Sustainable Vineyard Production Systems

ARS LOCATION:
Crops Pathology and Genetics Research Unit
One Shields Avenue
University of California
Davis, CA 95616

PRINCIPAL INVESTIGATORS:
Dan Kluepfel, Research leader, Research plant pathologist
Phone: 530-752-1137; E-mail: Daniel. Kluepfel@ars.usda.gov

Kendra Baumgartner, Lead scientist, Research plant pathologist
Phone: 530-754-7461; E-mail: Kendra.Baumgartner@ars.usda.gov

Kerri Steenwerth, Research soil scientist
Phone: 530-752-7535; E-mail: Kerri.Steenwerth@ars.usda.gov

Andrew McElrone, Research plant physiologist
E-mail: Andrew.McElrone@ars.usda.gov

Mysore Sudarshana, Research plant pathologist
Phone: 530-752-3621; E-mail: Mysore.Sudarshana@ars.usda.gov

PROJECT OBJECTIVES:
1. Develop sustainable disease control practices (Baumgartner).
2. Develop cover crops as a management tool: a) Characterize cover crops as functional types according to weed suppression, water use, growth characteristics, b) Evaluate the effects of cover crops on grapevine physiology, growth, and fruit yield and quality (Steenwerth and McElrone).
3. Develop sustainable water management practices for vineyards through improved understanding of grapevine water use physiology and stress response (McElrone).
4. Identify and characterize viral & graft-transmissable agents of grapevine (Sudarshana)
5. Characterize the rhizosphere microbial community of grapevine as a function of host genotype and vineyard floor management practices. (Kluepfel)

MAJOR ACCOMPLISHMENTS (2007–2010):
Sustainable disease control for grapevines (Baumgartner):
We demonstrated that the cultural control double pruning, which was previously developed for the trunk disease Eutypa dieback, is also effective on the trunk diseases Botryosphaeria canker and Esca. This practice is used by growers in place of several dormant-season fungicide sprays, and such prevention of trunk diseases is expected to increase the longevity of vineyards. We developed cultural and biological controls for Armillaria root disease that were evaluated on a commercial scale and have since been adopted by growers. Such practices are used in place of soil fumigation with methyl-bromide, which was previously the only effective means of controlling the disease. These field applications are possible in large part due to our basic research accomplishments, such as developing study tools (e.g., genetic transformation systems for the fungal pathogens, infection assays), determining pathogen reproductive mode,

and identifying resistant germplasm. Only with such investigations of pathogen biology, pathogen genetics, host transcriptomic response, and infection biology, are we able to identify the best means of preventing infections and disease spread.

Cover crop functional types and their effects on grapevines (Steenwerth and McElrone):
Cover crops have been touted as a tool that can be used to manage water availability to grapevines, but little understanding how cover crop type affects this process. We looked at water use by four different cover crops: California brome (annual grass), Chewings fescue (bunchgrass), Trios (grain, low growing until late spring), and California red oats (grain, aboveground growth earlier than Trios). Weed suppression characteristics were also documented. Findings from these studies are forthcoming.

Several studies have addressed the effects of cover crops, tillage, and under the vine weed control practices on weed establishment and seedbank composition in vineyards near Oakville (Napa County, CA) and Lodi (San Joaquin County, CA). These vineyards, which supported Merlot, had been established 7 (Oakville) and 12 (Lodi) years prior to initiation of these studies. The general findings are that cover crops and tillage shift weed communities within a short period of time (approximately 3 years), and that in no cases were detrimental effects on grapevine nutrition, yield, or juice characteristics (titratable acidity, pH, and soluble solids) detected.

These specific in-row weed control practices were winter–spring glyphosate, spring cultivation, fall–spring cultivation, fall cultivation–spring glyphosate applications, and were carried out in the wine grape vineyard for 3 years in Oakville. Cultivation alone was not as effective as glyphosate, based on lower weed biomass in the glyphosate-only treatment in 2 of 3 years. Pairing fall cultivation with glyphosate was as effective at reducing weed biomass as two glyphosate applications in 2 of 3 years, suggesting that substituting a glyphosate application with cultivation may be an effective method of reducing herbicide use in vineyards. Field bindweed and sowthistle species are problematic vineyard weeds that grow into the vine canopy and disrupt canopy management practices. These were favored in the cultivated treatments, indicating that it is possible that either the presence of soil disturbance or the absence of herbicides favored these species.

In a separate study in this same vineyard, cover crop treatments planted in the interrow included a combination of tillage and/or annual grasses, and a permanent perennial bunchgrass sward; the 'under the vine' region was treated with two applications of glyphosate. Here, it was found that the 'under the vine' area in each cover crop treatment was not influenced by the composition of the weeds or cover crops in the interrow, suggesting that these practices are unlikely to interfere with chemical weed control beneath the vine. Findings from the current study in a commercial vineyard located in Lodi are forthcoming; this work demonstrated that vineyard floor management can maintain fruit yields and quality and alter weed communities/soil organic carbon content with no discernable negative impacts from competition for limited resources (e.g. water).

Sustainable vineyard water use through understanding of grapevine physiology (McElrone):
Grapevine water-use measured with a novel sap flow sensor technique compares favorably with crop coefficients. With impending limits on irrigation water in California and other arid grape growing regions of the United States, growers need to more accurately measure water use by grapevines in order to irrigate more efficiently. ARS scientists in Davis, CA, used their newly-developed heat pulse technique to track water use in several grape varieties across growing regions. Sap flow sensors accurately tracked seasonal water use at all sites and changes in water use imposed by irrigation and atmospheric conditions. Results compared favorably with crop coefficients measured concurrently at these sites. Accurate on site measurements of sap flow will help growers conserve irrigation water by applying exact, site-specific amounts as needed.

Grapevines are far less vulnerable to water-stress induced cavitations than previously reported. Vulnerability to drought-induced cavitation was evaluated in grapevines using embolism/cavitation detection techniques, including Nuclear Magnetic Resonance imaging of live grapevines to track embolism formation in situ. ARS scientists in Davis, CA revealed grapevines are not susceptible to significant drought-induced embolism within normal operating water potentials. We used High Resolution Computed Tomography (HRCT; a type of CAT scan) to model the xylem network of grapevines. Using unprecedented resolution of the HRCT, we found unequivocal evidence to describe the mechanism of embolism repair in grapevines; researchers worldwide had suspected this mechanism for decades but until now were unable to visualize this process in living plants.

Identify and characterize viral and graft-transmissable agents of grapevine:
(Sudarshana)
We have recognized two new graft union disorders, grapevine necrotic union and stem necrosis-distortion, affecting grapevines and result in early fall red leaf symptoms on red wine grape varieties in California. Affected vines eventually die because of the death of the union. Grapevine necrotic union was noticed in Pinot Noir clones 02A, 667, 777, and UCD04, 110 Richter rootstock and necrosis stem distortion was seen in Pinot noir clone 23 on 3309 Couderc. Our surveys have indicated that grapevine necrotic union disease increased from 2 percent to more than 22 percent in 5 years. The agent responsible for grapevine necrotic union was found graft-transmissible in bench graft assays. Deep sequencing analysis has given some leads towards establishing the causal agent. Right now, removal of dead scions and rebudding on the rootstock has been found to be a viable strategy to manage the disease.

The effect of grapevine phenology and rootstock genotype on the rhizosphere microbial community structure and function (Kluepfel).
The rhizosphere microbial community significantly impacts plant health, growth, and crop yields. Thus, understanding factors affecting the rhizosphere microbial community are vital to improving soil health and enhancing plant health and production. Since plant-microbe interactions in the rhizosphere of woody perennial crops, like grapevine, occur over decades, the consequence of these interactions is enormous. To answer several fundamental questions, we examined the effect of

grapevine rootstock genotype and crop phenology on the rhizosphere microbial community in California vineyards. The carbon utilization profiles produced in EcoPlates were used to analyze the functional aspects of the microbial communities. Phospholipid fatty acid composition was used to document the culture independent composition of the rhizosphere microbial community during four phenological stages.

TECHNOLOGY TRANSFER/OUTREACH (2007–PRESENT):

- Baumgartner: 25 presentations were given to academic colleagues at USDA-ARS stations e.g. Salinas, CA, universities e.g. Bristol University, England, and annual meetings for scientific societies, e.g., American Phytopathological Society, and 15 presentations were given to stakeholders, e.g., San Joaquin Valley Grape Growers, California Association of Pest Control Advisors.
- Steenwerth: Presentations have been made at California Society of Weed Science, Recent Advances in Viticulture and Enology at University of California-Davis, and the Group of International Experts of vitivinicultural Systems for CoOperation (GiESCO).
- McElrone: Numerous presentations have been made to academic colleagues and stakeholders including: Recent Advances in Viticulture and Enology at the University of California, Davis, CA; Sonoma County Viticultural Tech Group; Napa County Viticultural Tech Group; NGWI Executive Board Annual Meeting; National Viticulture Research Conference; International Society of Horticultural Sciences Sap Flow Workshop; American Geophysical Union Joint Assembly Meeting; Santa Rosa Junior College; International Terroir Meeting; Kearney Grape Day- University of California, Davis, CA; and American Society of Plant Biologists Annual Meeting.
- Sudarshana: Four presentations, the National Viticulture Conference, the annual meeting of the American Phytopathological Society, and two presentations to viticulture stake holders meeting.

EXTERNAL SUPPORT (2007–PRESENT):

- National Clonal Germplasm Repository, Davis, CA, “Resistant grape varieties for Eutypa dieback” (Baumgartner as co-PI).
- California Competitive Grants for Research in Viticulture and Enology and the American Vineyard Foundation, “Identifying the routes of infection of Eutypa dieback among vineyards, orchards, and riparian areas in California” (Baumgartner as co-PI).
- USDA-CSREES, Crops at Risk, “Preventative pruning and resistant varieties for long-term control of grapevine trunk disease” (Baumgartner as PI).
- NIFA, Specialty Crops Research Initiative “Developing sustainable water management strategies for vineyards” USDA (McElrone as Project Manager)
- National Science Foundation, “The role of systems level properties in the transport function of the grapevine xylem network” (McElrone as Co-PI)
- American Viticulture Foundation (AVF), Viticulture Consortium West (VCW), “Aquaporin-regulated response of grapevine roots to salinity” (McElrone as PI).
- AVF/VCW “Measuring vine transpiration using sap flow sensors: Validation/calibration of a new sap flow technique on grapevines growing in a weighing lysimeter” (McElrone as Co-PI)
- NGWI, “A meta-analysis of the effects of deficit irrigation on wine grape yield and fruit quality parameters” (McElrone as PI)

- NGWI, "Development of a user-friendly and self-calibrated surface renewal system to measure vineyard-scale and vine" (McElrone as PI)
- VCW, "Production of sensitive and specific antiserum for the diagnosis of grape viruses using ELISA and an immunocapture RT-PCR" (Sudarshana as PI)
- VCW, "Characterization of new Grapevine leafroll-associated viruses in California vineyards" (Sudarshana as PI)

COLLABORATORS (2007–PRESENT):

Baumgartner:

M. Andrew Walker, and W. Douglas Gubler, University of California, Davis, CA; Wayne Wilcox, Cornell University, Geneva, NY; Lance Cadle-Davidson, ARS Geneva, NY; Philippe Rolshausen, University of California, Riverside, CA; Andy Bailey and Gary Foster, University of Bristol, England; Grant Cramer, University of Nevada, Reno, Nevada; Mark Sosnowski, South Australian Research and Development Institute, Adelaide, Australia; Pascal Lecomte, INRA, Santé Végétale, Villenave d'Ornon, France; Francois Halleen, ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa; Jean-Pierre Peros, INRA, Montpellier, France; and Sarah Bergemann, Middle Tennessee State University, Murfreesboro, TN.

Steenwerth:

Thomas Shapland, University of California, Davis, CA; Chris Storm, Vino Farms, Lodi, CA; Jean-Marie Mauretze, Dominus Estates, Napa, CA; Dr. Jean-Jacques Lambert, Department of Viticulture and Enology, University of California, Davis, CA; Robert Mondavi Vineyards (Napa, CA); and John Roncoroni, University of California, Cooperative Extension, Napa, CA.

McElrone:

Jim Ayars, ARS Parlier, CA; Mark Battany, University of California, Cooperative Extension Service; Tim Bleby, University of Western Australia; Craig Brodersen Greg Gambetta, Mark Matthews, KT Paw U, Ron Phillips, Ken Shackel, Tom Shapland, Rick Snyder, Andy Walker, Larry Williams, and Eric Lee, University of California, Davis, CA; Brendan Choat, Australia National University; Noah Heller, BESST, Inc; Jerry Lohr, JLohr Vineyards and Wines; and Angelos Patakas, University of Ionnina, Greece.

RECENT PUBLICATIONS (2007–PRESENT):

- Baumgartner K, Fujiyoshi P, Foster GD, Bailey AM. In press. Agrobacterium-mediated transformation for investigation of somatic recombination in the fungal pathogen Armillaria. Applied and Environmental Microbiology.
- Baumgartner K, Fujiyoshi P, Smith RF, Bettiga L. 2010. Weed flora and dormant-season cover crops have no effects on arbuscular mycorrhizae of grapevine. Weed Research 50:456-466.
- Baumgartner K, Travadon R, Bruhn J, Bergemann S. 2010. Contrasting patterns of genetic diversity and population structure of Armillaria mellea sensu stricto in the eastern and western United States. Phytopathology 100:708-718.
- Baumgartner K, Bhat R, Fujiyoshi P. 2010. A rapid infection assay for Armillaria and real-time PCR quantitation of the fungal biomass in planta. Mycological Research 114:107-119.

- Blaedow KE, Baumgartner K, Cox KD, Schnabel G. 2010. Natural infection of an herbaceous host by Armillaria: a case study on Hemerocallis. Canadian Journal of Plant Pathology 32:351-360.
- Brodersen C, McElrone AJ, Matthews MA, Choat B, Shackel K. 2010. Dynamics of embolism repair in grapevine: in vivo visualizations using HRCT. Plant Physiology (in press).
- Choat B, Drayton W, Brodersen C, Matthews MA, Shackel KA, McElrone AJ. 2010. Vulnerability to cavitation in grapevines has been overestimated by the centrifuge technique. Plant Cell and Environment.
- Gambetta GA, Matthews MA, Shaghasi TH, McElrone AJ, Castellarin SD. 2010. Sugar and abscisic acid signaling orthologs are activated at the onset of ripening in grapes. Planta 232: 219–234.
- Steenwerth KL, Baumgartner K, Belina KM. 2010. Vineyard weed seedbank composition responds to glyphosate and cultivation after three years. Weed Science. 58:310-316.
- Gadoury DM, Andrews J, Baumgartner K, Bjerkness M, Burr TJ, Kennelly MM, Lichens-Park A, MacDonald J, Savary S, Scherm H, Tally A, Wang G-L. 2009. Disciplinary, institutional, funding, and demographic trends in plant pathology: what does the future hold for the profession? Plant Disease 93:1228-1237.
- Baumgartner K, Grubisha L, Fujiyoshi P, Garbelotto M, Bergemann SE. 2009. Microsatellite markers for the diploid Basidiomycete fungus, Armillaria mellea. Molecular Ecology Resources 9:943-946.
- Baumgartner K, Bergemann SE, Fujiyoshi P, Rolshausen PE, Gubler WD. 2009. Microsatellite markers for the grapevine pathogen, Eutypa lata. Molecular Ecology Resources 9:222-224.
- Cheng X, Euliss AC, Baumgartner K. 2008. Nitrogen capture by grapevine roots and arbuscular mycorrhizal fungi from legume cover-crop residues under low rates of mineral fertilization. Biology and Fertility of Soils 44:965-973.
- Baumgartner K, Steenwerth KL, Veilleux L. 2008. Cover crop systems affect weed communities in a California vineyard. Weed Science 56:596-605.
- Baumgartner K, Steenwerth KL, Veilleux L. 2007. Effects of organic and conventional practices on weed control in a perennial cropping system. Weed Science 55:352-358.