Sustainable Vineyards in the Age of Climate Adaptive Viticulture

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Ancient Ways

Viticulture is old… very old

Practices have been developed over centuries

People often don’t want to change

Fear of changing ‘what wine is’

Grapes – A history

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Dogs Domesticated

30,000 BCE

2022 CE

Grapes – A history

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30,000 BCE

Wheat Domesticated

8,500 BCE

2022 CE

Grapes – A history

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Cows & Sheep Domesticated

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2022 CE

Grapes – A history

Dogs Domesticated

30,000 BCE

Wheat Domesticated

8,500 BCE

Cows & Sheep Domesticated

8,000 BCE

Grapevines Domesticated

6,000 BCE

2022 CE

Spread of *Vitis vinifera*

ion

Origins of *V. vinifera* in Americas

Thomas Jefferson was terrible at farming grapes & tried several times

- Really, it was just Grapevine Phylloxera 🥲

Hybrids of N. American species and *vinifera* started to gain ground.

- e.g., Norton cultivar

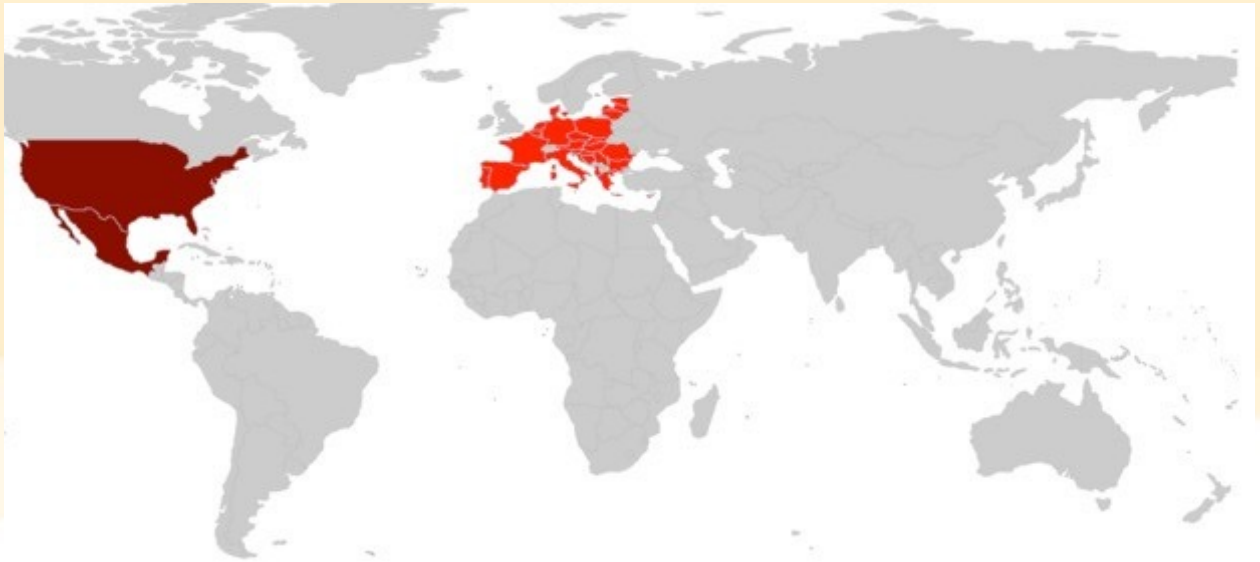
And then we found the benefits of native grapevines as rootstocks

- and California's Mediterranean climate

Spread of Grapevine Phylloxera

Phylloxera image source: UC ANR IPM

Spread of Grapevine Phylloxera

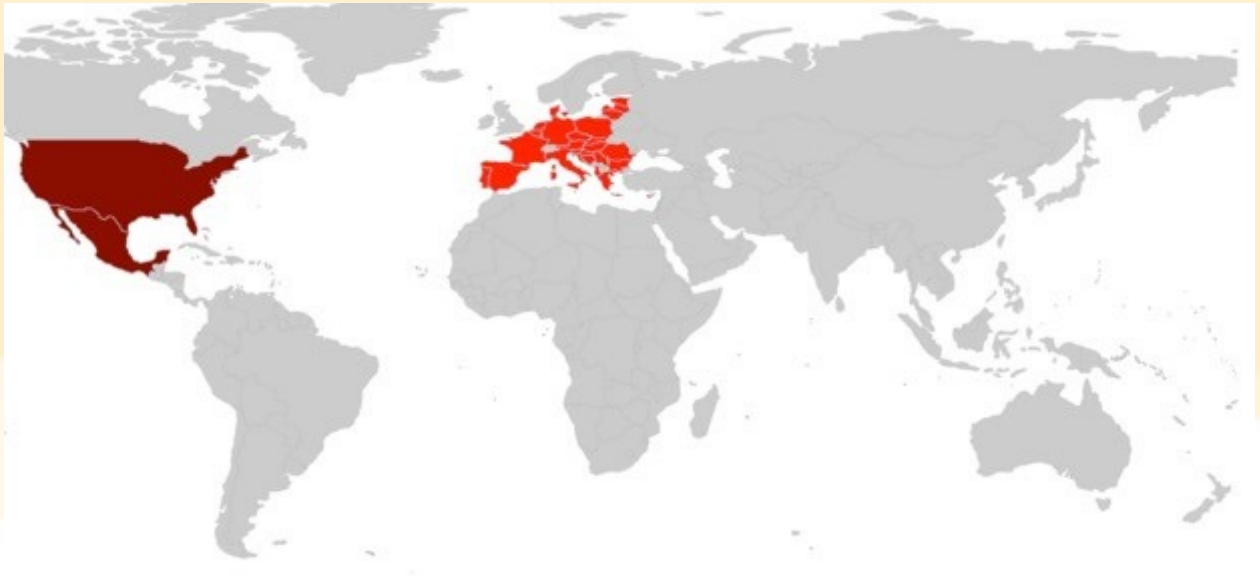


Phylloxera image source: UC ANR IPM

Spread of Grapevine Rootstocks

Phylloxera image source: UC ANR IPM

Spread of Grapevine Rootstocks



Phylloxera image source: UC ANR IPM

We have to talk about…

The Green Revolution

- Prior to this, many farms were subsistence-based (limited production)
- WWII resulted in lots of chemical developments and remnants
  - Nitrate for explosives (also good for plant growth)
  - Herbicides and pesticides developed for chemical warfare (e.g., DDT)
- Farms became like factories
  - Higher output with chemical assistance

Costs and Benefits: 550nm Turnaround

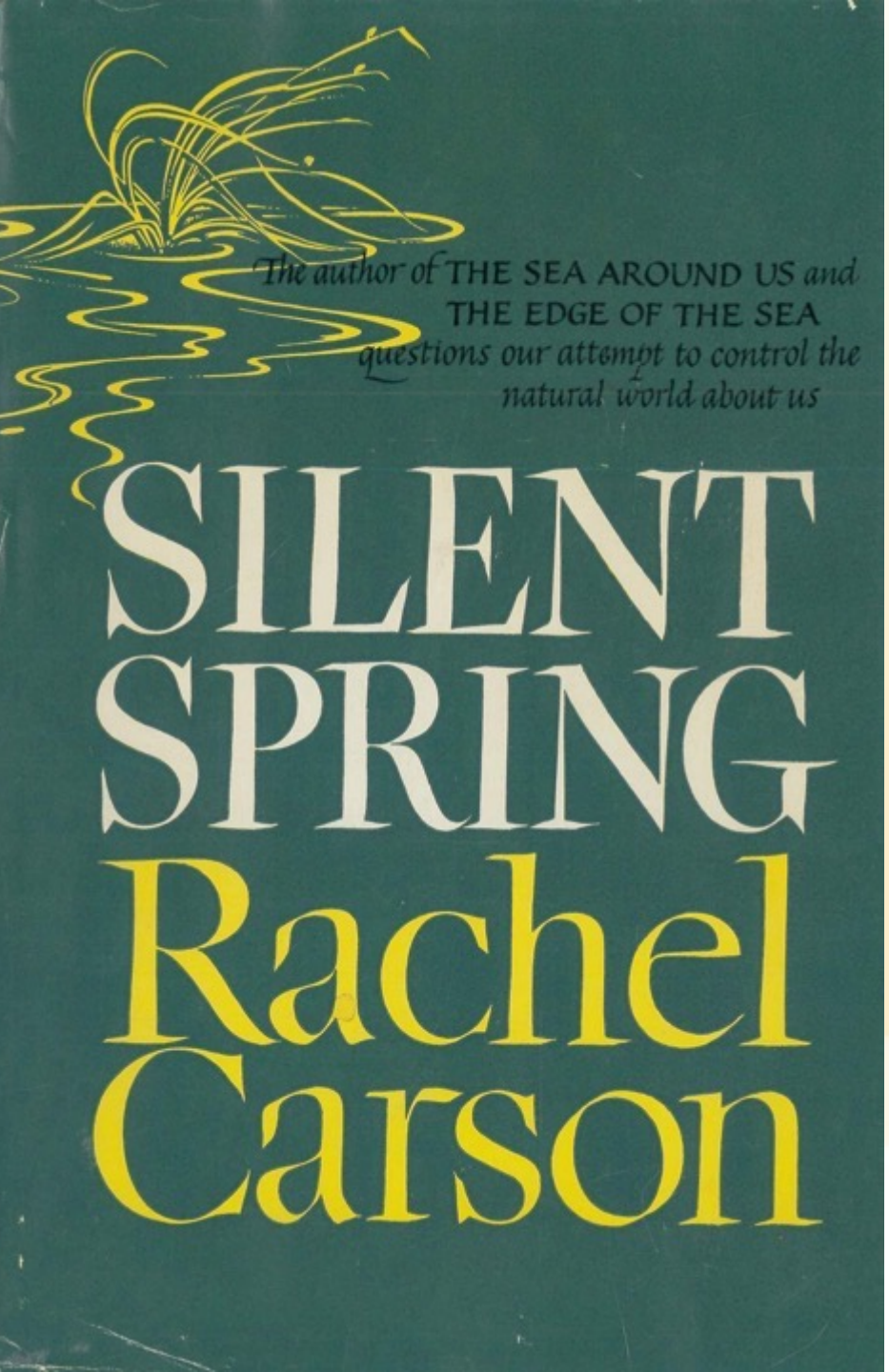
Benefits:

1. More food and less people required to grow it
2. Farmers have gone from more than ½ the population to < 5%

Costs:

1. Environmental – excess chemicals leaching into ecosystems
   - We are still seeing this today in Nitrate toxicity of waterways = algae blooms
   - Loss of beneficial predators and parasitoids of agricultural pests
2. Health – acute and chronic toxicity from chemicals
3. Societal – loss of agrarian society as people move to cities

Norman Borlaug
– photo by Arthur Rickerby



And then, of course…

Silent Spring (Rachel Carson, 1962):

- Brought attention to the costs of the Green Revolution
- But there was more trouble than the obvious problems:
  - Natural habitat destruction
  - Huge soil losses from intense cultivation
  - Farm consolidation to agricultural economies of scale
  - Consolidation of actors in the market – wholesalers and distributors shrank to a handful

Sustainability

- Used in the same, nebulous way as ‘Soil Health’
- *Sustainable Agriculture: farming in sustainable ways meeting society's present food and textile needs, without compromising the ability for current or future generations to meet their needs.*
- Think of it like camping – Leave no trace, preserve for the future
- How do we make our society sustainable as a whole?

Legally Defined

"Sustainable agriculture" as legally defined in U.S. Code Title 7, Section 3103 means an integrated system of plant and animal production practices having a site-specific application that will over the long term:

- Satisfy human food and fiber needs.
- Enhance environmental quality and the natural resource base upon which the agricultural economy depends.
- Make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls.
- Sustain the economic viability of farm operations.
- Enhance the quality of life for farmers and society as a whole.

Integrated Pest Management (IPM)

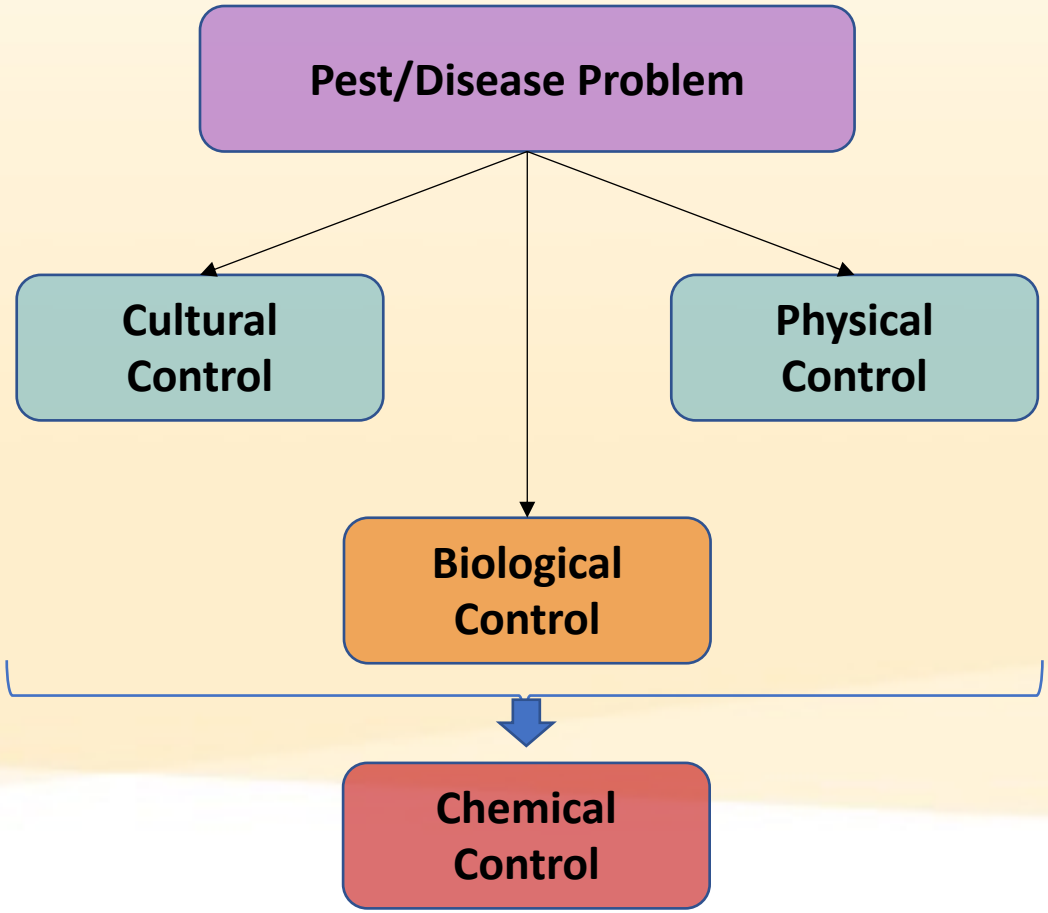
You'll hear this acronym a lot

Est. 1959 but really took off in the 60s

IPM is a foundational pillar of sustainable agriculture

Utilized practices:

1. Cultural
2. Physical
3. Biological
4. Chemical



Integrated Pest Management (IPM)

Definition:

a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks.

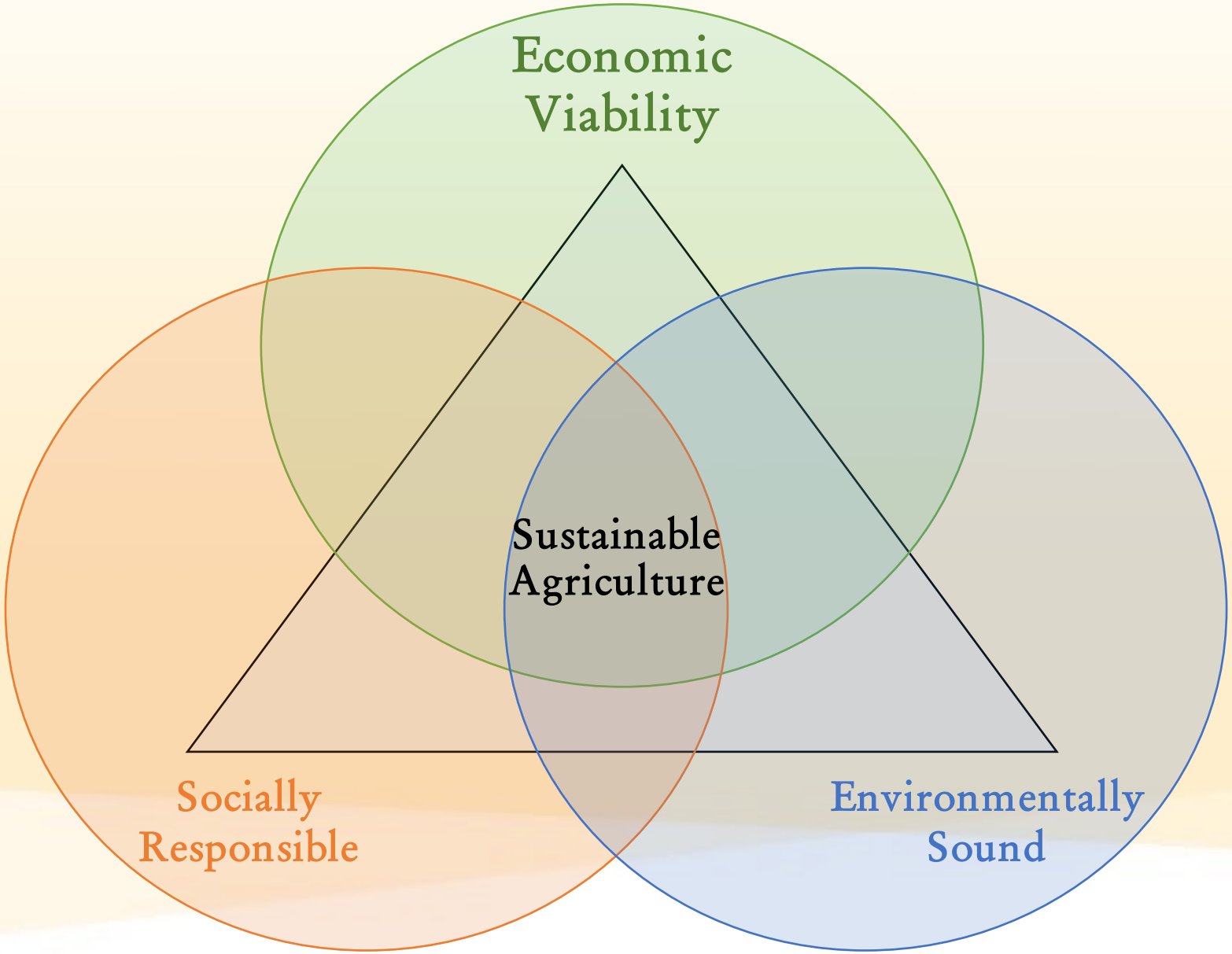
Key Tenants:

1. Identifying the pest
2. Monitoring and assessing the population size, damage, and favorable conditions
3. Using economic injury thresholds to determine when management is needed
4. Preventing pest problems
5. Combining management methods (biological, cultural, physical, chemical)

Tip-Toeing Towards Sustainable Agriculture

Sustainable Agriculture should be:

1. Economically Viable – grower still needs to make a profit
2. Socially Responsible – must not damage our society
3. Environmentally Sound – conserve our environment and ecosystems


Economic
Viability
Sustainable
Agriculture
Socially
Responsible
Environmentally
Sound

Sustainable Viticulture

Based on: Code of Sustainable Winegrowing Workbook
Broadest category besides Conventional

Certifications:

- Sonoma Certified Sustainable
- SIP (Sustainability in Practice)
- Certified California Sustainable
- Certified Green (Lodi Rules)
- And more…

Organic Agriculture

- Focused on the Health of individuals, communities, and the environment
- Fueled by distrust of Technology (like many people distrust science today) – can't understand it? Don't trust it.
- Environmental movement influenced
- Are we going to farm based on Profit or Health motivations?

Organic Farming Defined

Organic farming:

"an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony."

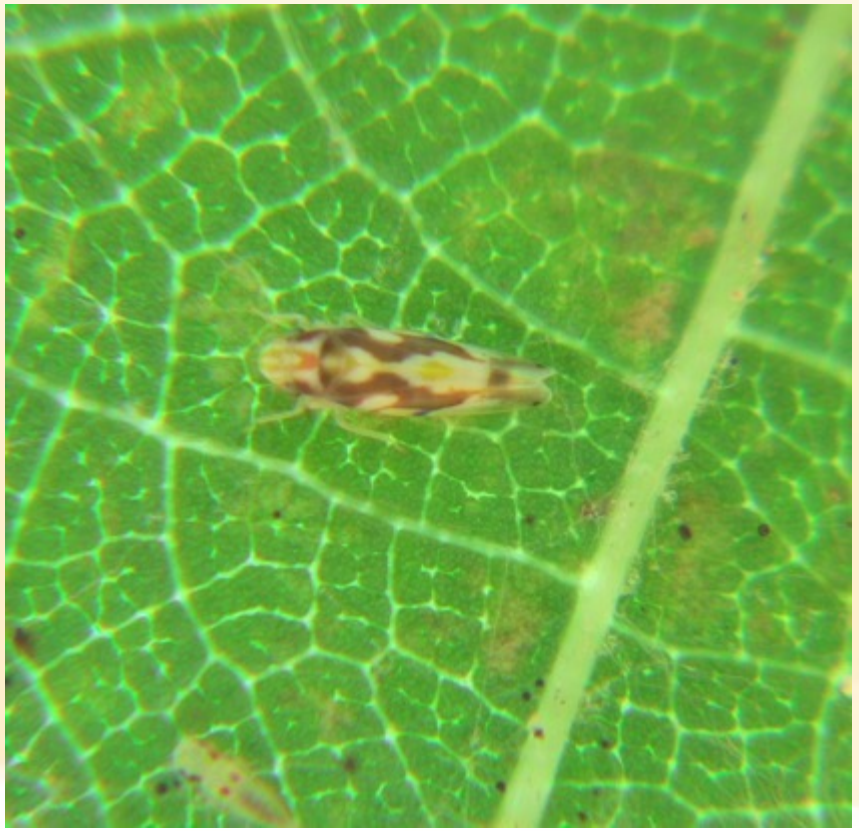
(National Organic Standards Board, 1998)

Core Principles of Organic Farming

1. The farm is a living system
2. Managing organic matter is critical to plant health
3. Synthetic chemicals are to be avoided
4. Nature can control pest and disease problems best, and cultural practices are used to keep the crop from being susceptible to problems
5. Each property is unique and needs a custom approach to organic farming based on resources that are present

Goals of Organic Pest Management

- Increase beneficial insect activity
- Decrease use of toxic sprays
- Increase monitoring of pests
- Increase biodiversity of habitat in the vineyard




Soil Amendments

Soil Management and Fertility Goals

- Utilize as much of the soil profile as is possible
- Slow mineralization of nutrients
- Adequate but not excessive fertility
- Well structured soils with good tilth
- Raise organic matter content due to its ability to hold water and nutrients

Soil Management and Fertility Goals

- Building up organic matter
- Cover crops: grasses for tilth, legumes for nitrogen
- Initial deep tillage to open soils for an extensive root system
- Added minerals are slowly soluble

Organic Matter

- Decomposed plant and animal residues
- Helps bind soil particles together to give the soil “structure”
- Good source of plant nutrients
- Gives the soil its dark color - coats the mineral portion of the soil
- Improves CEC and water retention

Compost

Compost is often used to:

1. Incorporate essential nutrients
2. Increase Soil Organic Matter
3. Improve water and nutrient retention
4. Improve soil aggregation
5. Reduce soil erosion

Compost often contains most or all of the nutrients needed for plant growth and is a general nutrient amendment.

If a specific nutrient is required (e.g., potassium) it would be better to apply it as a fertilizer rather than increasing compost applications.

Compost

Compost is often made out of:

1. Animal manure and plant matter
2. Custom compost using grape pomace

Types of compost:

1. **Raw** – hasn't gone through the entire composting process and often contains weed seeds, pathogen inoculum, or pests. Unpredictable, heterogeneous nutrient content.
2. **Finished** – more uniform color and texture with C:N ratio ≤ 20. Doesn't contain pests and diseases as often.

Compost

Application rates vary by site. However, nutrients in compost become available over time (slow-release).

For example:

Approximately **30-50% of the Nitrogen** content of the compost will eventually become available to the plant. About ½ of that will be accessible in the first year after compost is incorporated and the rest over the next few years.

Apply in Spring to avoid Nitrogen leaching from rains

Manure

Applied for the same reasons as compost.

Rarely applied on its own in vineyards.

Manure is most often mixed with straw bedding to create a raw or finished compost before application.

Apply in Spring when the vine can take up the most Nitrogen

Mulch

Mulch is commonly applied to the top of the soil and often used for:

1. Erosion control
2. Weed suppression
3. Reduces soil evaporation
4. Gradual nutrient additions


Forage
Prevent Erosion
Improve Soil Structure
Soil Moisture
Organic Matter and Soil Fertility
Soil microbiome diversity
Impact Microclimates
Attract Beneficials
Cover Crops

Types of Cover Crops

1. Grass and Legume Mixes
    - Legumes help increase Nitrogen (N-fixing bacterial nodules)
    - Grass helps build Soil Organic Matter
    - Example: Peas, Vetch, Bell Beans and Oats

2. Forbes/Broadleaves
    - Clover (Subterranean, Crimson)
    - Mustards help prevent the spread of nematodes

Organic Fungicides: Sulfur and Stylet Oil

1. Sulfur
    - Used for fungal control in both organic and conventional vineyards
    - Relatively safe and minimally toxic to humans
    - Applied multiple times throughout the year
    - Extra applications in necessary situations (e.g., Summer rains)
2. Stylet Oil
    - Used to control arthropods with *piercing-sucking mouthparts*
    - 'Suffocates' them without direct chemical reactions
    - Must be applied ≥ 2 weeks apart from sulfurs

Mechanical Cultivation

1. Undervine cultivation
2. Interrow cultivation
3. Cover crop seeding
4. Discing, tilling, and ripping

Organic and Biodynamic - Similarities

- Use of compost, cover crops for soil fertility
- Prohibition of synthetic fertilizers, crop
- protectants, growth regulators and GMO's
- Third party certification
- Strong conservation ethic and interest in environmental health, food safety

Components of Biodynamic Viticulture

- Viewing a vineyard as an ecosystem
- Trying to make the vineyard a closed system with few off farm inputs
- Encourages recycling of nutrients
- Utilizes cover crops extensively
- Use nature to keep farmland and crops healthy and fertile

Unique Ideas - Biodynamic

- Plant and animal biology respond not only to sun cycle (day and seasons), but also to **3 lunar cycles** and the **sidereal (fixed constellations) cycle.** Some on farm activities should be scheduled at certain celestial positions for optimum effects
- Plants and animals should be integrated in the farming systems, as they compliment each other , and assist in health and fertility of both
- Increasing biodiversity is important for system health
- Most of these concepts have not been validated by
- conventional reductionist science

Unique Ideas - Biodynamic

•Biodynamic preparations or bioregulators are used in small amounts for

i. making compost
ii. improving soil
iii. affecting foliar and fruit growth

•Preps 500, 501 used, 4 applications total/year

•Create a closed, self-regulating system

Crop Rotation

- Soil Enrichment
- Provides Natural Habitat
- Encourages Beneficial Insects
- Reduces Compaction
- Recycles Nutrients

Biodynamic Preparations

1. Homeopathic Blend 500
   - Promotes root activity, stimulates microbial activity

2. Homeopathic Blend 501
   - Improves photosynthesis and chlorophyll production
   - Impacts color, aroma, and flavor of grapes

Biodynamic Preparations

1. Stirring Machine

2. Flow forms

Livestock Integration

- Sheep/Compost – Soil Enrichment and Weed Control
- Chickens/Compost – Pest Control
- Local Wildlife – Species Diversity

Livestock Integration - Sheep

- Can be used for
    1. Vineyard Floor Management (weed control)
    2. Vine, basal-leaf removal
    3. Fertilizing the soil

Sustainability in Changing Climates

Climates – Small and Large

- Global average temperatures have risen by at least 3 °F since the start of the 20th century (1)
- Drought persists in the West Coast (2)
- Extreme weather events have become more frequent (3)
- Pests and diseases are migrating or adapting

Climates – Small and Large

Frost damage, heat, and drought

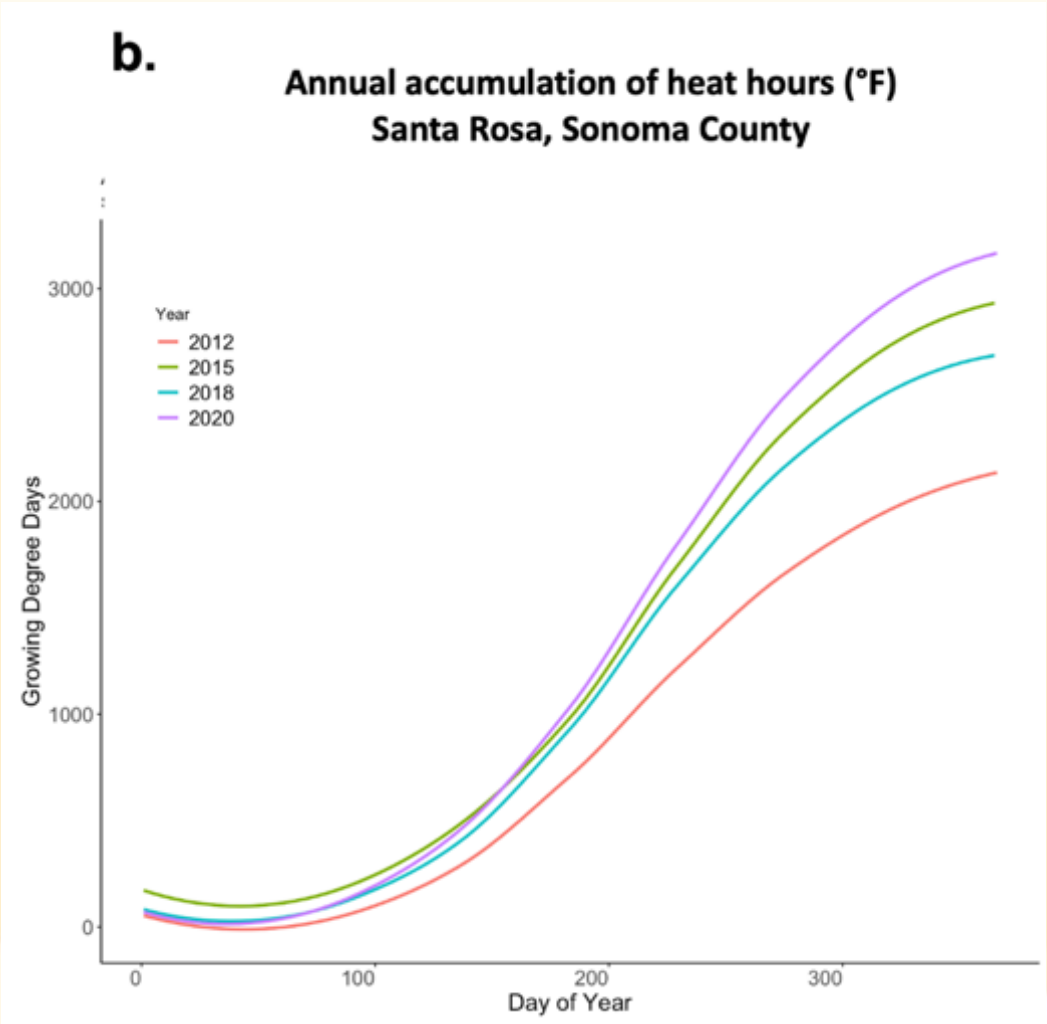
Vine susceptibility ~ abiotic stress

No natural immune system

- Additive resistance
- Defense compound synthesis
- Abiotic stressors redirect resources

Can tolerate pests/diseases under best conditions

Shifting Phenology



Cumulative heat accumulation in Santa Rosa, California in 2012, 2015, 2018, and 2020; linear model. (Data from https://cimis.water.ca.gov)

Changes in Phenological Timing

In Central Europe the impact of warming climates has been documented in Bernáth et al. 2022 (pre-print)

Between 1985 and 2018

- Budbreak: 5-7 days earlier
- Flowering: 7-10 days earlier
- Berry maturity: 18 days earlier
- Harvest: 8-10 days earlier

Pests and Diseases in New Climates

Pest/Disease Responses ~ Changing Climates

Insects can respond to climate change in several ways, however three major responses that have been cited are [9] :

1. Moving to a climate more suitable to them
2. Shifting their phenology to correspond with the local changes in environmental conditions, or
3. Adapt to the new conditions and the associated impacts on the ecosystem

Pest and disease responses to climate change

As a result of the indirect impacts of:

1. Increased average temperatures
2. Higher atmospheric CO_2
3. More environmental pollutants
4. Changes in distribution and range of host plants

We expect to see changes in:

1. Pest and disease migratory behavior
2. Over wintering success
3. Species interactions
4. Effectiveness of pest predators and parasitoids

‘New’ diseases in vineyards

Often can be difficult to identify:

- Lime disease on the West Coast or GRBV in vineyards

Grapevine Red-Blotch Associated Viruses

- Flagship example for grapevines
- Not known until 2008 (Oakville, CA)

Case Study: GRBV

Red blotch was an unknown disease in grapevines for decades and likely was already present in the north coast during the 20th century.

Large, clean-material vineyards used to source pathogen-free material did not know it existed and thus, did not know what to test for.

The future of our climate may increase the likelihood of new diseases we cannot test for or expression of existing pathogens becoming more problematic

Vineyard Asynchrony

Both the pest and host can respond to changing climates in unpredictable ways [5]

Changes in temperature and atmospheric CO_2 levels have impacted the timing of generational cycles of insect species in vineyards [6, 7, 8]

- Resulting in some asynchrony between pest and predator/parasatoid

What can be done?

The unpredictable nature of climate change

We know what to expect, but not when and where to expect it

- e.g., Spring frost damage as far south as Fresno in April 2022

Extreme events are occurring more frequently and unexpectedly, with long-term weather forecasts are becoming less reliable. [21]

Impact of such events like heatwaves are more noticeable in regions unaccustomed to them (i.e., coastal heatwave impacts > inland heatwaves) [3]

21. Stephen Ornes. How does climate change influence extreme weather? impact attribution research seeks answers. Proceedings of the National Academy of Sciences, 115(33):8232–8235, 2018. doi: 10.1073/pnas.1811393115.

Tools for tolerance

1. Breeding and genetic solutions (GRN rootstocks; PD-resistant scions)
2. New monitoring techniques/Proximal sensing (LiDAR sensing; non-invasive disease ID)
3. Promotion of beneficials
4. Research on combined-stress responses in grapevines

Resistant Cultivars

Rootstocks have long been used as a method of tolerance to both biotic and abiotic stressors. (22)

- GRN rootstocks for nematode tolerance

Scions are also being developed to help impart tolerance to specific pests and/or diseases (23)

- Pierce's Disease resistant scions

22. M. Mumtaz Khan, Muhammad Tahir Akram, Rashad Waseem Khan zQadri, and Rashid Al-Yahyai. Role of grapevine rootstocks in mitigating environmental stresses: A review. Journal of Agricul- tural and Marine Sciences [JAMS], 25(2):1–12, Sep. 2020.

23. A. F. Krivanek and M. A. Walker. ii¿vitisi/i¿ resistance to pierce's disease is characterized by differential ii¿xylella fastidiosai/i¿ populations in stems and leaves. Phytopathologyà, 95:44–52, 1 2005. ISSN 0031-949X. doi: 10.1094/PHYTO-95-0044.

New Monitoring Solutions

Remote sensing for pest and disease monitoring in vineyards

Examples

1. LiDAR sensing and modeling to identify flying insects on site
2. Radio Wave surveys of internal biological components of a living vine
3. Drone-based NDVI for disease impacted vines

Promotion of Beneficials

New phenological cycles of phytophagous insect pests may require a 'reworking' of our understanding of efficacy of certain beneficial species.

An asynchronous hatching of pest and beneficial may lead to a decline in their effectiveness

New distribution methods may increase survival rate of introduced beneficials in vineyards

- e.g., Drone-distributed beneficial mites

Research into combined stress responses

Plant responses to combined stressors may be unique to the specific combination of stressors.

- e.g., drought and *Xylella fastidiosa*

Research on phytotoxic metabolite biosynthesis in response to changing environmental conditions (10)

Combined stressors may be thought of as a third-type of stress beyond biotic and abiotic (14)

Other Promising Research

Biostimulants [24]

- Formulations of natural substances and/or microorganisms used to improve vine health and efficiency or tolerance from abiotic or biotic stressors.
- Currently show promise as a buffer against stress damage in grapevines
- But much more research is needed
    i. What mechanisms does each biostimulant act on to induce the observed results?
    ii. What are safe levels of application?
    iii. What phenological stage should they be applied at?
    iv. How and how often should they be applied?

24. Eliana Monteiro, Berta Gon ̧calves, Isabel Cortez, and Isaura Castro. The role of biostimulants as alleviators of biotic and abiotic stresses in grapevine: A review. Plants, 11(3), 2022. ISSN 2223-7747. doi: 10.3390/plants11030396.

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Dogs everywhere (because dogs are great)


Thank You