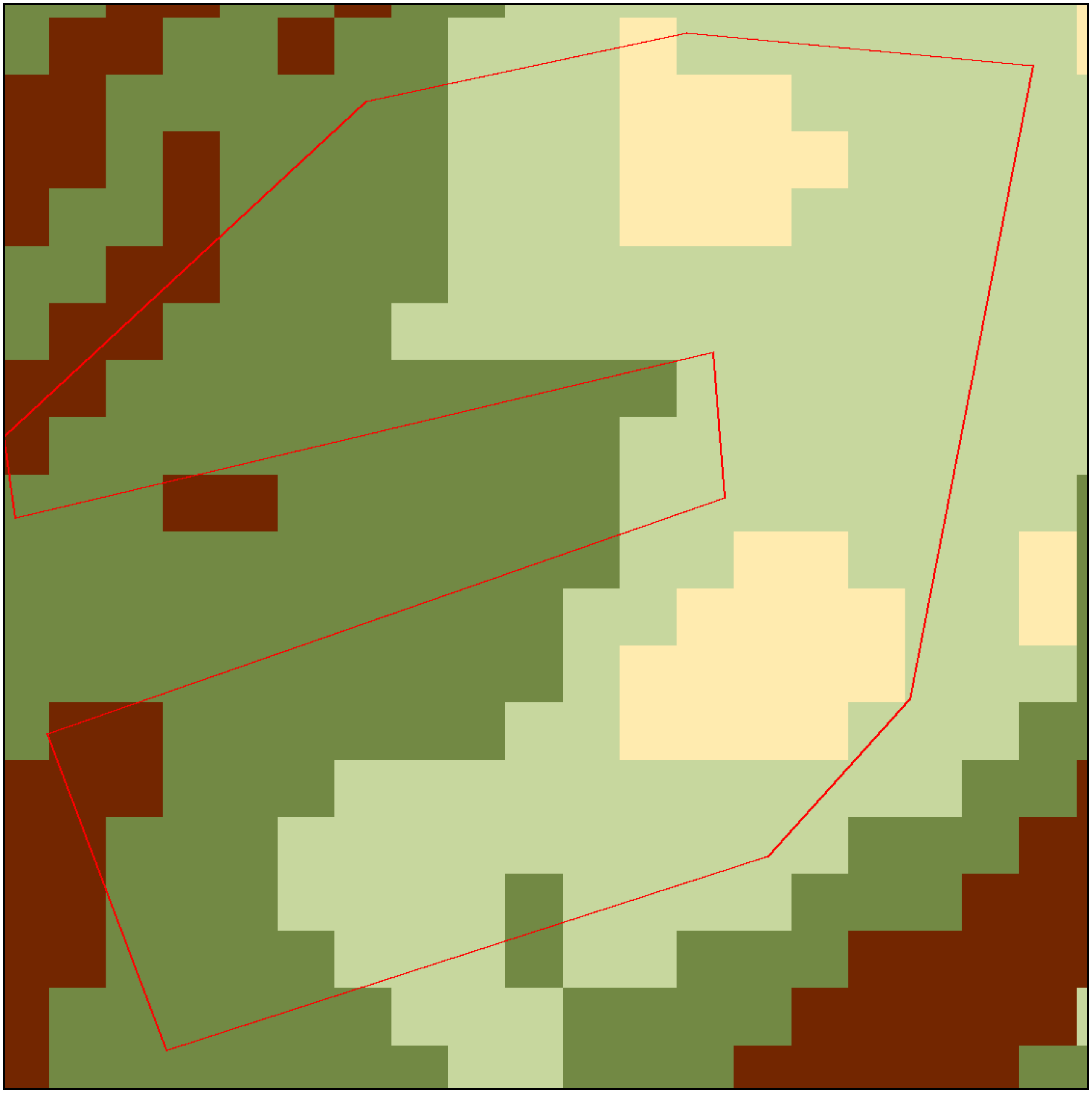
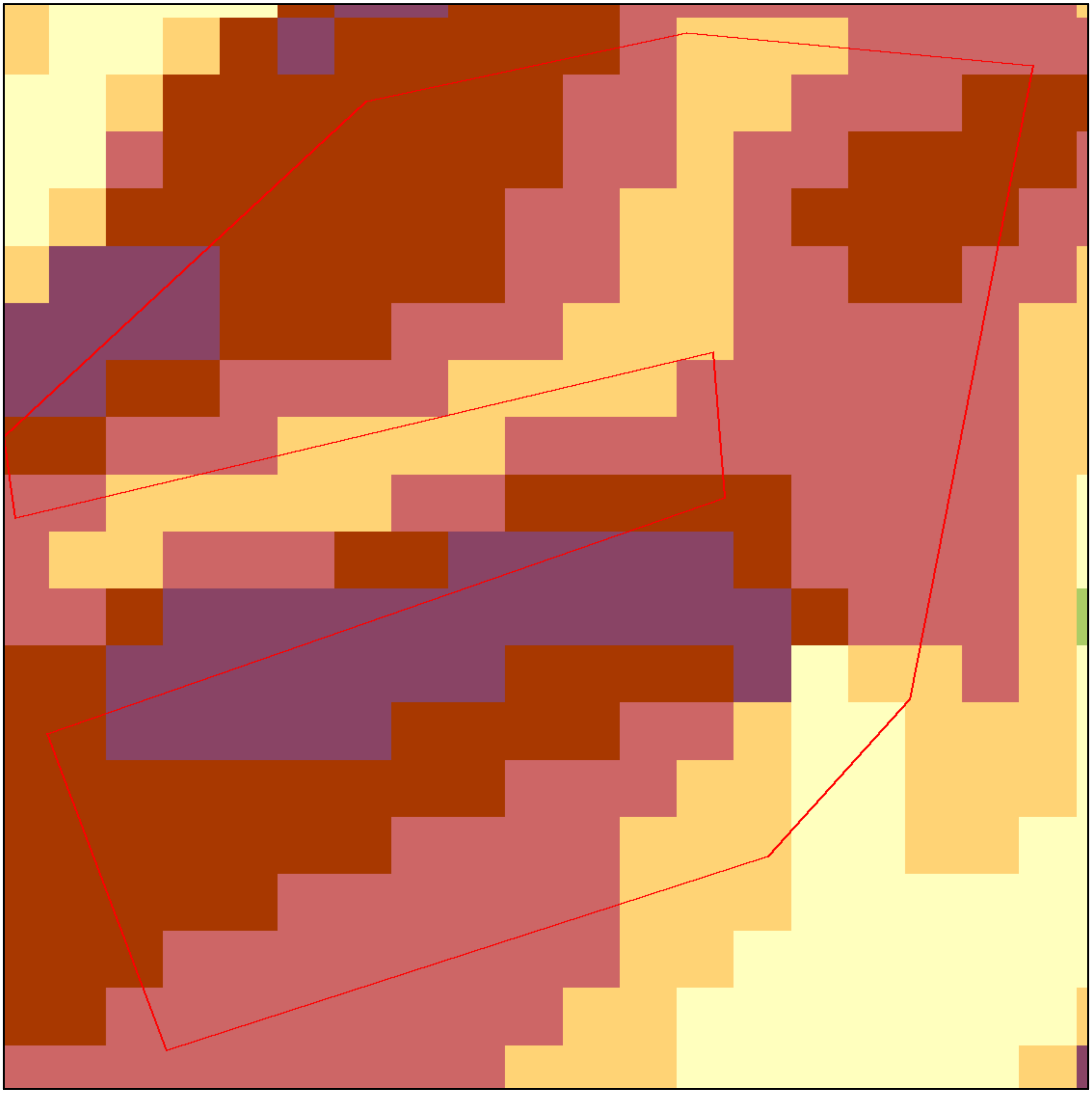
Appendix IV - Slope



Flat Land	0% - 2%
Suitable	2% - 5%
Highly Suitable	5% - 15%
Unsuitable	> 15%

Appendix V - Aspect



Direction	Bearing (°)	Direction	Bearing (°)
Northern	337.5 to 22.5	Southern	157.5 to 202.5
Northeastern	22.5 to 67.5	Southwestern	202.5 to 247.5
Eastern	67.5 to 112.5	Western	247.5 to 292.5
Southeastern	112.5 to 157.5	Northwestern	292.5 to 337.5

Appendix VI - Land Cover

Appendix VII - USGS Topographic Moisture Potential (supplemental)

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Mesic Uplands	Dry Uplands	Very Dry Uplands
Potential Wetlands (Periodically Saturated or Flooded Land		

This dataset was derived from the Compound Topographic Index (CTI) dataset, which was itself a derivative product of the National Elevation Dataset (NED), created by the Elevation Derivatives for National Applications (EDNA) project.

Appendix VIII - USGS Landforms (supplemental)

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Flat Plains	Irregular Plains	Low Hills	Breaks/Foothills	Low Mountains
Smooth Plains	Escarpments	Hill	Drainage Channels	High Mountains/ Deep Canyons

This dataset was derived from the NED based on various neighborhood analysis using a 1-km^2 analysis window. However, it was determined that the NED did not include sufficient elevation data on Canadian side of the northwestern U.S.-Canada border. As a result, in the areas within approximately 600-meters to the south of this border, neighborhood analysis were run with insufficient input data therefore land surface form classes in this area are expected to have lower accuracy.