

Regenerative Agricultural Winegrowing Systems Play a Role in Refining the Expression of Terroir in the Pacific Coast Region of United States and Canada

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California's North Coast

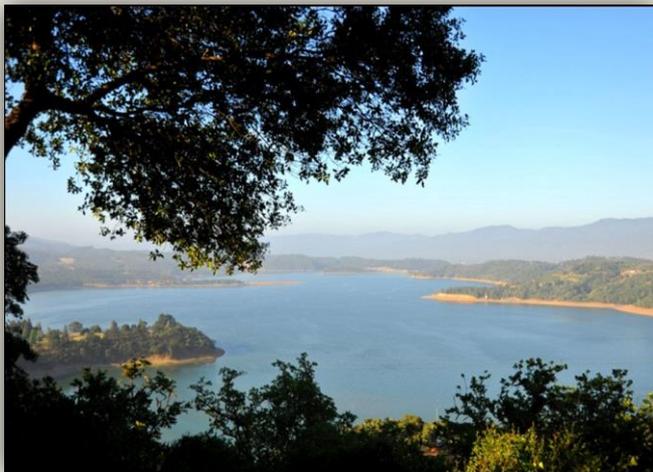




Mendocino County: 2/3 of the land area is forest



Mendocino County Vineyards



Lake County and Clear Lake

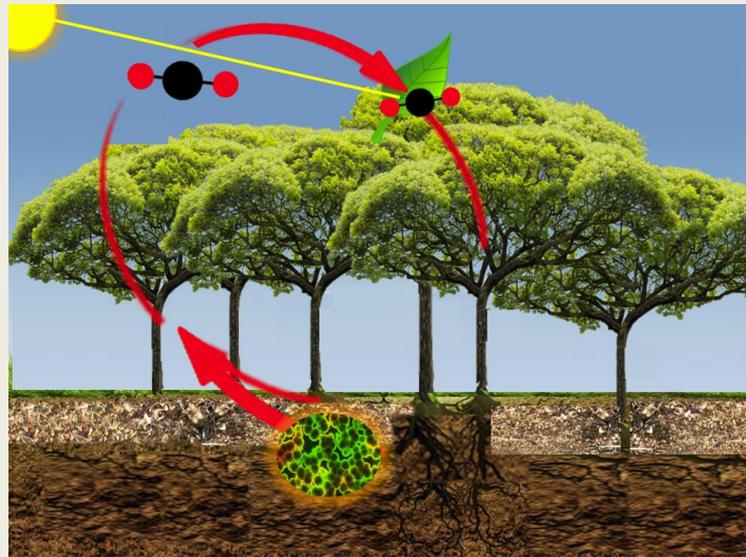


Lake County Vineyards

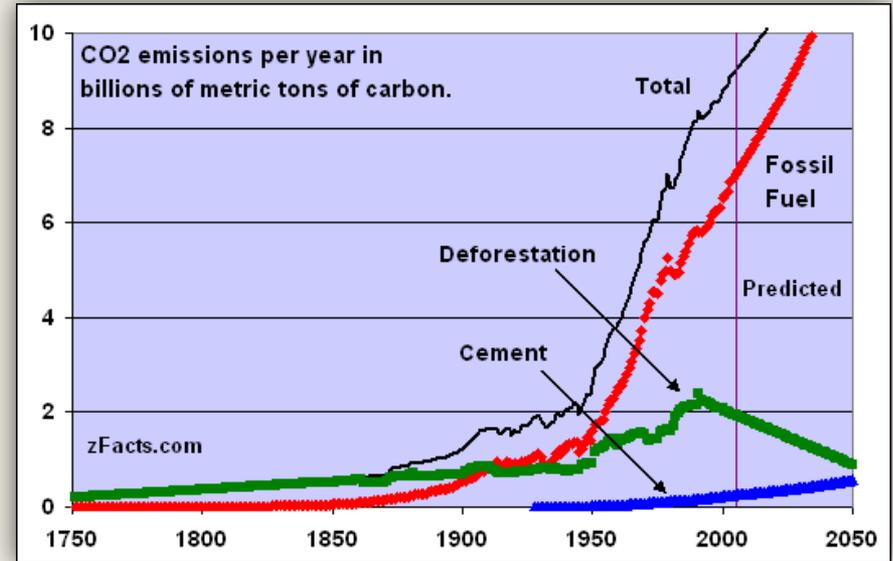
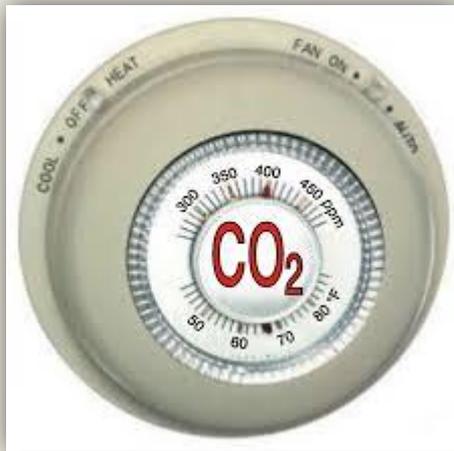


Regenerative Agricultural Systems

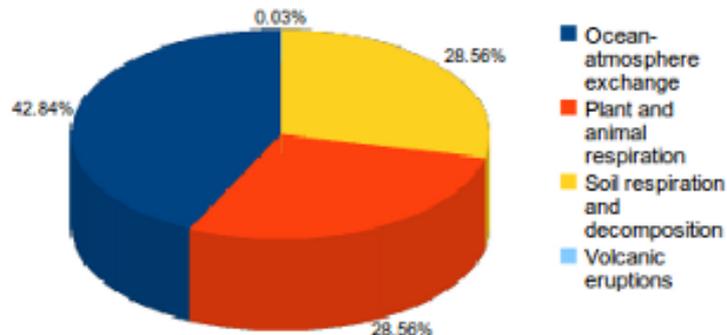
- Seek to promote soil and plant health by using photosynthesis for the removal and retention of atmospheric carbon dioxide into stable soil carbon.



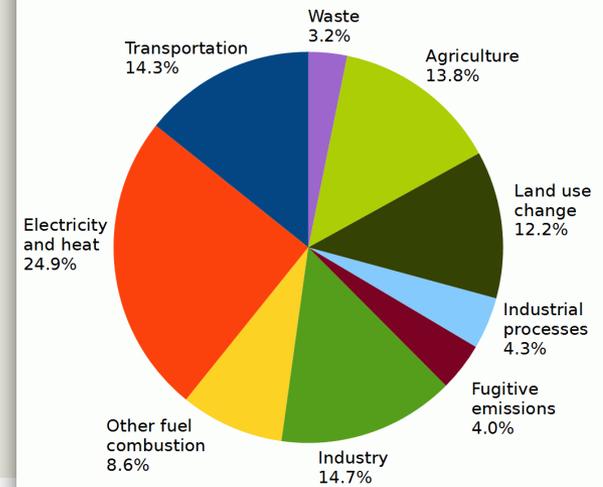
What is the big CO₂ picture?



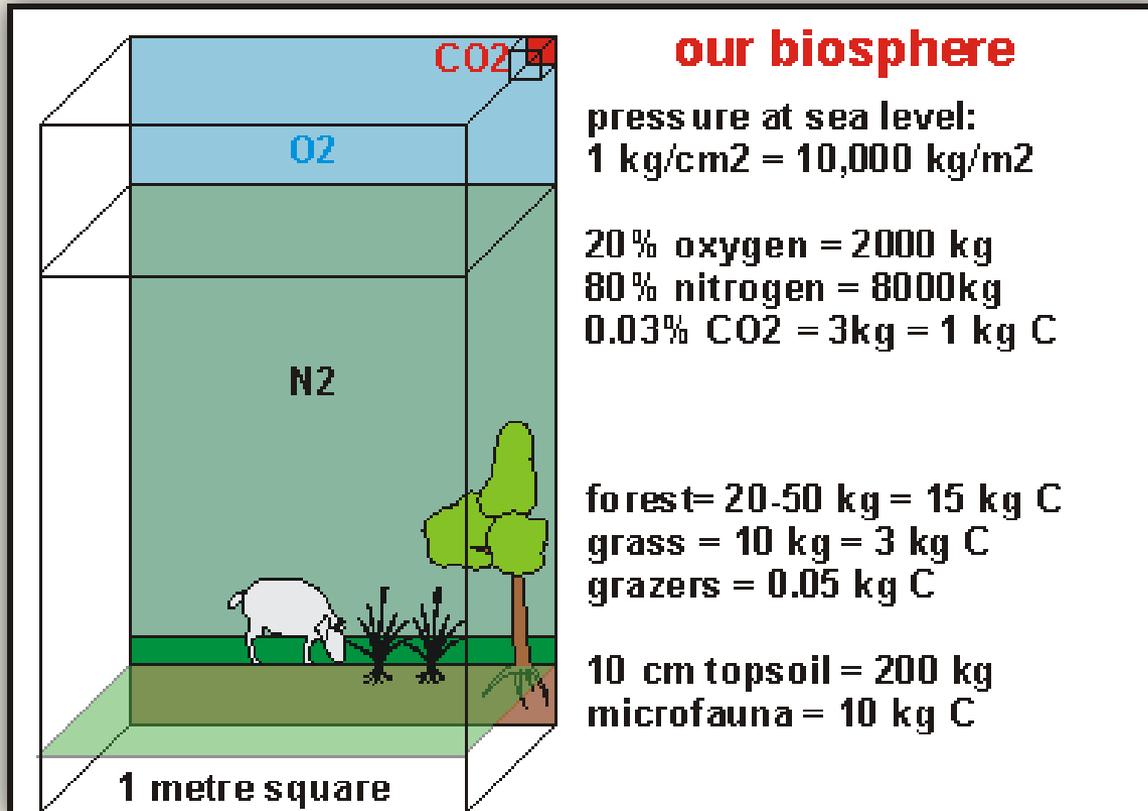
Natural sources of carbon dioxide



Annual world greenhouse gas emissions, in 2005, by sector



How Much CO₂ Are We Talking About?



<http://www.seafriends.org.nz/enviro/soil/ecology.htm>

Rethinking the Role of Farms: Ecological Services

Watershed: protecting soil and
water ways, storing water

Beneficial Insects and Pollinators

Habitat for Diverse Species

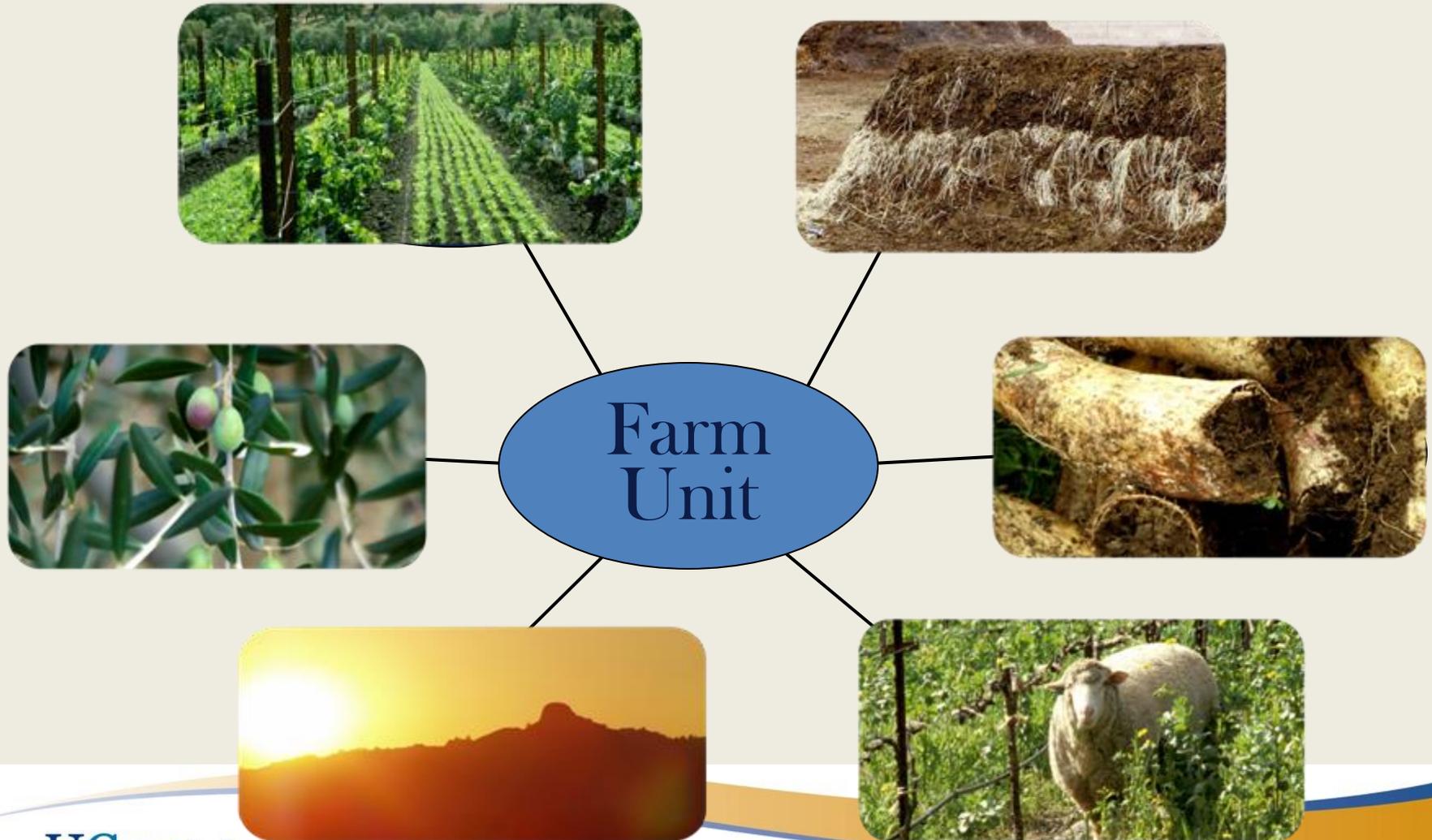
Sequestering Carbon

Biodynamic and Organic Farming

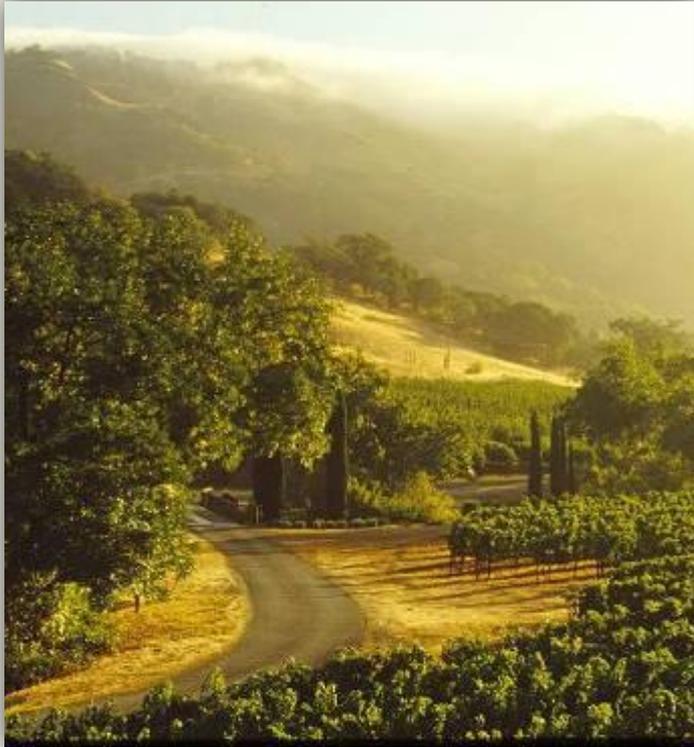
Systems embrace these practices



Biodynamic Farming: a Holistic Approach



Is Soil Important for Wine Flavor?



Is This the Best Way to Express Terroir?



Soils: Stomach of Our Ecosystem

Component (grass land system in a humid climate)	Kg/ha	Population Numbers
Organic Matter all	120,000	
Organic Matter non living	105,000	
Microbes	5,000	10×10^{18}
Nematodes	20	2×10^9
Earthworms	100	7×10^3
Arthropods	100	4×10^{17}
Vertebrates	42	4×10^5

From H. Foth: Fundamentals of Soil Science, 7th Edition

Organic and Biodynamic Agriculture: Require Addition of Organic Matter

- Compost
- Cover Crops
- Conservation Tillage



Cover Crop Benefits

- Soil protection
- Regulate vine growth
- Improve soil fertility
- Improve soil quality
- Biological diversity in soil and vineyard
- Firm footing for harvest and pruning
- Build SOM
- Improve water infiltration and retention



Immediate Effects of Cover Crops

- Plant tissue is the primary source of SOM
- Soil life is stimulated
- Cover crops serve as food source for vertebrates, invertebrates and microbes
- Soil respiration rates and microbe numbers increase

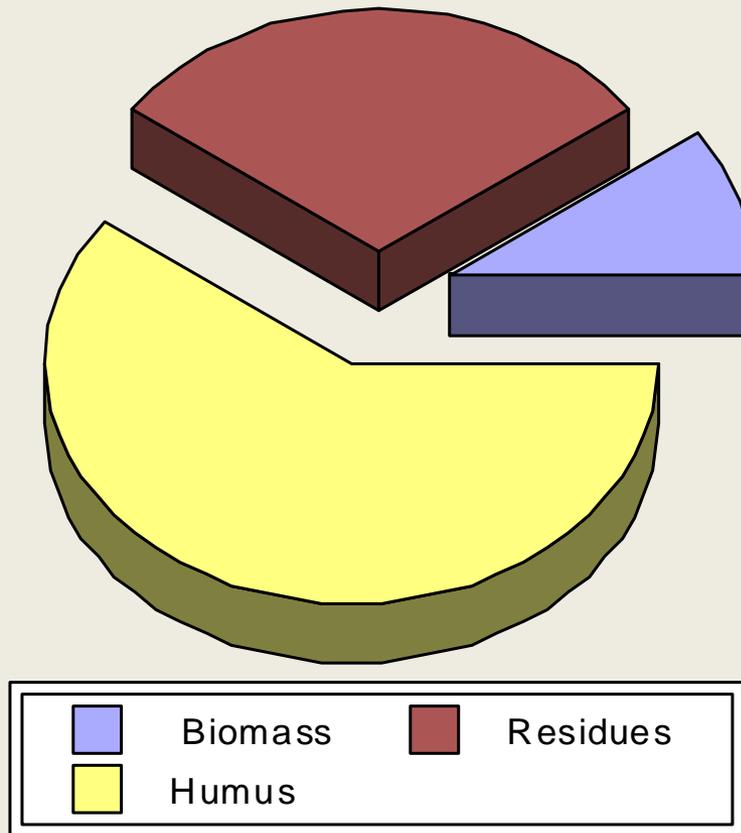
Beneficial Activities of Microbes

- Decomposition of plant residues for energy and growth
- N cycling
- Increase availability of P, Fe, So, K and others
- Humus formation, C cycling
- Aggregate formation
- Suppression of pathogens
- Mycorrhizal relationships

Vineyard Organic Matter Per Year, kg/ha

Item	Conventionally Farmed	Organic/Biodyn. farmed
Prunings	1000	1000
Leaves	1400	1400
Weeds/cover c.	1200	1200-12000
Compost	0	2300
Total, kg/ha	3600	5900—17900
Total, tons/acre	0.75	1.2—3.5

Soil Organic Matter by Percentages



Energy Consumption: Chemical Fertilizers Vs. Compost

Material	Joules required to synthesize	BTU's required to synthesize	Amt. of water heated by 1 degree F*
1 kg of N—chemical	78,914,000	75,000	9,350 gallons
1 kg of N— Compost	527,500	1,100	136.5 gallons

*1 BTU= 1055 joules = amount of energy to raise one gallon of water by 1 degree F

The Microbiome

The microorganisms in a particular environment, or the combined genetic material of the microorganisms in a particular environment.

“Understanding the microbiome—human, animal, and environmental—is as important as the human genome”

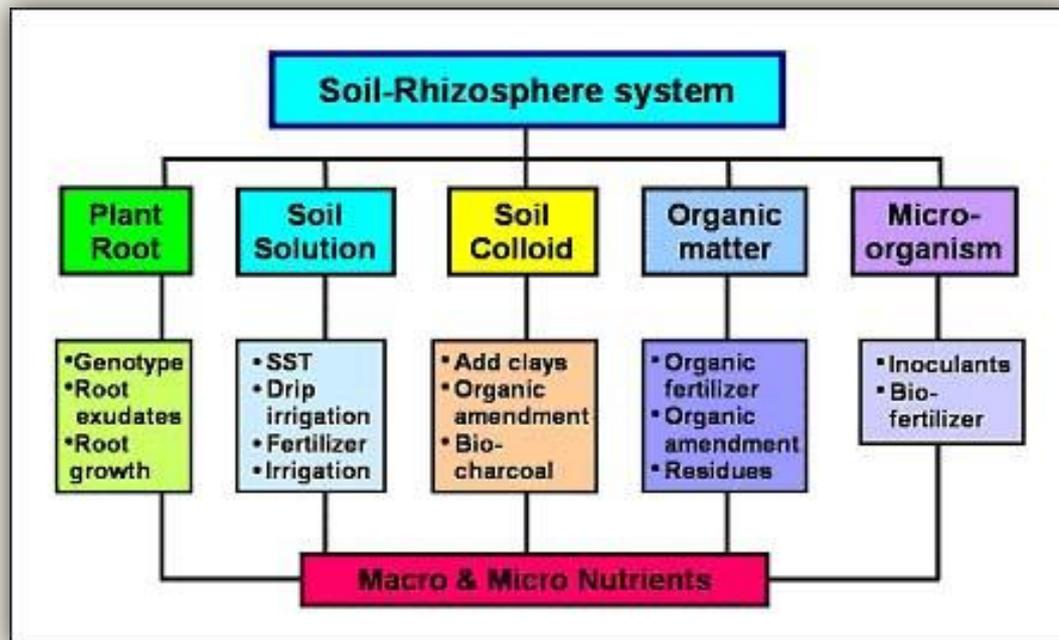
The Microbiome of Grape Vines:

- Phyllosphere: Leaf surfaces
- Fruit
- Rhizosphere: Roots and soil
- Traditional methods of isolating individual species in pure culture will be assisted by genomics
- New science that will rapidly change how we view farming systems ecology

Rhizosphere



Trends in Plant Science



<http://www.seafriends.org.nz/enviro/soil/ecology.htm>

What Happens In the Soil Can Affect the Entire Plant

7/5/2016 Rosmarinic acid is a homoserine lactone mimic produced by plants that activates a bacterial quorum-sensing regulator | Science Signaling

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RESEARCH ARTICLE HOST-PATHOGEN INTERACTIONS

Rosmarinic acid is a homoserine lactone mimic produced by plants that activates a bacterial quorum-sensing regulator

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Pathogens May Stimulate Plant Responses by Chemical Messaging

- *Quorum sensing* is a bacterial communication mechanism that controls genes, enabling bacteria to live as communities, such as biofilms
- Plants also produce previously unidentified compounds that affect quorum sensing.
- *Rosmarinic acid secretion* is a plant defense mechanism to stimulate a premature quorum-sensing response, protecting the plant when a particular pathogen is present.

Phyllosphere, Plant Surfaces



Samoray et al, 2016

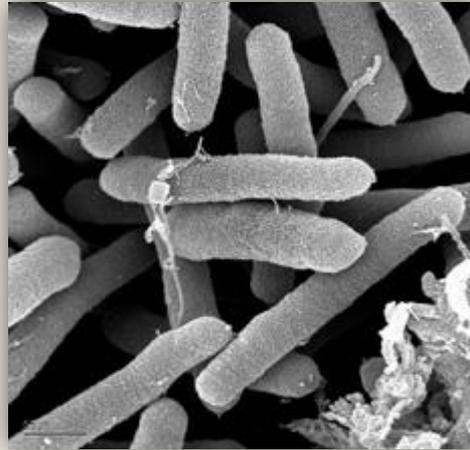
Phyllosphere of Grape Vines

- Generally, grape vine leaves don't seem to support large numbers of diverse species, or populations
- Ice nucleating bacteria affect freezing, research ongoing on controlling populations
- Bacteria most likely migrate from cover crops

Why Do Some Shoots Freeze But Not Others?



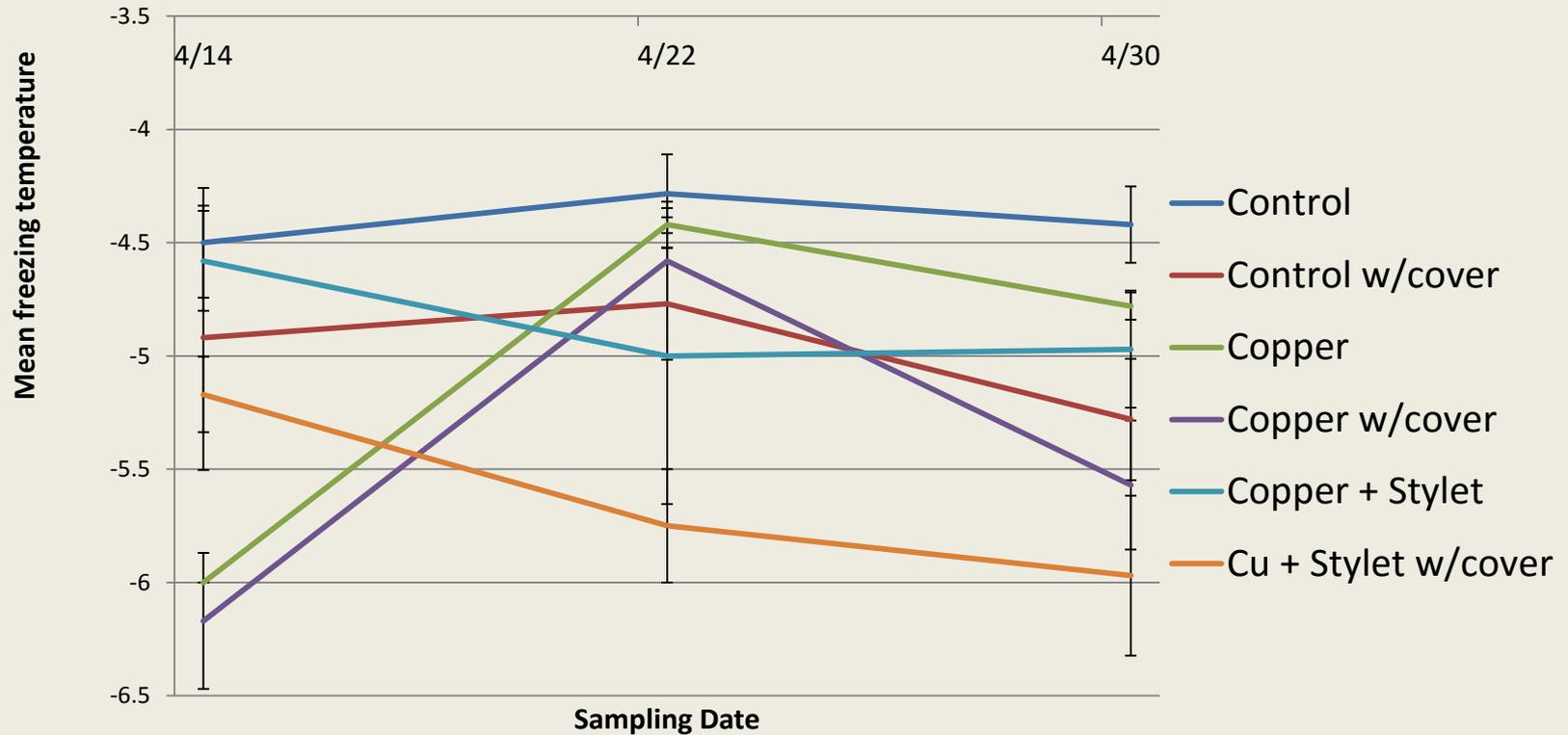
Ice Nucleating Bacteria



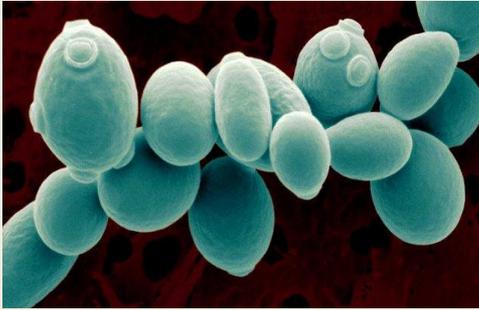
Total bacterial populations on various cover crop species

Treatment	Bacteria recovered	Log (cells/g)
Fine Fescue		8.26 a
Crimson Clover		8.02 a
Vetch		7.76 ab
Burr Clover		7.12 bc
Subclover		6.86 cd
Pea		5.84 ef
Grape		About 4.0

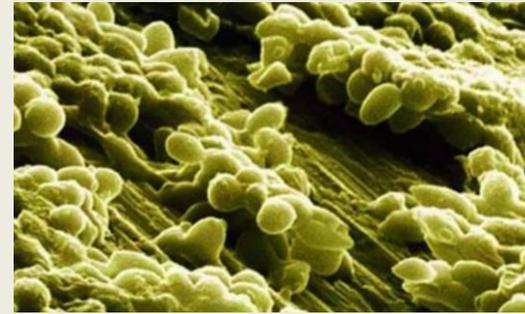
Mendocino Frost Study 2014



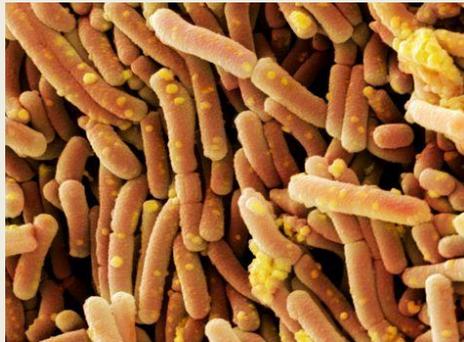
Microbes on Grapes Can Be Specific to Vineyard Sites



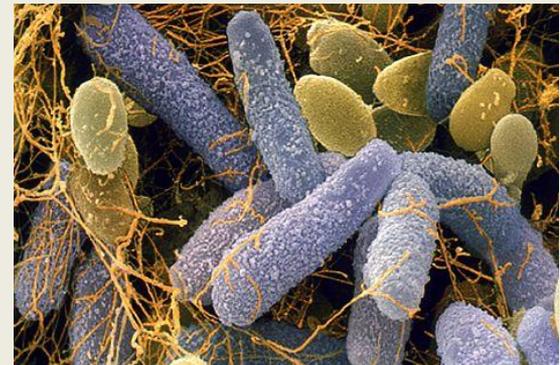
Saccharomyces cerevisiae



Saccharomyces on fruit



Lactobacillus



Schizosaccharomyces and Acetobactor

Associations among Wine Grape Microbiome, Metabolome, and Fermentation Behavior Suggest Microbial Contribution to Regional Wine Characteristics

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Department of Food Science and Technology, University of California, Davis, California, USA^a; Department of Viticulture and Enology, University of California, Davis, California, USA^b; Foods for Health Institute, University of California, Davis, California, USA^c; Food Safety and Measurement Facility, University of California, Davis, California, USA^d; Far Niente and Nickel & Nickel Wineries, Oakville, California, USA^e

* Present address: Nicholas A. Bokulich, Center for Microbial Genetics and Genomics, Northern Arizona University, Flagstaff, Arizona, USA; Thomas S. Collins, Viticulture and Enology Program, Washington State University, Richland, Washington, USA.

ABSTRACT Regionally distinct wine characteristics (*terroir*) are an important aspect of wine production and consumer appreciation. Microbial activity is an integral part of wine production, and grape and wine microbiota present regionally defined patterns associated with vineyard and climatic conditions, but the degree to which these microbial patterns associate with the chemical composition of wine is unclear. Through a longitudinal survey of over 200 commercial wine fermentations, we demonstrate that both grape microbiota and wine metabolite profiles distinguish viticultural area designations and individual vineyards within Napa and Sonoma Counties, California. Associations among wine microbiota and fermentation characteristics suggest new links between microbiota, fermentation performance, and wine properties. The bacterial and fungal consortia of wine fermentations, composed from vineyard and winery sources, correlate with the chemical composition of the finished wines and predict metabolite abundances in finished wines using machine learning models. The use of postharvest microbiota as an early predictor of wine chemical composition is unprecedented and potentially poses a new paradigm for quality control of agricultural products. These findings add further evidence that microbial activity is associated with wine *terroir*.

IMPORTANCE Wine production is a multi-billion-dollar global industry for which microbial control and wine chemical composition are crucial aspects of quality. *Terroir* is an important feature of consumer appreciation and wine culture, but the many factors that contribute to *terroir* are nebulous. We show that grape and wine microbiota exhibit regional patterns that correlate with wine chemical composition, suggesting that the grape microbiome may influence *terroir*. In addition to enriching our understanding of how growing region and wine properties interact, this may provide further economic incentive for agricultural and enological practices that maintain regional microbial biodiversity.

Some Key Findings Bokulich et al.

- Epiphytic fungi and bacteria have signatures in geographical areas, specific vineyard sites, “microbial biogeography”.
- Many species have influence on wine flavors
- Research in this paper demonstrates grape/wine microbiota and metabolites are regionally distinct, correspond with wine metabolome and fermentation performance

Biodynamic Approach

- Preparations and homeopathic sprays to “enhance plant and soil life”
- Natural fermentations of wine
- Attempt to make farms somewhat self regulating for fertility and pest management
- Emphasis on balance
- Some wines are quite good
- Lower energy inputs



“The Vineyard Is My Orchestra and I Am The Conductor”



Dave Koball, Former Vineyard Operations Director, Bonterra Vineyards

Thanks for your attention!

