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Using Soil Exopolysaccharides (EPS) to make California grapes more drought-adapted

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Project Summary

Crops—and plants in all ecosystems—depend on healthy soils that can supply water and nutrients even when it is not raining (or irrigating). One possible strategy for helping agricultural systems adapt to drought is to mimic soil bacteria. When soils dry out, bacteria are known to secrete extracellular polymeric substances (EPS) that act as sponges to increase water retention. However, nothing is known about the link between soil EPS and plant production. What if EPS could be added to soil during drought as a way of helping crops adapt? This question was explored using soils from Sea Smoke Vineyard near Lompoc, CA. Pinot noir grapevines were grown in a greenhouse with soils of varying amounts of xanthan gum. Xanthan gum is a commercially available, organic EPS produced by bacteria. Close-up images showed how strands of xanthan gum act as pipes to connect soil particles. Laboratory tests showed that a soil xanthan concentration of at least 0.5% by mass was required to increase water-holding capacity (WHC).

Therefore, soil xanthan concentrations of 0.5% and 1% were set up in a greenhouse to nearly double soil WHC. During a six-month growing season, xanthan gum amendment reduced irrigation demand by 28-38% in bare soils. With grapevines present, irrigation demand was similar with xanthan amendment, but production of plant biomass increased by 55%, resulting in a 45% increase in crop water-use efficiency. Xanthan amendment also moderated the release of mobile nitrogen early in the growing season. The beneficial effects of bacterial EPS on soil water and nutrient retention, as well as plant growth, should motivate farmers and land managers to promote naturally occurring biological EPS production and links to soil health. For young perennial crops and extremely degraded soils, xanthan gum amendment in the rooting zone could be an economically viable strategy for drought adaptation.

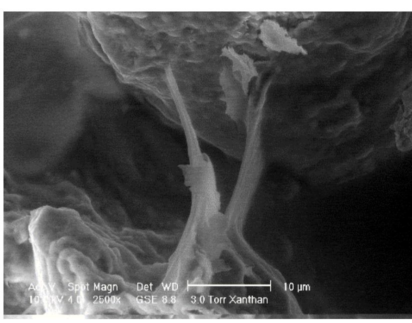

Fig.1. Xanthan gum in soil; image captured using environmental scanning electron microscope

Fig.2. Collecting soil at Sea Smoke Vineyard near Lompoc, CA

Fig.3. Growing pinot noir grapevines in soils amended with xanthan gum

Research Program

Fig 4. Amending vineyard soils with xanthan gum

The scientific community is calling out for "climate-smart" soils that both mitigate *and adapt to* climate change, but how do we actually accomplish this? One soil-based strategy for drought adaptation is to enhance soil organic matter (SOM), because SOM is an effective sponge for capturing and retaining water from irrigation or natural precipitation. But which kind of SOM is most effective for making soils "water smart?"

When soils dry out, bacteria are known to secrete extracellular polymeric substances (EPS) into the soil environment, which are potent forms of SOM. EPS are remarkable at holding onto water molecules and are thought to be an evolutionary adaptation of bacteria to water-limited conditions. EPS also act as pipes to increase the diffusion and physical accessibility of soluble resources. While it remains difficult and unclear how to extract bacterial EPS from soil, it is possible to add EPS to soil because xanthan gum is commercially available, organically certified EPS produced by bacteria.

The overarching goal of this project was to explore the potential benefits of bacterial EPS for reducing irrigation demand while sustaining soil nutrient supply and plant production. My objective was to add an EPS analog to quantify its function in a plant-soil system. Do EPS contribute to water savings, crop production, and nutrient retention?

Soils from a pinot noir grape vineyard on the central coast of California were transferred to 5-gallon pots and transported to a greenhouse at University of California at Santa Barbara. After growing winter cover crops and simulating tillage, three xanthan gum treatments were set up: 1% (by mass), 0.5%, and no xanthan added. Pots of soil with and without grapevines were maintained for a six-month growing season. Pots were irrigated whenever soil at a depth of 10 cm dried below 15% volumetric water content. Irrigation amount, soil moisture at 10 cm and 30 cm depths, plant growth (dry biomass, stem length, leaf count), and fluxes of plant-available soil nitrogen (nitrate, NO_3^-) were monitored throughout the growing season using buried ion-exchange membranes.

Xanthan gum amendment reduced seasonal irrigation demand by 28-38% in bare soils. Surprisingly, it took over two months for the soil wetting front to reach a depth of 30 cm due to changes in porosity and infiltration rate. Increased moisture associated with xanthan gum gradually shifted from shallow to deep soils. With grapevines present, xanthan amendment did not affect irrigation demand, but plant production increased by 55%, resulting in a 45% increase in crop water-use efficiency. Xanthan gum also moderated the rapid release of NO_3^- early in the growing season.

The beneficial effects of microbial EPS on soil water and nutrient retention, as well as plant growth, should motivate land managers to promote natural EPS production and links to soil health. For young perennial crops and severely degraded soils, xanthan gum amendment in the rooting zone could be an economically viable strategy for reducing irrigation demand and jumpstarting ecosystem recovery, particularly during drought.

Information Transfer/Outreach Program

Goals, data, and impacts of this project have been transferred through a variety of forums:

1. Docents and concerned citizens at UC Sedgwick Reserve and Santa Clara River Restoration; the lecture and field trip included discussion of the importance of soil organic matter and microbial EPS for agricultural sustainability and ecosystem drought resilience;

2. Santa Barbara County government and resource conservation leaders at a soil carbon meeting in downtown Santa Barbara to improve soil health in California rangelands;

3. Agricultural industry outreach: Agri-Turf Supplies (Santa Barbara, CA); Frey Farming Vineyard Management (Buellton, CA); Prolific Earth Sciences (Dr. Judith Fitzpatrick, Englewood, NJ); Ecological Landscape Management (James Sittilo, Hauppauge, NY);

4. Farmer outreach: Sea Smoke Vineyard (Victor Gallegos, Lompoc, CA), Manzanita Berry Farm (Dave Peck, Santa Maria, CA), and Roots Organic Farm (Jacob Grant, Santa Ynez, CA);

5. University of California Cooperative Extension in San Luis Obispo and Ventura;

6. University of California Santa Barbara undergraduate research colloquium;

7. International conference presentations at the ASA/CSSA/SSSA Tri-Societies Annual Meeting and the Ecology of Soil Health Summit.

Notable Achievements

1. *Awards*: An environmental scanning electron microscope (ESEM) image of xanthan gum strands in soil won Dr. Blankinship 2nd Place in the University of California Santa Barbara 2015 Art of Science Competition. Mr. Henry Morse (undergraduate assistant) was a finalist at the UC Santa Barbara Research SLAM designed to foster science communication skills.

2. *Achievements*: First, this idea actually worked: amending soil with xanthan gum lead to a 40% increase in crop water-use efficiency and moderated nitrogen losses. Second, this project was very well received at the ASA/CSSA/SSSA Tri-Societies 2016 Annual Meeting. After his presentation, Dr. Blankinship received many questions and research collaboration interests. The approach/results were clearly novel and intriguing to the broader community.

3. *Collaboration*: After the Tri-Societies meeting, Dr. Blankinship was contacted by Judith Fitzpatrick (Prolific Earth Sciences) and James Sittilo (Ecological Landscape Management) to discuss the possibility of testing soil amendment of xanthan gum at the field-scale in parks in the eastern US in erosional areas and in sandy soils that need improved water retention during drought conditions.

4. *Broader Impacts*: This project has contributed to a deeper understanding in the Santa Barbara community of why soil organic matter is so important for drought resilience. Collaborations have been built with the Cachuma Resource Conservation District, the Chamberlin Ranch, as well as Santa Barbara County government agencies (e.g., waste management and air pollution control) and non-profit organizations (e.g., Santa Barbara Foundation). The common goal is to increase soil carbon storage and water-holding capacity by amending agricultural soils with municipal green waste (i.e., compost). This is a more cost-effective strategy than amending soils with xanthan gum, but may very well encourage the same mechanisms of water and nutrient retention.

Student Support table

	Students Funded Through This Project		Supplemental Awards	**Total**
	Federal Funding	State Funding		
Professional Researchers	1	0	0	**1**
Masters Students	1	0	0	**1**
PhD. Students	0	0	0	**0**
Acad. Coordinator	0	0	0	**0**
Other Acad./Researchers	4	0	0	**4**
Professor/summer	0	0	0	**0**
Total	6	0	0	**6**

Publications from prior projects

1. Blankinship, Joseph, Steven Fonte, Johan Six, and Joshua Schimel, 2016, Plant versus microbial controls on soil aggregate stability in a seasonally dry ecosystem, Geoderma, 272, 39-50.

2. Marchus, Kenneth, Joseph Blankinship, and Joshua Schimel, *In review*, Environmental controls on extracellular polysaccharide accumulation in a California grassland soil, Soil Biology and Biochemistry.

3. Blankinship, Joseph, Henry Morse, Kenneth Marchus, and Joshua Schimel, *In prep*, Using extracellular polysaccharides to conserve soil water and nutrients. Applied Soil Ecology.

4. Blankinship, Joseph, 25 March 2016, The brown belowground, Public lecture at University of California's Sedgwick Reserve with over 80 docents and concerned citizens in attendance.

5. Morse, Henry, Joseph Blankinship, and Joshua Schimel, 17 May 2016, Agricultural applications of microbial extracellular polysaccharides, Poster presentation at University of California Santa Barbara's 2016 Undergraduate Research Colloquium.

6. Morse, Henry, 19 April 2016 and 17 May 2016, Agricultural applications of microbial extracellular polysaccharides, Oral presentations at University of California Santa Barbara's Undergraduate Research SLAM competition which is designed to foster effective scientific communication; Henry was one of the finalists.

7. Blankinship, Joseph, Henry Morse, Carlos Rodriguez, Kenneth Marchus, and Joshua Schimel, 6 November 2016, Oral presentation, Using extracellular polymeric substances (EPS) from bacteria to make soils more drought-adapted, Agronomy Society of America/Crop Science Society of America/Soil Science Society of America Joint 2016 Annual Meeting, Phoenix, AZ.

8. Blankinship, Joseph, Kenneth Marchus, and Joshua Schimel, 8 June 2017, Oral presentation, Using extracellular polysaccharides to conserve soil water and nutrients while sustaining plant growth, Ecology of Soil Health Summit, Fort Collins, CO.