Topics in Subtropics Newsletter

University of California Cooperative Extension

Fresno, Kern, Madera, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara,Tulare,&Ventura Counties

News from the Subtropical Tree Crop Farm Advisors in California

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An Automated Delivery System for Therapeutic Materials to Treat HLB Infected Citrus

Ozgur Batuman[1] and Louise Ferguson[2]

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Why is this research needed?

In 2005, a disease called Huanglongbing (HLB, citrus greening, was identified in Florida's commercial citrus groves. The disease is caused by a bacterium that affects all citrus cultivars by disrupting the flow of nutrients from the source of production, to the site of use, causing tree decline. HLB weakens the root system, increases early fruit and leaf drop, lowers tree productivity and fruit quality and ultimately kills the tree. The disease has spread to all the major production regions in Florida. Economic losses have exceeded more than $4 billion dollars. Currently, more than 95% of Florida's trees are infected. There is currently no cure for the disease.

Efforts to control HLB have been unsuccessful as the bacterium cannot be cultured, literally grown, in a petri dish, and once in the plant it proliferates within the citrus phloem. Phloem is the system that transports sugars from their site of production, the leaves, to plant parts that use sugars, the roots or flowers. Phloem transport is generally downward but can be upward as well.

Once the HLB bacterium is in a tree's phloem, it has the potential to infect the entire tree. It is exceedingly difficult to introduce any control agent into the phloem with the conventional control methods of foliar spraying or soil drenching.

Thus far, no treatment preventing HLB infection, or controlling the bacterium once within the tree, has been developed. Potential chemicals are being investigated, but in order to test them, direct or indirect phloem delivery, where the bacterium proliferates, is needed. Therefore, an effective method of delivering an effective volume of therapeutics into the phloem is needed to evaluate potential treatments.

What is the focus of this project?

Our project focuses on developing a method of delivering therapeutic liquid materials, bactericides, microbial metabolites, RNAi, or biologicals, into the citrus vascular tissues, both the xylem which conducts water and nutrients upward from the roots and the phloem, which conducts sugars and other metabolic products downward from the leaves. We are investigating diffusion, trunk punctures with a surrounding liquid reservoir for passive uptake and infusion, low-pressure active injections. We are focusing on these methods as foliar sprays and root drenches have not been successful phloem delivery methods.

Who will be doing the research?

The project is led by plant pathologist Dr. Ozgur Batuman with colleagues at the Southwest Florida Research and Education Center (SWFREC) at University of Florida in Immokalee. This four-year project will also study the citrus vascular system with a multidisciplinary research team including UF Plant Pathologists Drs. Nabil Killiny and Amit Levy at Lake Alfred, SWFREC UF Plant Physiologist Ute Albrecht, Citrus Horticulturist Fernando Alferez, Precision Ag. Engineer Yiannis Ampatzidis, Agricultural and Natural Resources Economist Tara Wade, University of California-Davis Extension Specialist Louise Ferguson and Texas A&M-Kingsville Citrus Center Plant Pathologist Veronica Ancona as well as number of graduate students, postdocs, and Florida, Texas and California citrus industry members.

How will this research be done?

Our earlier research involving comparisons of delivery methods including foliar sprays, soil drenching and trunk injection determined **Needle-Assisted Trunk Infusion (NATI)** was the best potential delivery method (Figure.1). In initial experiments, using NATI, 1 ml of rhodamine (1%) dye was injected into the trunks of one-year-old citrus seedlings. A visible red color, indicative of rhodamine uptake and movement, was detected in the upper-most leaves within 30-60 min and an increase in color intensity was observed within 24 hours. Similar results were observed in two-year-old grafted Valencia plants within 48 hours. If the NATI delivery method can be automated, large numbers of trees could be treated quickly. Once the delivery method has been developed, implementation will be tested with potential treatments developed within other research projects.

Our proposed automated delivery would consist of a robotic arm with several modules at the end of the arm, installed on an ATV or tractor. One module with needles would grip and puncture the trunk, a second module would wrap a reservoir around the trunk below the punctures and third module would fill the reservoir. (Figure 2). Hopefully, a robotic arm plus automated system will be inexpensive enough for growers to purchase and simple enough to use.

Another approach is disease prevention; application pf prophylactic chemicals that prevent infection. In this scenario, our system would be used treat healthy young trees with bactericides or boost their immune system. When infected by the ACP the bacterium would either be killed or suppressed, perhaps below the level that harms tree growth and productivity. This option is analogous to the vaccinations that prevent diseases in humans and animals.

What are the greatest challenges and opportunities?

The greatest challenge is successful phloem delivery. The greatest opportunity is that, if successful, we will have developed a method that will allow much more precise deliver of therapeutics to citrus trees. For example, if an effective phloem delivery method is developed, it could be used to control insects that feed on citrus plant parts. Or, it could be used to deliver growth regulators, perhaps nutrients and carbohydrates, to roots and fruits to increase growth, development and fruit quality; much like an intravenous injection functions in an animal.

Among the questions we hope to investigate are:

- When, what kind of, and what amount of therapeutics can be applied by NATI?
- At what frequency?
- What type of citrus tree: cultivar, age, infected, healthy is the best for treatment by NATI?
- Can we kill the bacterium? How and when to assess a change in bacteria titer after treatment?
- When will become available and be economically feasible for growers?

Figure 1. Distribution of rhodamine (red dye; 1%) applied by NATI in various tissues (left) of grafted and non-grafted young citrus plants grown in the greenhouse (right). Photos taken 2 weeks after the treatments. Treatments and tissues observed are indicated. Yo = year-old.

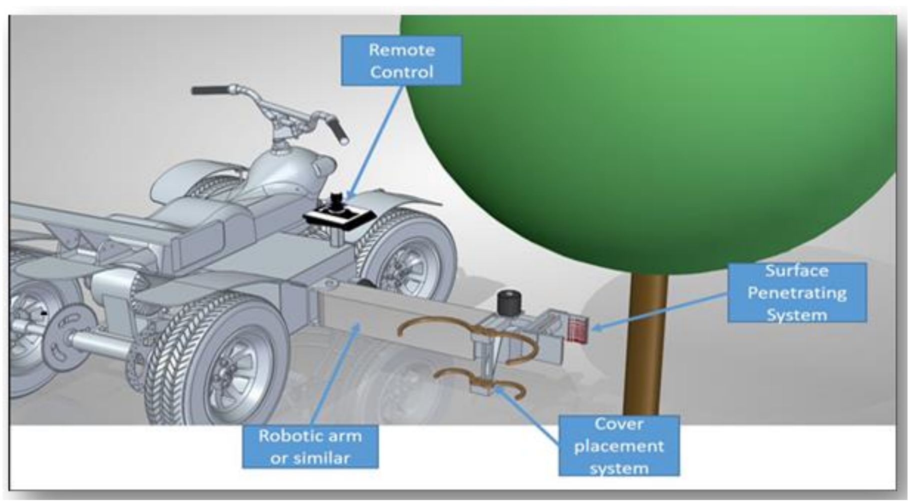
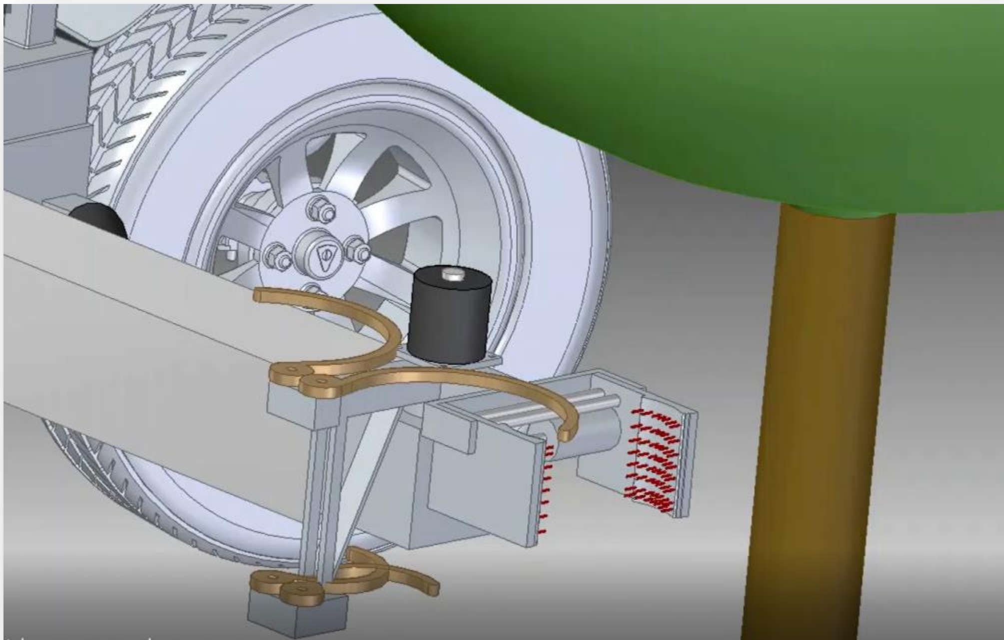


Figure 2. Projected automated delivery system (ADS); an ATV with extendable arm with NATI and the cover placement systems on the arm guided onto the tree trunk (upper panel), and closeup of NATI and cover placement system (panel below).



Acknowledgement
The United States Department of Agriculture National Institute of Food and Agriculture (USDA-NIFA) Grant # **2019-70016-29096.**

For more information, please visit this project's dedicated website:
https://swfrec.ifas.ufl.edu/programs/citrus-path/automated-delivery/

On-Farm Research
Ben Faber

Evaluating claims of new products that could potentially improve yield and tree health is a daunting task. Every week I get calls and literature from people promoting fertilizers and techniques that "resist insects," "reduce salt levels in the soil," "increase crop quality," "release that natural fertility of your soil," and numerous other claims. There just is not enough time in the day to approach each and every one of these materials or techniques, even though some may, in fact, be promising.

So what does a grower do? You hear about a new product. It only costs $20 an acre to apply. Might as well fly it on all 50 acres. But then, how do you know it has done anything? What results do you have to compare it with? Last year's yield which was miserable? We know how variable avocado yields are, so last year's harvest may not be a good comparison.

When we conduct field trials, we assume a clear comparison is available to test the effects of the treatment. With field trials, there are usually small plots, repeated several times (at least three), and arranged in an apparent haphazard (random) fashion. The reason is threefold: 1) to account for variability in the field, 2) to prevent a systematic bias in favor of one treatment over another and 3) to see if differences in treatments are due to chance or to the superiority of the treatment.

How are observational trials different from replicated one? The big difference is that they are not replicated. Each treatment occurs only once, so we have no measure of the natural variability in the field or trees. As a result, we risk thinking we have a difference due to treatment which is actually due to field variability. Without replication, there is no way to tell.

Let's examine this replication idea a little more closely. We had a frost trial where we applied copper or a water control spray to young trees in November. Copper is a noted bactericide and the idea was to control the frost-nucleating bacteria. Forty trees, randomly spaced in the orchard were sprayed with either a dilute copper spray according to instructions or water alone. We evaluated frost damage to the trees in January. The first counts showed 40% frost damage with the copper spray and 60% with the water alone. Great. Let's go out and spray the whole orchard next year with copper. However, successive counts showed 50% frost damage with the copper and only 30% from the water. In the end, there was no significant difference to trees that had been sprayed with either material.

These results show the natural variability in biological systems and demonstrate the disadvantages in looking at results from a non-replicated trial based on a single year. This becomes even more important when interpreting information from a trial site different from your own. If every grower sprayed a non-replicated treatment at their own ranch, the risk of coming to the wrong conclusion about that treatment at each location is still 50%. Just like flipping a coin. Is that worth spending money on?

As each of the variables (soil type, irrigation quality, management, etc.) increases, the risk of making a poor decision about a product or practice increases, as well. You can see that there are difficulties associated with relating information from a non-replicated trial based on a single year of data at a different location to your own situation.

How does someone go about evaluating a new practice or material at home without going through all the complications of a complicated research trial? Mary Bianchi, retired Farm Advisor in San Luis Obispo and I came up with a little checklist.

1. Be conservative in your approach and critical observations. Resist the urge to spray the whole grove. Leave something, so that a comparison can be made. Preferably run a side-by-side comparison.
2. Use consistent farming practices across all areas of the trial.
3. Compare the new practice to one which is a standard for your operation.
4. Don't bias your results by implementing the new practice where it stands to have the best effect anyway. For example, don't spray boron on the trees that always give a good yield.
5. Run the test more than one year and in more than one location, especially if the new practice is costly.
6. Talk to the industry and use the experience of others in different locations as a check on your own experience. A good place to swap ideas is at the California Avocado Society/CA Avocado Commission/University of California Cooperative Extension sponsored bimonthly meetings.

Research does not need to be complicated, but it needs to be thought out before hand with consistent data collection and given time. And time is critical, especially for nutrient studies and with a tree like avocado, that has a prolonged bloom with alternate bearing and usually more than one crop at a time. The effects of application timing at a given rate might not be determined for several years of crop yield.

Persistence is the key to experimentation. Unless it's a pesticide trial, do you see results in the first year?

Bam - Dry Root Rot Season

Ben Faber

The calls have come in. We've gone from cool to hot and Dry Root Rot of Lemon has struck, It's shocking how fast the trees go down.

Dry Root Rot has menaced growers in Ventura County for many years. In the '50's and '60's it seemed most prevalent on older orange trees. A few years after the wet winter of 1968-69, dry root rot became an increasing problem among citrus trees of all ages. At that time, most of the damaged trees were on sweet rootstock (susceptible to *Phytophthora*), and growing in fine-textured soils or soils with poor drainage. A few years after another wet winter/spring (of 1983), dry root rot again reared its ugly head, but this time predominately on young lemons.

The disease is caused by the fungus, *Fusarium solani*. This fungus is most likely present in all citrus soils in California. It is a weak pathogen in that by itself it will not attack a healthy tree. However, experiments conducted in the early 1980's by Dr. Gary Bender, showed that when seedlings were girdled, root invasion occurred. In the field, the fungus can infect trees once gophers have girdled the roots or crown. A *Phytophthora* infection will also predispose trees to *Fusarium*, as will asphyxiation. Therefore, the mere presence of the fungus in the orchard soil will not lead to the disease.

Description

Fusarium is a soil borne fungus that invades the root system. Once infected, the entire root will turn reddish-purple to grayish-black. This is in contrast to a *Phytophthora* infection which, in many cases, will attack only the feeder roots, but when larger roots are infected, only the inner bark is decayed and it does not discolor the wood. In addition, when observing the cross section of a dry root rot infected trunk, a grayish brown discoloration in the wood tissue can be observed.

Dry root rot is a root disease, but symptoms of the root decline are seen above ground. They are similar to any of the root and crown disorders such as *Phytophthora* root rot, oak root rot fungus (*Armillaria*) and gophers. The trees lack vigor, leaves begin to turn yellow and eventually drop (especially in hot weather) causing twig dieback. Finally, the foliage will become so sparse that one will be able to see through the canopy of the tree. A period of two to three years may pass from the time of invasion until noticeable wilt. Many times, the tree will collapse in the summer, after a period of prolonged heat. In the case of dry root rot, the collapse is so rapid that the tree dies with all the leaves still on the tree. When looking for symptoms of dry root rot, keep an eye out for symptoms of other maladies as well — *Phytophthora*, oak root rot fungus and gophers being the most prevalent.

Control

We presently have no direct control for dry root rot. To control the disease, we must control the predisposing factors such as gophers, *Phytophthora*, poor drainage and over-watering. If the predisposing factor(s) cannot be identified for a given diseased orchard, it will indeed be difficult to control the disease. Two things are certain though: 1.) There are no chemicals to date which will control this disease; and 2.) Presently, there are no rootstocks resistant to the disease.

So what to do?

Good orchard management, especially careful irrigation, is essential for preventing dry root rot. If the soil around the tree crowns and roots is saturated for long periods of time, the chances for injury and subsequent fungal infection increase.

- Irrigate carefully:
  - Ensure that the application matches tree water requirements.
  - Keep the trunk dry (adjust sprinklers so water does not hit the trunk).
- Check drainage: water should not be allowed to stand in contact with the tree crown for an extended period of time.
- Clean equipment thoroughly before moving it between orchards. Movement of equipment facilitates the spread of the pathogen.
- Avoid mechanical injury to the underground portions of the crown during cultural operations, especially during the cool and wet season.
- Follow label instructions for applying fertilizers, herbicides, and nematicides at recommended rates to avoid causing phytotoxicity and burning root tissues when excessive amounts of these materials are used. Before fertilizing young trees, wait at least 6 weeks after planting or until the trees show new growth.

Check regularly for signs of Phytophthora root rot or vertebrate damage that may provide entry sites for dry root rot. If you suspect a dry root rot infection

- Dig all the way around the tree, because the decay may be underneath the crown roots or on one or more of the main lateral roots. You may be able to slow the spread of the disease by exposing the crown region and allowing it to dry.
- Prune the tree skirts.
- Remove the soil from the crown region.
- Correct any adverse soil conditions, such as poor drainage.
- Remove trees that have become unproductive because of severe infection.

A summary of what is known about Citrus Dry Root Rot can be found in Citrograph 2011, 2(7): 29-33 – "Current Knowledge on Fusarium dry root rot of citrus" by Adesemoye and Eskalen
http://citrusresearch.org/wp-content/uploads/Nov-Dec_Citrograph.pdf#page=29
Listen to Akif Eskalen tell the Dry Root Rot story
https://www.youtube.com/watch?v=K2fyBcC1HXk&feature=youtu.be



(A) (B) (C)
Symptoms of dry root rot seen (A) around the bud union, (B) in a cross section of a tree branch and (C) roots


(A) (B)
Dry root rot infection in (A) Lemon in Ventura County and (B) Beck Navel in Tulare County.

Dr. Beth Grafton-Cardwell to Retire –
Her View on 30 Years of Citrus IPM and Lindcove Leadership

Through the years I have had many collaborators and numerous technical staff studying a wide variety of pests including California red scale, citricola scale, cottony cushion scale citrus cutworm, katydids, earwigs, Fuller rose beetle, citrus peelminer, citrus leafminer, citrus thrips, citrus red mite, snails, ants, aphids and Asian citrus psyllid as well as their natural enemies. In the early years, the main controls for these pests were organophosphate (OP) and carbamate insecticides. The initial research goal was to get these replaced with more selective insecticides that would allow natural enemies to participate in pest management. We successfully documented OP resistance in California red scale and citrus thrips and developed replacement insecticides that created a more balanced situation resulting in a reduction in pesticide use (as few as 4 treatments/year in the San Joaquin Valley). But alas, citrus IPM programs must change because new situations arise. For the citrus industry, the three drivers of change in the second half of my career have been drought exacerbating some pests, export countries demanding in-field treatments for insects as a replacement for Methyl Bromide (MeBr) fumigation, and the arrival of various invasive pests. These situations have provided me ample opportunities to work with regulators and the citrus industry and challenged my creative problem-solving abilities – never a dull moment.

It is hard to say if the past 8-9 years of higher temperatures and on and off drought conditions are a permanent 'climate' change or are part of a cycle. However, they have certainly made California red scale more difficult to control. Growers have shifted from treating for California red scale once every other year to treating 3-4 times per year. Extra heat units have added an extra generation of scale per year and occasionally allowed scale development in winter. My research response has been to study and provide outreach on the use of California red scale pheromone disruption as an assist to reduce insecticide treatments. I am encouraged to hear reports of some acreage going back treatments every few years for California red scale.

Export issues with S. Korea (Fuller rose beetle and California red scale) and with Australia and New Zealand (bean thrips and mites) began to crop up in the 2010s. In the past, shipments from California would be inspected at destination and, if there were any insects or mites of phytosanitary concern, the fruit would be fumigated with MeBr. With the worldwide reduction in MeBr use, there is now the expectation that California growers apply in-field treatments to eliminate these pests so fumigation at destination is not necessary. Complete disinfestation of an orchard is impossible to achieve so we launched studies on alternative fumigants and cold treatments that could be applied in California or during transport.

Invasive pests such as glassy-winged sharpshooter, Diaprepes root weevil, citrus leafminer, and Asian citrus psyllid have been arriving regularly into California since about 2000. In each case, I evaluated chemical and biological controls, evaluated the level of damage they could inflict and conducted outreach to prepare the citrus industry. Of course, Asian citrus psyllid has been the most significant invasive pests because of its ability to transmit the bacterium that causes the deadly disease huanglongbing. My role has been to develop control strategies for growers around the state and assist them with their psyllid management programs.

If I had to list the top three favorite projects of my career, they would be the following:

1. Working with colleagues to survey 13 crops around the state to see what species of predatory mites are found and developing a 'Key to the Phytoseiid Predatory Mites of California Crops' (submitted for publication with UC ANR).
2. Working with cottony cushion scale and predatory vedalia beetle and figuring out how to protect the vedalia from insect growth regulators by careful timing of the application of those pesticides. This is a great example of making an incompatible insecticide compatible with a sensitive natural enemy.

3. Directing five technicians to scout 224 commercial citrus orchards around the state and see how grower applied pesticide treatments affect the psyllid populations. The results of this project led to strong recommendations for eradication and areawide psyllid treatment programs.

For the past 14 years, all of this was accomplished while also acting as Director of the Lindcove Research and Extension Center. That position also had challenges with hiring and directing personnel, building facilities such as a laboratory, a greenhouse and a screenhouse structure, and attracting research and extension programs to the Center. It has been very rewarding to see the Center expand its capacity and reputation.
Finally, I couldn't have done any of this without the amazing technical staff and collaborators that have supported my projects for many years. I will miss the challenges of this job, but I expect to dip back in when needed at Lindcove and I look forward to new life challenges as I spend more time with my family and my community.

What are the UC Ag Experts Talking About?

Join a series of 1-hour webinars, designed for growers and Pest Control Advisers, which highlight various pest management and horticultural topics for citrus and avocados. During each session, a UC Expert on the subject makes a presentation and entertains write-in questions via chat during and/or after the presentation. As we develop this program, we may expand to other crops.

Topics: pests and diseases of citrus, avocado and other crops

Register for the series at: https://ucanr.edu/sites/ucexpertstalk/

Here's a list of upcoming presentations:

October	Phoebe Gordon	Reading soil analysis reports
September 9	Mark Hoddle	invasive species and persea mite/avocado mites
August 19	Ashraf El-kereamy	PGRs in citrus
July 8	Mark Hoddle	Ants of citrus

Here is a list of archived topics, viewable at any time. Enjoy.

Past Topics (http://bit.ly/UCAgExpertsPlaylist)

Avocado

- Avocado thrips
- Avocado cankers
- Laurel wilt disease
- Avocado root rot
- Gibberellic acid use
- Invasive Shot Hole Borers

Citrus

- Pesticide resistance
- Asian citrus psyllid
- California red scale
- Citrus spray application
- Citrus dry root rot
- Weed management
- Plant-parasitic nematodes
- Fuller rose beetle
- Citrus thrips
- Citricola scale

Other

- Pesticide Label reading for safe applications
- Slugs and snails
- Management of glyphosate-resistant weeds
- Respirators

Memorial to Dr. Travis Bean

Photo: AgAlert

Travis Bean
1977 - 2020

Travis Bean, University of California, Riverside Assistant Cooperative Extension Specialist in Weed Science in the Department of Botany and Plant Sciences, passed away on May 27, 2020. Travis joined the UCR Department of Botany and Plant Sciences in 2014 as a weed scientist with expertise in weed management in wildland, rangeland, and agricultural settings.

Travis was born in Nebraska but raised in Arizona and had spent most of his adult life there. Travis earned a B.S. in Plant Sciences from the University of Arizona in 2000. He then earned a M.S. degree in Range Management from the University of Arizona in 2002. His M.S. research addressed the problem of revegetation in desert climates. Following his Masters, he held a number of positions in the School of Natural Resources and the Environment at the University of Arizona, including Graduate Research and Teaching Assistant, Research Specialist, Senior Research Specialist, and Principal Research Specialist, 2002-2014. During that time, he was also working to complete a Ph.D. in Ecology and Management of Rangelands at the University of Arizona. His dissertation research addressed management of the invasive weed buffelgrass and he served as coordinator of buffelgrass eradication and outreach at the University of Arizona Desert Lab. His work on buffelgrass was recognized by a Public Service Award from the University of Arizona School of Natural Resources and Environment and a United States Department of Interior Partners in Conservation Award.

Within a short time of his arrival at UCR in 2014, Travis established himself as a key member of the University of California "weeders" group. He immediately made an impact to address critical issues in California wildlands and provided much needed help to citrus and avocado growers. Travis' research program was aimed at determining the safest and most effective means of managing weeds and his extension program communicated his expertise in weed science to an extensive clientele, providing them with practical advice for addressing weed management problems.

Travis was an active member of the California Weed Science Society, serving on the Board of Directors for two years, as secretary and vice-president. He was quite visible in the California Invasive Plant Council, a statewide organization focused on weedy plants in the millions of acres of non-crop land in the state. He was a statewide resource for invasive-plant management and restoration and wildfire prevention and recovery. Travis served a prominent role in guiding policy in weed control statewide. Within UC, Travis held leadership positions in several important UC Agriculture and Natural Resources Workgroups that serve clientele by hosting workshops and field days.

When not working, which was very unusual because Travis enjoyed his work so much, you could find him out in nature, brewing his own beer, or eating the most exotic entrée at a restaurant! Travis was a great contributor to weed research and extension in California and the western United States and his loss will be felt greatly by his friends and colleagues at UCR and throughout the weed science community.

Ben Faber, Soils/Water/Subtropical Crops Advisor
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Topics in Subtropics