Cover Page

In the role of commodity advisor, it is essential to maintain expertise in several disciplines to address variable needs. I accomplished that by conducting research and comprehensive collaboration with UC specialists, advisors and colleagues in other public institutions and industry. Successful projects led to adoption by clientele and recognition by peers in Horticulture, Weed Science, Plant Pathology and Entomology and document evidence of the robust and balanced program required at Full Title VI.

My Research and Creative activity focused on most critical issues (pest and water management) and was supported by >$1 M in competitive grant funding, resulting in adoption and use of:

1. Drip-only irrigation and partial sprinkler for establishment of strawberry and vegetable crops in all coastal California production regions. This saves at least 10,000 gal/acre of water and minimizes or eliminates runoff and nutrient and pesticide losses to the environment.
2. Integrated strategies to manage two new deadly strawberry diseases (Fusarium wilt and Macrophomina charcoal rot) developed in my collaborative research work (used industry-wide).
3. Blackberry cultivar performance and management programs that allowed new growers to successfully grow and sell fruit.
4. Anaerobic soil disinfestation in strawberry and raspberry fields in all coastal regions, which tripled the treated acreage from 2012 to 2018 (26 organic and six conventional fields).
5. Conventional and organic control methods of yellow nutsedge in vegetables and strawberry that made production possible in infested fields. Control programs for weeds with hard seed coats that specialist Fennimore and I developed are used by about 60% of strawberry growers.
6. Biocontrol methods for *Eutetranychus lewisii* mite in strawberry that my SRA and I identified are essential to IPM for most organic berry growers.
7. Effective runoff management treatments in plasticulture tunnels established in a collaborative project that I led help growers comply with regulatory requirements and prevent pollution of waterways.

In area of professional competence and activity I was:

1. Invited on state, national and international levels to provide trainings speak/contribute content; evaluate professional work of others, including reviews and recommendations on 36 CDFA proposals ($62 M. total), 14 journal manuscripts; and by giving 64 professional presentations during this review period.
2. Invited to be on the scientific panel for the International Strawberry Symposium.
3. Published as lead or co-author in professional journals in several subject areas (11 peer-reviewed during review period and 79 during career)
4. Provided leadership in hosting North American conferences that connected world experts with clientele (North American Strawberry Growers Association, N. Am. Raspberry and Blackberry Growers Association. and N. Am. Strawberry Symposium).

University service included contributions to academic evaluation process (Personnel Committee) recruitment and evaluation of specialists and advisors (hiring committees), directions to RECs development (REC users committee and UC ANR Hansen Advisory Board) and vegetable industry liaison functions. **Public service** leadership focused on ag. education and training/oversight of Master Gardeners and volunteers in research projects, via symposia and classes, youth education at ag career events that highlighted role of UC ANR is sustaining agriculture.

Affirmative Action in my programs has a strong continued commitment to extension of information in Spanish. This was accomplished with translation at all outreach events, individual contacts with limited resource Hispanic growers, development and maintenance of bilingual strawberry disorder web site and runoff management guidelines. Additionally, I worked with small growers, including rare fruit growers of Southern California who became successful blackberry growers as a result.

PROGRAM SUMMARY NARRATIVE, Oct 2016-Oct 2019.

I. EXTENDING KNOWLEDGE AND INFORMATION/APPLIED RESEARCH AND CREATIVE ACTIVITY

The primary issues in production of row crops in Ventura County are related to urbanization and associated regulatory restrictions: 1) Management of persistent and new pests in effective, economical and environmentally acceptable manner; 2) Management of water and nutrients to optimize use by crops and minimize losses to the environment and 3) Maximize crop value and efficiency of production as resources continue to become increasingly expensive. **These issues are central to ANR's vision of sustainable food systems and have been identified as critical issues by commodity groups/industry and state and federal agencies to receive priority funding and support.**

While focusing on these areas, my program aligns with ANR strategic initiatives

ANR strategic initiatives	Themes in my program
Manage endemic and invasive pests and diseases	**1. Management of emerging new and persistent diseases, weeds and arthropod pests**
Enhance competitive, sustainable food systems	**2. Evaluation of new crops and production methods for economic and environmental sustainability of agriculture in Ventura County**

Theme 1: Integrated management of emerging new and persistent diseases, weeds and arthropod pests for improved environmental quality of production.

Overview: In the last decade, Ventura County led all state regions in phase out of methyl bromide (none used since 2015) and adoption of impermeable tarps (to control emissions) in combination with alternatives. This fundamental change in the industry was due to extensive collaborative research and outreach programs that included trials, demonstrations, short-courses, meetings and information transfer that led to policy decisions in which I was playing an integral role. Globally (and mandated my Montreal protocol), the dramatic reduction in methyl bromide use caused the ozone hole to shrink, thus, reducing UV-induced damage (cancer, cataracts and DNA damage). Locally, it allowed cost-effective production of high value crops to continue, while adoption of impermeable tarps dramatically reduced fumigant emissions (which contributed to ground-level ozone, a pollutant). My recent work focused on integrating new and current IPM components into soil-borne pest management to sustain berry and vegetable production in coastal California facing increasing production costs and foreign competition. In my projects, I focus on overcoming the barriers for adoption (costs and ease of application).

Clientele: Growers, PCA's, berry and vegetable crop production industry, commodity groups that rely on soil disinfestation, regulatory agencies.

Goals:

a) Continue improvement of alternative fumigation systems and non-fumigant alternatives for soil-borne pest management.
b) Evaluate management methods for new (*Macrophomina phaseolina* and *Fusarium oxysporum* ssp. *fragariae*) soil pathogens.

c) Improve control of yellow nutsedge (a key problem locally and among world's 10 worst weeds) and weeds in non-competitive vegetable crops.
d) Evaluate organically acceptable contrtol methods of *Drosophila suzukii* fly (spotted-wing drosophila, SWD), a key pest of soft fruit in CA and worldwide.

Inputs:

a) I collaborate with UC ANR specialists and advisors, USDA researchers, UC Davis and U. Florida breeders, UC Santa Cruz faculty, researchers and students, scientists at ARS in Florida and Washington State and Univ. Tennessee. Funding includes USDA, Cal. Strawberry Commission and in-kind contributions from industry and labor and equipment from grower collaborators. In 2017 the teams in which I am a co-PI obtained $4.5 and 2.5 M. competitive NIFA grant funds to expand and continue this work. My co-PIs (UCR, UC ANR and USDA ARS) and I also secured a CDPR grant ($486,900) for site-specific/precision management of soil-borne pathogens in strawberry. The largest fumigation company – Tri-Cal is a key partner in these precision application projects. Aerial imaging and precision yield data collection equipment has been provide by UC ANR advisor Greer and contracted partner (Food Origins Inc.)
b) As Co-PI or collaborator with UC Davis and UC Riverside faculty and post-docs in Plant Pathology and U. Florida pathologists I'm supported annually by California strawberry Commission and competitive grant funding mentioned in (a). We use grower fields and Hansen REC sites for trials.
c) As co-PI with UC ANR specialist Fennimore and support from IR4 program ($30, 000) I investigated injury potential of prometryn to several vegetable crops. With industry support, I also evaluated pronamide application on lettuce via drip, to eliminate drift potential. California Strawberry Commission funded projects on yellow nutsedge management and growers and industry helped in treatment application in commercial fields.
d) With initial support of UC Hansen grant funding and an SRA, I also obtained plant material and in-kind contribution from caneberry nursery Nourse Farms. Field assistant, two interns and UCCE-Ventura Master Gardeners contributed to data collection and analyses in this project.

Methods

a) *Integration of anaerobic soil disinfestation (ASD) into organic soil management:* I conducted seven replicated studies in grower fields and at Hansen REC in collaboration with my colleagues. Four trials evaluated alternative carbon sources (more affordable than standard rice bran) and three evaluated minimized/reduced irrigation during ASD process to save water.
b) *Soil-borne pathogen management in conventional systems:* Two RCB-deigned studies focused on performance on newly developed UCD resistant strawberry cultivars at five pathogen levels in soil (to create response curves). Three other replicated trials evaluated site-specific/variable rate fumigant application for control of pathogenic fungi and strawberry production while reducing overall fumigant use and associated costs.
c) *Nutsedge control studies.* I evaluated nutsedge suppression with impervious barriers at two grower sites and tested end-season drip applied EPTC and metam sodium or potassium in two replicated trials focusing on tuber survivorship in heavily infested fields. At Hansen REC RCB-designed trials, I evaluated effects of three rates of prometryn applied in cilantro on following vegetable crops (peppers, spinach, Brussel sprouts and Napa cabbage) and compared two rates of drip vs overhead-applied pronamide on weed control and romaine lettuce injury.
d) *Spotted-wing Drosophila control.* In one replicated project I evaluated lignin enhancing products aimed to prevent oviposition into fruit and in another multi-year project assessed fruit colonization and quality with or without protection of insecticidal mesh. Both projects were conducted in primocane blackberry and included yield and fruit quality data analyses.

Outcomes:

a) *Integration of anaerobic soil disinfestation (ASD) into organic soil management:* Ventura County leads other counties in adoption of anaerobic soil disinfestation (ASD), this technology was used on ~1400 acres of berry crops in 2018 (10% of acreage).. Growers are able to use less water during ASD compared to pre-plant fumigation based on results from trials in their fields with various soil types. Water savings can contribute to necessary irrigation needs later during fruit production. Two growers included cover crops with reduced rates of labile carbon sources, making it more economical to utilize ASD that they have already adopted. One grower commented that he 'would not be able to farm economically without it".
b) *Soil-borne pathogen management in conventional systems:* Five growers are trying variable rate fumigation in their pathogen-infested fields and limited resource Hispanic growers reached out to our team and are currently participating in large scale evaluation. Tri-Cal GPS-guided fumigation equipment has been developed and used for variable rate application within infested fields, based on need and identified in pathogen maps. Data so far shows that improved application accuracy provided 16-20% reduction in fumigant use without compromising yields. Investment in precision technology was cost-effective according to preliminary economic analyses (conducted by UCD prof. Goodhue, collaborator). Resistant varieties of strawberry that my collaborative research identified are essential for maintaining production as number of fields with *M. phaseolina* and *F. oxysporum* infestations increases annually. UC breeders prioritize resistance to these new pathogens during selection process and my current trials show that newly released cultivars are highly resistant to Fusarium wilt and are more productive than old susceptible cultivars, with or without the pathogen. Additional season of data will enable us to develop pathogen response curves for key cultivars to help growers predict potential losses based on cultivar and pathogen density in the field soil.
c) Barriers (paper, high-density plastics) proved cost-effective since they provided nearly complete shoot suppression of nutsedges and have been adopted in plasticulture berry and vegetable production by organic growers. End-season metam drip fumigation of beds provided good nutsedge control, which was limited in areas most distant from drip lines, but is an important and affordable management tool since it also provided excellent soil pathogen control. It has been used by growers in Ventura and Santa Cruz counties. EPTC did not provide control and is an unlikely fit in current production systems. Weed control in cilantro was excellent with prometryn and showed that it was safe to transplant vegetables 45 d after application or direct seed after 60 d, thus, enabling our vegetable production to be more efficient and flexible. Drip application of pronamide was not different from spray application in efficacy against weeds and safe to lettuce. Drip application eliminates need for spray equipment in the field and potential drift, therefore improving pesticide safety in ag-urban interface environments.
d) We confirmed that exclusion of spotted-winged drosophila flies with mesh fabric is a successful organic control method in blackberry - not only fruit were free of maggots in mesh-protected tunnels, but also fruit yields were greater compared to unprotected production. Since other methods have not been effective, exclusion coupled with sanitation (identified in previous work) can enable organic caneberry production in the presence of this devastating pest.

Impacts

a) Environmentally acceptable soil disinfestation for high value crops production in coastal California and worldwide is essential for their viability. The ability of growers to use the tools that my colleagues and I are developing may determine how the berry and vegetable production will evolve in the next decades in areas of urban-agricultural interface. Precision application of all pest management

tools (not just fumigation that we currently evaluate) will allow their cost-effective use, allow strategic pathogen control and make local industry more competitive.

b) Ability to continue farming in the presence of these new lethal pathogens depends on integrated management utilizing strategies that our research teams have already identified and continue to develop. This fact is recognized with continuous support from industry, USDA and producers of strawberry in California and around the world.
c) Effective non-chemical weed control and improved herbicide safety are important for coastal crops with poor competitive ability due to lack of current management methods, prohibitively expensive labor costs for weeding and minimized potential risk of pesticide exposure.
d) I generated information that was not previously available in organic caneberry – exclusion is the only known effective method of protecting soft fruit from SWD damage. I communicated this to coastal clientele and there is interest among organic growers in using this approach.

Theme 2: Evaluation of new crops and production methods for economic sustainability of agriculture in Ventura County

Overview: My previous work focused on reducing non-target water losses during strawberry establishment by minimizing reliance on solid set sprinkler irrigation in plasticulture production and, instead, irrigating and fumigating via additional drip lines. Multi-year multi-site field studies that I led showed improved distribution of water and fumigants with additional drip lines, resulting in at least 20% savings of water and 5-15% yield increases due to improved fumigation efficiency. The increased number of drip lines per bed and conversion to reduced overhead sprinkler irrigation for strawberry establishment are now wide-spread practices and essential in sustaining production amid limited water availability caused by droughts. As Pi , co-PI or collaborator I received > $300, 000 in competitive grant funding for projects focused on optimizing irrigation and nutrient management in vegetable, strawberry and raspberry (CDFA, UC Hansen, National Sustainable Strawberry program and UC ANR). My recent collaborative work focused on improving quality of runoff from large-scale plastic-covered tunnels that all caneberries and several other commodities use.

I have concluded multi-year, multi-site evaluations of public caneberry varieties generating key information for small and medium-size growers who do not grow proprietary cultivars. Additionally, in collaboration with four UCCE advisors in other counties I evaluated pepper varieties for suitability by mechanical harvesting – an objective of reducing the great expense ofmanual labor for fruit picking.

<u>Clientele:</u> Growers, consumers, irrigators, PCA's and CCA's, regulatory agencies, Resource Conservation District (RCD) and other stakeholders involved in improving environmental quality of production agriculture.

<u>Goals:</u>

a) Research, demonstrate and implement best management practices (BMPs) for runoff management from plasticulture tunnels.

b) Provide information about new publicly available raspberry and blackberry and their management in coastal California.

c) Evaluate pepper cultivars for ease of mechanical harvesting

Inputs:

a) I conducted large-scale projects in grower fields in Ventura and Santa Barbara Counties. Growers provided field equipment and materials, Ventura County RCD and grower crews provided field assistance, RCD and UCCE personnel helped with treatment implementation and assessment, CDFA Specialty Crops Block Grant ($218,400) funded the research and outreach, UCR specialist Wu and his lab analyzed runoff samples. UCCE economist Takele analyzed feasibility of tested BMPs.
b) A $68, 000 completive grant from UC ANR Hansen competitive grant program and $5,000 contribution by Nourse Farms in addition to supply of plant material enabled me and advisor Gaskell to conduct multi-site germplasm evaluation over three years. Key input was perennial involvement of the UCCE-Ventura Master Gardeners who assisted with data collection.

c) A $24,000 grant from CA Pepper Commission helped initiate multi-site project in grower fields, including one I led in Ventura. Saticoy Pepper (Processor Company) provided additional equipment and growers provided management of the crop.

Methods:

a) We conducted replicated studies with five treatments spanning three years, shared and discussed information during field demonstrations, meetings and educational workshops reaching > 800 participants. I led publication of bi-lingual guidelines for tunnel runoff BMPs and development of a peer-reviewed California Agriculture article in addition to two industry publications.
b) In replicated studies we evaluated production, three management regimes and post-harvest fruit quality of five new primocane raspberries and four blackberries from Oregon, Arkansas and Europe. This included primo- and floricane management and evaluations of fruit characteristics. Outreach was diverse: from Central Coast caneberry meetings to Small Farms conference and >50 individual consultations.
c) In replicated studies I evaluated the same 12 pepper cultivars (as my colleagues in other counties) for ease of fruit dislodgement from stem necessary for mechanical harvester. SRA, field assistant and personnel from Saticoy Pepper helped in data collection and analyses.

Outcomes:

a) Our project showed effectiveness of treatments in reducing nitrogen in runoff and leaching to groundwater, reducing phosphorus, turbidity and sediment (and potential legacy pesticides sorbed to soil) in runoff. We provided users with economic analyses of treatments and illustrated guidelines about implementing them. The BMPs that we identified not only help growers comply with regulatory requirements but also improve soil health by minimizing erosion and nutrient losses and protect aquatic environments that receive agricultural runoff from pollution.

b) We generated public information about performance and management of new cultivars in Southern and Central California coast. We showed the flexibility of production in all cultivars with pruning management and ability to adjust fruit production to needs/market demands. This information was not previously available and will help decision making for current and prospective growers. In addition to information extension by PIs of the project, the first-hand knowledge is shared by UCCE -Ventura Master Gardeners, reaching both consumers and small-scale growers.

c) The data are currently being analyzed and we expect to draw conclusions about these cultivars and evaluate consistency among the five sites within the state.

Impacts

a) The largest berry company (Reiter/Driscoll AC) and several other producers showed interest in the effective BMPs and two growers already used mulch and several used weed barrier fabric, which we tested in the project. Although the project finished in 2019, the surveys showed that ~90% of responders plan to implement BMPs as a result of my collaborative, bilingual outreach programs.

b) The project finished in 2019, but the popularity of these varieties during the last three years had already increased among small-scale and limited resource growers from San Diego to Watsonville. More than 50 CA Rare Fruit growers are currently producing and marketing these primocane caneberries successfully. Fruit of these cultivars are attractive to consumers, provide health benefits and are easily adopted by local direct marketing operations.

c) Utilization of mechanical harvesting and availability of cultivars compatible with it are essential to viability of pepper production in California. We expect the project will continue (in future seasons) to identify the traits in varieties necessary for mechanical harvesting. With increasing labor costs and reduced availability, this work can greatly improve competiveness of the pepper production in the state.

In addition to carrying out planned research and outreach programs, I routinely engage in problem solving based on increased number of inquiries/field visits and samples dropped by PCAs and growers at my office (~50 per year). This essential commitment helped in identifying new pathogens and monitoring issues affecting region's vegetable and berry production. In 2017-2019, I provided leadership outside of my program area by conducting weed control studies and herbicide injury evaluations in citrus at Hansen REC in collaboration with advisors Rios and Faber and specialist Bean.

II. PROFESSIONAL COMPETENCE AND ACTIVITY

During this review period, I continued to serve as a professional journal manuscript reviewer, student judge and contributor to four professional societies in North America. I published 11 peer-reviewed and 53 other papers. I provided local leadership on the organizing committee of the North American Raspberry and Blackberry Grower Association conference and served as CDFA Specialty Crops Block Grant reviewer. In 2017, ACDI-VOCA invited me to provide trainings in pest and fertility management in southern Mozambique (with UCCE emeritus advisor Phillips). I received invitations to lead international aid efforts in berry production and pest management in 2019 (Republic of Georgia) and have a record of accomplishments of similar international trainings (Lebanon, Dominican Republic, Kenya). My colleagues and I identified new vegetable diseases (Alternaria leaf spot and Rhizoctonia root rot of cilantro, Fusarium basal rot of leek) and pest management methods that have international significance.

International Strawberry Symposium (Italy) conveners invited me to serve on the scientific panel and present a paper on California strawberry soil-borne pest management. During the current review period, I gave 64 professional presentation (29 invited) mostly in coastal California, including invited talk at the MBAO Intl. Conference in San Diego and seven other presentations at international conferences.

III. UNIVERSITY AND PUBLIC SERVICE

During the review period I served on the UC ANR Personnel Committee and in 2019 was appointed to the UC ANR Program Review Committee. I was a member of search committees for UC ANR advisor, community educator and lab assistants and evaluated advisors and specialists for advancement. I continued to act as UC liaisons of the California vegetable industry (celery, leafy greens, onion and garlic) by evaluating proposals for accuracy and merit and in 2019 was invited to serve as UC liaison to the CA Celery Research Board. In three instances, I served as acting county director at UCCE-Ventura and am an active member of UC Hansen REC Advisory Board and REC Users Committee appointed by AVP Powers. Additionally, I was the primary supervisor for a SRA III, a Field/Lab Assistant I and co-supervised two other SRAs. I provided orientation (including field visits and clientele meetings) for new UCR pathology, entomology and weed science specialists, in addition to developing collaborative program with new UCD strawberry breeders. I served on a Ph.D. student committee (U. Laval) and consult UC and other students and post-docs frequently.

Public education about agricultural issues and efforts that UC ANR undertakes to address them is central to my service. I engage Master Gardeners in my projects and teach classes about weeds and their management. I initiated the Ventura Master Gardeners symposium which has become a popular annual event. I presented at the Ventura County Agricultural Symposium, highlighting our UCCE projects in caneberries and the role of UCCE Master Gardeners in the county. I also have one-on-one discussions nearly weekly while sharing information with news media, various city or state agencies about pest identification and management or answering vegetable and fruit production inquires. Besides leadership in working with Master Gardeners, I volunteered with demonstrations of my projects at Hansen REC for schoolchildren, college students and the general public, including area-wide 'See Ag' open-farm day. Public Service also included Farm Bureau and County Ag Commissioner collaboration in planning and project development and service as information resource to CA Women in Agriculture and serval volunteer groups.

IV. AFFIRMATIVE ACTION

All programs that I conduct adhere to the principles of equity and in accordance with the University of California Affirmative Action Policy. I completed all required trainings and am in parity and continue to compare clientele information from sign-up sheets (always used in all of my extension events) to Agricultural Commissioner's records. Additionally, I place special emphasis in my affirmative action efforts on: 1) Development of staff and 2) Education and outreach to Hispanic clientele, the largest minority group among my clientele contacts. This includes communication in Spanish and/or simultaneous interpretation into Spanish during all of my outreach events. I have also worked with small and limited resource growers that successfully grew berry and vegetable crops as a result.

For complete details about my projects, collaborators, outreach, publications and other activities in the four evaluation criteria, please refer to the tables in 'Supporting documentation' below.

SUPPORTING DOCUMENTATION

Extension Activities Table

Extension activities summary Oct. 2016 - Oct. 2019.

Meeting organized	**12**
Educational/professional/public presentations	**64**, including 46 (to clientele), 9 (to non-clientele), and 8 public talks
Invited presentations	**34**

Meetings Organized				
Date	**Meeting Names/Topics**	**Role**	**Location**	**Attendance**
19 Sept 2019	18th Annual strawberry production	Organized and presented 1 talk	Camarillo, CA	78
16 May 2019	Fumigants and alternatives: regulation and current research	Organized and gave 2 talks	Ventura, CA	76
2/21/2019	Caneberry Production	Co-organizer and presenter of 2 talks	Watsonville, CA	73
11/7/18	Fresh Garbanzo production	Organized and facilitated grower and shipper meeting for production of fresh garbanzo beans in Ventura County	Ventura, CA	9
10/16/2018	Stormwater manager in plasticulture systems	Organizer, presenter	Santa Maria, CA	21
9/27/2018	Annual Strawberry Production meeting	Organized and presented	Camarillo, CA	76
6/13/2018	Stormwater management in tunnels workshop	Organized and presented 2 topics	Santa Paula, CA	57
5/18/2018	Fumigants and alternatives	Organized and presented 1 talk, 5 guest speakers	Ventura	63

5/10/2018	Vegetable production	Organized and presented 2 talks, 5 guest speakers	Camarillo, CA	57
2/21-24/2018	NARBA: North American raspberry and Blackberry Association	Co-organizer of the conference. This included leadership in: • organizing tour of field and labs in Ventra county • organizing and moderating scientific program and grower/PCA sessions • logistics and arrangement for successful conference that brought researchers and growers /industry together • authorship of four presentations and co-authorship of two • Interview – in Spanish for UC ANR Spanish language broadcast service. The interview highlighted our current work in runoff management and caneberry germplasm evaluation	Ventura, CA	357 from North America, CA and >50 international participants
9/7/2017	16th Annual strawberry production meeting	Organizer, coauthor of 3 talks	Camarillo, CA	78
4/28/17	Fumigant and non-fumigant solutions to soil disinfestation	Organizer. Presenter, 6 guest speakers. 2 talks by me: • Trial update from Ventura County • *C. acutatum*	Ventura, CA	75

		survivorship with alternative fumigants		

Educational/Professional Presentations at Meetings

Date	Meeting Name	My presentations (and role)	Location	Attendance
10/3/2019	Cover crop field day	• Invited presenter for 7 groups (7 presentations on low profile cover crops)	Santa Paula, CA	120
19 Sept 2019	18th Annual strawberry production	• Fusarium inoculum density affects strawberry cultivar performance	Camarillo, CA	78
6/18/2019	PAPA seminars for continued education	• Invited talk 'SWD exclusion with mesh barriers'	Oxnard, CA	168
16 May 2019	Fumigants and alternatives: regulation and current research	Talks: • Fusarium levels affecting strawberry varieties • Reducing water and carbon inputs in summer ASD	Ventura, CA	76
5/14/2019	Annual Strawberry field day	Invited to discuss: • Precision fumigation • Fusarium management	Santa Maria, CA	176
3/23/2019	Pest Control Consultants meeting	• Nutsedge and Fusarium management in strawberry (invited)	Santa Barbara, CA	27
2/21/2019	Caneberry Production	Co-organizer and presenter of 2 talks, and co-presenter of another: • Caneberry germplasm evaluation • Stormwater management in plasticulture systems • Exclusion of SWD as organic management tool	Watsonville, CA	73

02/14/2019	Central Coast Annual strawberry production meeting	• Weed and soilborne pathogen management research update from Southern California	Watsonville, CA	215
02/13/2019	CAPCA	• Update of weed and pathogen management in cilantro (invited)	Santa Paula, CA	142
10/16/2018	Stormwater manager in plasticulture systems: field day	• Stormwater treatments impacts on weed management as • Costs of BMPs for plasticulture tunnels and demonstration of Polyacrylamide use	Santa Maria, CA	21
9/27/2018	Annual Strawberry Production meeting	• Nutsedge control with end-season fumigation and herbicides	Camarillo, CA	76
6/13/2018	Stormwater management in tunnels workshop	• Stormwater treatments impacts on weed management as • Costs of BMPs for plasticulture tunnels	Santa Paula, CA	57
5/18/2018	Fumigants and alternatives	• Ventura county soil disinfestation trials - an update	Ventura	63
5/10/2018	Vegetable production	• Prometryn in cilantro effects on rotational vegetable crops	Camarillo, CA	57
2/21-24/2018	NARBA	• 4 presentation by me: three posters: 1) runoff management in plasticulture raspberry 2)primocane caneberry variety trial and 3) CO2 enrichment in	Ventura, CA	357

		tunnel grown raspberry) + talk on 4) New research on Fusarium in berry crops and co-authorship of 2 other talks: • With A. Biscaro: water and nutrient management. • With A. Howell: Mites in caneberries: biology and control		
2/14/18	CAPCA	• Soil disinfestation update • Weed control in caneberries and vegetables (invited)	Santa Paula, CA	123
02/01/2018	Central; Coast strawberry production	• Soil disinfestation updates from Southern California (invited)	Watsonville, CA	189
12/25/17	CWSS	• Effect of prometryn applied in cilantro on rotation vegetable crops (invited)	Santa Barbara, CA	486
11/28/17	Vegetable and strawberry production	• Soil-borne pest management in organic and conventional production. • BMPs for plasticulture tunnels runoff management (invited)	Santa Maria, CA	121
11/14/2017	PAPA	• Weed management in caneberry with herbicides and mulches • Citrus weed control (Invited)	Oxnard	321
9/28/2017	PAPA	• Weed management in caneberry with herbicides and mulches • Citrus weed control	Santa Maria	129

		(Invited)		
8/16/2017	Nutrient and irrigation management	• Role of soil amendments and impacts on soil properties (invited)	Oxnard, CA	76
6/14/2017	CAPCA	• New carbon sources for ASD • Weed control in citrus with new herbicides and mixtures	Santa Paula, CA	127
4/27/17	Field tour with Driscoll's /Reiter grower	• ASD current work and how to avoid problems for successful application X 2 locations (invited)	Oxnard, and Somis, CA	36

- **For all of the extension activities that I organize, I apply for and receive Continuous Education hours (from DPR) and Certified Crop advisor hours necessary for participants to maintain their professional licenses.**
- **90% of the events that I organized had professional simultaneous interpretation into Spanish**
- I Inspected celery and strawberry fields and provide letters of assessment to support the need for H2A workers visas to accommodate harvest needs. Feb 2016.
- **All extension presentations are posted to by web page of the UCCE-Ventura website under 'Recent Meetings'. For example, strawberry-related presentations are on line at :**

http://ceventura.ucdavis.edu/Com_Ag/comveg/Strawberry/Recent_Meetings/

Professional Competence

Professional Competence Summary for Oct. 1, 2016 – Sept. 30, 2019

Professional Training, hours	**31**
Review of journal manuscripts, #	**15**
Professional presentations	**17**

Professional Development and Training

Date	Location	Duration (hours)	Name and/or Description of Activity
10/7/2019	On-line	1	UC Cyber Security Awareness Fundamentals
12/3/2018	On-line	1	Completed UC Cyber-security training
12/26/2018	Davis	16	Vegetbale program team program: food safety, pest

			managemnt and water and soil manahemnt.
4/6/18	Oxnard	2	Breedng program field day participation
1/9/18	On-line	1.5	Completed cybersecurity training
6/13/17	Santa Paula	2	Practical methods for measuring impacts – UC ANR training.
4/18/2017	On-line	2	Completed required course 'Physical science responsible conduct of research' course, certificate on – line at: https://www.citiprogram.org/verify/?kcd1e7b05-4b84-4e29-af9c-cc13b9b3f1bb-22918265
3/14-16/2017	Ontario	16	UC ANR Water SI meeting
1/23/2017	On-line	0.5 h	UC ANR UC Cyber Security Awareness Training - Refresher
10/6/2016	Ventura, CA /On-line	2	UC ANR PR merit and promotion training

Disciplinary Society/Professional Associations

Disciplinary Society/Prof. Assoc Name	My Role
North American Raspberry and Blackberry Association	As a host, helped to develop program, tour, arrangements and interactive workshops for scientists, growers and industry resulting in one of et most successful conferences in NARBA history with over 300 participants from North America and overseas.
Intl Journal of Fruit Science	Reviewer for special issue based on strawberry symposium at Ventura, CA. Reviewed and provided recommendations on 4 manuscripts
North American Strawberry Growers Association and North American Strawberry Symposium (NASGA/NASS)	Played a key role in organizing largest ever in US combined conference and tour in Ventura, CA. That included: identifying world-class key-note and other speakers, facilitating CA researchers and industry involvement, development of program, agenda and other pertinent logistical issues and organizing full day tour. The event attracted over 400 participants from over 20 countries and was most successful in organization history. I also authored or co-authored 6 oral papers and 2 posters.

Disciplinary Society/Prof. Assoc Name	My Role
Elsevier Editorial Systems	Served as a review for Journal of Food Science and Emerging Technologies and Soil Biology and Biochemistry • SBB12185. 5/30/2017 • IFSET-D-14-00590, Dec 13, 2014.
Crop Protection Journal	Reviewed manuscript and made recommendation • CROPRO-D-16-01138 (3/8/17)
California Weed Science Society (CWSS)	• Jan 2018: served as student judge for oral presentations at CWSS conference at nt Barbara, CA • Sept 2017: evaluated student internship application packages (10) and made award recommendations • Jan 2017: student poster judge, presenter (Organic weed control in strawberries) and session chair (berry crop weed control) at CWSS.
California Agriculture	Reviewer (2012-on going). In this capacity I reviewed manuscripts: • CalAg-0287 (11/30/16)
International Society for Horticultural Science	Manuscript reviewer for International Journal of Fruit Science • (ID WSFR-2018-0126) • (ID WSFR-2018-0126 REVISED)
American Society for Horticultural Sciences (ASHS)	• Served as graduate student poster judge at the ASHS annual conference, Waikoloa, HI 9/20/2017. Member and Reviewer of HortScience and HortTechnology Journals. In this capacity reviewed Manuscripts: • HORTSCI-14347 (8/2/2019) • HORTTECH-04017 • HORTSCI-09979 (6/26/2015) • HORTTECH-02920 (Sept 3, 2014)

Disciplinary Society/Prof. Assoc Name	My Role
Weed Science Society of America (WSSA)	Serve as a reviewer for Weed Science and Weed Technology Journals. In this capacity, reviewed manuscripts: • WT-D-19-00091 • WT-D-19-00007 (2/4/2019) • WS-D-18-00091 (6/1/2018) • WS-D-18-00018 (2/14/2018) • WS-D-17-00204 (11/21/17) • WS-D-17-00125 (8/21/17) • WT-D-16-00140. (10/25/2016)

Other examples of professional competence

Date	Activity
2018	Served as contributor and reviewer for chapter 3.9 of the California's Fourth Climate Change Assessment: Agriculture: Climate and agriculture in the Los Angeles region. The publication focuses on quantitative vulnerability assessment of CA specialty crops for climatic change. Available on line at: http://www.climateassessment.ca.gov/regions/docs/20180827-LosAngeles.pdf
2017-2018-2019	Served as reviewer for CDFA SCBG program and reviewed 45 pre-proposals and 36 full proposals and provided recommendations for funding. The program provides key financial assistance for projects in CA crops and averages $28 mln. in competitive grant funding annually. Invited and appointed by CDFA as qualified reviewer.
2016-2017	Served as committee member for PhD student at U. Laval (Canada) and evaluated his dissertation and defense.
May 2017	ACDI-VOCA: pest and fertility management in southern Mozambique. As Invited instructor, in a team with advisor emeritus Dr. Phil Phillips conducted trainings, presentations and demonstrations in vegetable IPM and soil and irrigation management for sustainable crop production. We reached158 stakeholders, including growers, extension personnel and Ag ministry staff with > 10 formal trainings on various topics, field visits and development of final report (28 pages).
11/15/2016	Served as reviewer for proposal for BARD - The US-Israel Agricultural Research & Development Fund. I evaluated and ranked the proposal.
10/21/2016	Identified pest flies for APHIS inspection of strawberry shipments to China from Ventura County growers

Professional Presentations to non-clientele

Date	Meeting Name	My presentations	Location	Attendance
7/24-25/2019	ASHS	• End-season fumigation with metam in strawberry reduced infestations of nutsedge and soilborne pathogen. • Management Practices to Minimize Stormwater Pollution from Macrotunnel Production Systems • Caneberry Evaluations at Central and Southern Coast of California * Moderated two sessions	Las Vegas, NV	2,800
12/26/18	Vegetable program team	• Southern California vegetable production issues: an update	Davis, CA	38
3/8/18	Ventura College	• Invited lecture on weeds in agricultural systems	Ventura, CA	14
11/13/2017	MBAO	• Current status and distribution of pest problems in southern California and pro's and con's of disinfestation practices., MBAO proceedings 5:1-2. San Diego, CA. Nov. 13-15 2017. (Invited talk)	San Diego, CA	168
9/20/2017	ASHS Annual conference	• Management Practices to Minimize Stormwater Pollution from Macrotunnel Production Systems • Carbon Sources for Anaerobic Soil Disinfestation in Southern California	Waikoloa, HI	3,000
3/15/2017	UC ANR Water SI meeting	• Differential susceptibility of strawberry to salts in irrigation water (poster)	Ontario, CA	65

University and Public Service

Summary of university and public service: Oct 2016-Oct 2019

Examples of University Service	19
Examples of public service	8
Presentations to public	8

University service

Dates	Activity	My Contribution and Leadership Role
December 2019	Search committee member for Lab/field Assistant	Conducted reviews, section and background checks for candidates.
2019- on going	Serve on ANR PRC	Evaluated PRs for promotions and accelerations
2017-on going	Served on Hansen REC advisory board	Participated in all activities of the board and provided recommendations to director and AVP. Reviewed off-cycle proposals.
9/5/2019	Evaluated specialist for promotion	Provided evaluation in four criteria at request of the Department head.
Dec 2018	Served on search/hiring committee for Healthy Soils program (community educator) for Ventura County	Participated in candidate evaluation and selection process
2018-2019	Served on REC users committee (invited by W. Powers)	Participation (monthly) in discussions for finding solution to help sustain and improve UC RECs.
2018, 2019	Served as Proposal reviewer for CA leafy green board	Reviewed proposals and provided recommendations
9/24/2018	Consulted UC Berkeley student about strawberry IPM	Discussed issue pertaining to her Thesis and provided reference resources for her work on pesticide use in strawberry
9/19/2018	Participated in program discussion	Gave an overview of

	meeting with AVP Wendy Powers and director of special programs Mike Bell	program priorities and row crop situation in Ventura county
5/16/2018	Consulted MSc student about grower-advisor interface and challenges in adoption and information transfer	Contributed to development of MSc thesis for UCSC student
2/21/2017	Evaluation of advisor seeking acceleration	Provided evaluation in the 4 criteria and made recommendation
Dec.2017-Jan. 2018	Served on search committee for area entomology IPM advisor for three Central coast counties	Worked with committee members to screen 22 applicants, developed interview question and provided materials for diagnostics during interviews.
3/13-3/17/2017,	Served as acting county director	Fulfilled the responsibilities in the absence of eth UCCE CD
October 2016, October 2017, October 2018, and 2019	Serve as UC Reviewer for California Garlic and Onion Research Advisory Board	Reviewed submitted proposals and made recommendations in 2016 2017, 2018
1/9/2017	Evaluation of advisor seeking acceleration	Provided evaluation in the 4 criteria and made recommendation
12/7/2016	Participated in the tour visit for AVP Powers	Explained: • Caneberry production research at HAREC field site • Highlights of my program in ag and env. issues for row crops in Ventura County (presentation)
10/20/2016	Evaluated UC ANR specialist for promotion	Provided evaluation in four performance criteria
10/7/2016	Discussed my projects and their contribution to Ag. and Environmental sustainability of the region (recycling of waste for ag. benefit) with a representative of the Office of Assembly member Das Williams	Informed the representative about the role UCCE plays in sustainability of ag . and natural resources.

2016-on going	Served on UC ANR Personnel Committee	Fulfill the duties of the committee such as reviews of criteria and ANR policies

Public service

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Dates	Activity	My Contribution and Leadership Role
6/7/2019	Contributed to LA Times article on celery, available on line at https://www.latimes.com/food/la-fo-when-celery-ruled-the-southland-20190508-story.html	• Explained production practices and provided references for the story
2/25/2019	CA Rare fruit growers seminar	• Invited talk on caneberry production in Southern California (64 attendees, 14 got interested in growing caneberries)
5/20/2019	UCCE-MG continuous education field day, Santa Paula, CA	• Invited to show and explain my research trial in strawberry (27 attendees)
11/8/18	Cal State Channel Island Student Education tour, Hansen REC, Santa Paula, CA	• Explained strawberry propagation and production to the University students
6/11/2018	MG symposium	• Facilitated organization of symposium into annual event and presented 'Caneberry production', 76 attendees
3/29/18	Taught UC Master Gardener class 'Weeds'	• Explained biology and management of weeds to 36 students (Invited)
5/2/17	Presented a slide show about ACDI/VOCA assignment to Mozambique at UCCE –Ventura	• Discussed the project and impacts with UCCE and Hansen staff
3/31/17	Presented at the Ventura County	• Discussed UCCE work

	Agricultural Summit 2017: The STEM of Farming's Future: Sustaining Ventura County Agriculture through Science, Technology, Engineering and Math	and role in agriculture and natural resources

Affirmative action

All programs that I conduct adhere to the principles of equity and in accordance with the University of California Affirmative Action Policy. I completed DANRIS –X and CASA and Project board information and participate in all required trainings. I am in parity and continue to compare clientele information from sign-up sheets (always used in all of my educational extension events) to Agricultural Commissioner's records.
Additionally, I place special emphasis in my affirmative action efforts at:

1) Development of staff and,
2) Education and outreach to Hispanic clientele, the largest minority group among my clientele contacts.

<u>Examples of work with staff development (supervision of 1 SRA, co-supervisor of 2 SRAs and 1 field/lab research assistant):</u>

- Worked with multi-ethnic SRA to improve skills including training necessary for CA professional applicator license exam (she successfully passed the exam for Qualified Applicator)
- Completed Ethics training om 11/20/2018
- Completed sexual harassment training on 4/4/18.
- Entered DANRIS X annual plan and report and added contacts (10/5/2017) and 10/20/2016 and project board information in 2018-2019.
- Completed supervisor training webinar, 5/10/2016
- Trained research assistants in the areas of: 1) preparation and presentation of the poster at the Cal Weed Sci Society, 2) use of precision equipment for soil measurements and 3) use of software for data processing
- Worked with SRA in the areas of: 1) pesticide application, 2) development of peer-reviewed publications, 3) management of supervised employees and volunteers
- Empowered SRA to take leadership on 3 research projects including execution, outreach presentations and publications in journals and industry outlets.

<u>Examples of education and outreach to Hispanic/limited resource clientele</u>

- 8 out of 9 meetings that I organized had translation into Spanish. I communicate individually with clientele in Spanish.
- Strawberry disorders and runoff management guidelines that I developed are bi-lingual
- I worked with 2 Hispanic and 5 other limited resource growers (caneberry planting and soil disinfestation). Communicated with over 80 small or limited resource growers.

- Worked with two multi-ethnic limited resources growers who improved soil management and fruit production as a result.

Project Summary Table
Oct 2016-Oct 2019.

Theme 1. Management of emerging new and persistent diseases, weeds and arthropod pests.				
Project Title/Duration	**My Role**	**Collaborators**	**Support amount, $**	**Support Source**
Alternaria leaf spot of cilantro: integrated management	PI	Steve Koike, Tri-Cal	3,956	UC Hansen competitive grant program
Development and optimization of next generation propagation and diagnostic tools to improve strawberry production (pending)	Collaborator	Mark Hoffman, NC State Univ.	Not received yet	NIFA-SCRI
Development of manual for beginning organic farmers (on-going since 2018)	Reviewer and collaborator	UC SAREP staff and county UCCE advisors	NONE for my work	UC SAREP/Western SARE grant
SCRI: Integrating ASD with other management tools in strawberry production (2017-2022)	Co-PI	Carol Shannol and Joji Muramoto (UCSC) , Erin Roskopf (ARS- Florida), Frank Lowes (NC State), Natalia Perez, U. Florida + 20 others	2.5 mln	NIFA- SCRI
SCRI: Next generation breeding for disease resistance in strawberry (2017-2022)	Co-PI	Steve Knapp (UC Davis), T. Gordon (UC Davis, V. Wittaker (U, Florida) and over 20 others	4.5 mln	NIFA-SCRI
Fusarium wilt in cilantro and celery: selection for resistance and sustainable control; 2016 -2018	Collaborator	L. Epstein (UC-Davis)	59,767	UC Hansen competitive grant program
Weed management in strawberry (On-going since 2016)	Co-PI	Steve Fennimore (UC Davis)	~9,000/ annually (~27, 000 in 3 years)	California strawberry commission
Macrophomina, Verticillium and Fusarium management - a comprehensive approach; 2016-on-	Co-PI	Steve Koike (Tri-Cal), Tom Gordon and Husein Ajwa (UC- Davis emiritus)	12,000 annually (total 36,000)	California Strawberry Commission

going				
Insecticidal mesh barriers for *D. suzuki* fruit flies as organic management option in caneberries; 2016-2017	Co-PI	Howell (UCCE-Ventura, later Gowan)	3, 000	Various donors
Site-specific soil pest management	Co-PI	Frank Martin (USDA-ARS), Alex Putman (UC-Riverside), Seve Fenniomre (UC Davis) Andre Biscaro (UCCE – Ventura) , Mike Staghellini, Tri-Cal and 12 others	486,900 and 37,000	Cal Dept Pesticide Regs and USDA-ARS
Support of Research and Extension Program in Ventura County strawberry; 2016-2018	PI	UCCE-Ventura SRAs and field assistants	8,700	California Strawberry Commission
Weed management in vegetable crops, 2016-2018	PI and Co-PI (2 projects)	S. Fennimore and R. Smith (UCCE-Monterey)	3,500 and 30, 000	Various donors and IR-4 grant (specialty crop pesticide evaluations program)
Weed management in citrus and avocado	Co-PI	Ben Faber, Travis Bean and Sonia Rios (UC ANR)	12, 000 and 14, 000	Citrus research board and Cal. Avocado Commission
Theme 2: Evaluation of new crops and production methods for economic sustainability of agriculture in Ventura County.				
Project Title/Duration	**Role**	**Collaborators (and affiliation)**	**Support amount, $**	**Support Source**
Management Practices to Minimize Stormwater Pollution from Macrotunnel Production Systems; 2016-2019	Director	J. Whiteford, (Resource Conservation District), B. Faber (UCCE-Ventura), E. Takele (UCCE-Riverside) and L. Wu, (UC-Riverside)	218,449	CDFA-Specialty crops block grant
Evaluation of pepper cultivars for suitability to mechanical harvesting	Co-PI	UCCE Advisors: Gazula, Smith, Aegerter and Turini	3, 000	Cal Peppers Commission
Evaluation of public raspberry and blackberry germplasm and cultural practices in coastal California production areas. 2016-2019	PI	Mark Gaskell (UCCE) and Miguel Ahumada (Sun Belle)	66,362 +5,000	UC Hansen + Nourse Farms

GOALS FOR THE COMING YEAR: October 1, 2019- September 30, 2020

Specific Goals	***Anticipated Collaborators***	***Anticipated Outcomes***
Continue soil disinfestation projects described above. This includes 1) repeating pathogen-rate response (*F. oxysporum*) in soil with new strawberry varieties 2) finishing evaluation in two site-specific pathogen management sites and 3) Finish studies evaluating carbon sources.	Same as in project summary table	Show that fumigant use reduction according to need can satisfactory control pathogens and reduce costs and observe use of precision application in IPM; Adoption of cost-effective carbon sources for ASD; Development of guidelines for pathogen reacted strawberry performance
Make BMPs for runoff management available to >80% of clientele. Continue bi-lingual outreach	Same as in project summary table	Increased adoption and ability to comply with runoff regulations.
Draft a Weed Technology manuscript on prometryn effect on rotational vegetable crops	S. Fennimore	When published, use it as reference for label development and future work
Develop paper presentations for Intl Strawberry Symposium and Act Hort in 2020 and participate in multiple roles in the symposium	Co-authors from UC and industry collaborating	Share information with and research and extension colleagues and receive feedback

BARRIERS/OBSTACLES IN ACCOMPLISHING YOUR GOALS

1) Loss of key collaborators in many projects: Steve Koike and his diagnostic lab. Also, retirement or loss of: Doug Gubler, Mark Gaskell, Karen Klonsky, and more recently Richard Smith, Lynn Epstein and Tom Gordon. Even with best efforts to establish new networks with colleagues, the losses of expertise coupled with ability to collaborate successfully have been very real.
2) Inability of California fruit growers to compete with Mexico (where ag. labor is 10 times cheaper) makes it difficult to justify investments in improving production and environmental quality of agriculture in California. This presents a challenge and an opportunity to find creative solutions for local industry to be sustainable.
3) Two years of continuous effort dedicated to rebuilding our house and lives after devastating Thomas fire destroyed our home. That included multiple relocations after initial evacuation and daily attention to recovery and reconstruction. This interfered with all aspects of daily planning, productivity, emotional health and ability to function normally. Majority of my professional travel was curtailed due to time constrains and necessity to be in Ventura.

Bibliography

(*Review period in Italic*, the rest of the career in regular font)

Summary of publications	During review period	Career total
Peer-reviewed		
Peer-reviewed journal articles	*9*	51
UC-peer-reviewed	*3*	25
Book chapters	*0*	3
Non-peer reviewed		
Printed newsletters, articles, UC sample costs, etc.	*9*	58
Published information that I have generated used by others	*0*	10
Videos	*3*	9
My Web site postings	*8*	>60
Blogs	*5*	>120
UC-Delivers stories	*1*	5
Project reports to granting agencies and industry:	*6*	51
Proceedings	*8*	71
Abstracts	*14*	69
TOTAL	***11 peer-reviewed and 54 non-peer-reviewed***	**79 peer-reviewed and > 453 non-peer reviewed**

According to scientific publication sharing platform 'Research Gate', in average year my publications were read 800 times, cited 156 times and downloaded 108 times.

Peer-reviewed journal articles

During 2016-2019

Daugovish, O., B. Faber, E. Takele, J. Whiteford and L. Wu. 2019. Stormwater runoff management from plastic tunnels. Accepted to Cal. Agriculture. Acceptance letter on file.

Gordon, T. R, M. Stueven, A. M. Pastrana, P. M. Henry, C. M. Dennehy, S. C. Kirkpatrick and O. Daugovish. 2018. The effect of pH on spore germination, growth and infection of strawberry roots by Fusarium oxysporum f. sp. fragariae, cause of Fusarium wilt of strawberry. Plant Disease Vol. 103, No. 4. Available on-line at https://doi.org/10.1094/PDIS-08-18-1296-RE

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Gaskell, M., Bolda, M.P., Muramoto, J. and Daugovish, O. 2009. STRAWBERRY NITROGEN FERTILIZATION FROM ORGANIC NUTRIENT SOURCES. Acta Horticulturae. (ISHS) 842:385-388 Available on-line at http://www.actahort.org/books/842/842_74.htm

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Larson, K. D., O. Daugovish and D.V. Shaw. 2009. OPTIMIZING STRAWBERRY PRODUCTION AND FRUIT QUALITY WITH USE OF PROTECTED CULTURE IN SOUTHERN CALIFORNIA. ISHS Acta Horticulturae 842:171-176. Available on line at: http://www.actahort.org/books/842/842_22.htm

Daugovish O., S. Fennimore and M. Mochizuki. 2008. Integration of Oxyfluorfen into Strawberry *Fragaria&xananassa*) Weed Management Programs. Weed Technol. 22:685-690.

Daugovish. O., S. A. Fennimore and R. F. Smith. Herbicide Evaluation for Fresh Market Celery (*Apium graveolens*). Weed Technology 21(3):719-723.

Downer, A. J., D. Crohn, B. Faber, O. Daugovish, J. O. Becker, J. A. Menge, and M. J. Mochizuki. 2008. Survival of Plant Pathogens in Static Piles of Ground Green Waste. Accepted to Phytopathology.

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Koike, S. T., Daugovish, O., and Downer, J. A. 2006. Sclerotinia petiole and crown rot of celery caused by Sclerotinia minor in California. Plant Disease 90:829.

Daugovish, O. J. Downer, O. Becker, G. Browne and J. Dunniway. 2004. Mustard-derived biofumigation for vegetable crops and strawberries. 'Agroindustria, revista quadrimestrale'. (Journal of the Italian Institute for Industrial Crops. ISCI, Bologna, Italy) 3:335-338.

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Daugovish. O., D. J. Lyon and D. Baltensperger 1999. Cropping systems to control winter annual grasses in winter wheat (*Triticum aestivum*). Weed Technol. 13:120-1261

UC peer-reviewed

During 2016-2019

UC IPM Cilantro & Parsley Pest Management Guidelines, update. 2019. Co-authored Pathology and Weed Management sections. Available on -line at: https://www2.ipm.ucanr.edu/agriculture/cilantro-and-parsley/

UC IPM Pest Management Guidelines Strawberry. UC ANR Publication 3468, available on line at: https://www2.ipm.ucanr.edu/agriculture/strawberry/. My role: as part of crop leadership team, worked with UC IPM authors to develop updates and new chapters. Author of 3 chapters: 1) Weeds, 2) Non-Fumigant Alternatives for Soil Disinfestation

(new) and 3) Characteristics of Public Strawberry Cultivars Commonly Grown in California. I also contributed content to 'Lewis mite' section in 'Entomology' chapter.

Smith R. and O. Daugovish. 2016. Pest Management in Peppers: Herbicide treatments. Available on –line at: http://ipm.ucanr.edu/PMG/selectnewpest.peppers.html

Smith R. and O. Daugovish. 2015. UC IPM guidelines: Cilantro /parsley: Weeds chapter. Available on-line at: http://www.ipm.ucdavis.edu/PMG/r112700111.html and http://www.ipm.ucdavis.edu/PMG/selectnewpest.cilantro-parsley.html

Daugovish O. and M. Bolda. 2015. UC-IPM Caneberry. Revised WEEDS chapter, including pesticide update. Available on line at http://www.ipm.ucanr.edu/PMG/selectnewpest.caneberry.html

Daugovish O. and R Smith. 2013. UC IPM Pest Management Guidelines: CELERY. I Co-authored 'Weeds' section and reviewed and edited other chapters. Available on-line at: http://www.ipm.ucdavis.edu/PMG/selectnewpest.celery.html

Smith R. and O. Daugovish. Pepper IPM Guidelines. 2012. Available on-Line at http://www.ipm.ucdavis.edu/PMG/selectnewpest.peppers.html

***In* UC ANR Strawberry Pest Management Guidelines 2012 contributed to three chapters:**

1. Fennimore S., O. Daugovish and R. Smith. 2012. Weeds (four sections)

2. Bolda, M. O. Daugovish, S.. Koike, K. Larson, and P. Phillips. 2012. General Information.

3. Bolda, M., O. Daugovish, S. Koike, K. Larson and P. Phillips. 2012. Year-Round IPM Program. Also, reviewed and edited all other sections. Available on line at: http://www.ipm.ucdavis.edu/PMG/selectnewpest.strawberry.html

Koike, S. E. Natwick, O. Daugovish, A. Poeng and T. Turini. 2012. Cole Crops Year-Round IPM Program. Available on line at: http://www.ipm.ucdavis.edu/PMG/TEST/ColeCrops/C108/m108yi01.html

Koike, S. T, C.T. Bull, M. P. Bolda and O. Daugovish. 2012. Organic Strawberry production manual. UC ANR PUB 3531. 160 pp. Available on line at: http://anrcatalog.ucdavis.edu/Items/3531.aspx

Smith, R., J. Bi, M. Cahn, M. Cantwell, O. Daugovish, S. Koike, E. Natwick, and E. Takele. 2010. Cilantro production in California. University of California • Division of Agriculture and Natural Resources Publication # 7236.

Daugovish O. and M. Bolda. 2009. UC IPM guidelines for Caneberry; Weeds section. Available on line at: http://www.ipm.ucdavis.edu/PMG/selectnewpest.caneberry.html

Smith R., R. Bugg. M. Gaskell, O. Daugovish and M. Van Horn. 2011. Cover Cropping for Vegetable Production: Grower Handbook. 2011. 90 page book. Editor and co-author of 5 chapters.

Smith. R., O. Daugovish. C. Bell and T. Lanini. UC PMG-Peppers: Weeds. 2009. UC ANR #3460 Available on –line at: http://www.ipm.ucdavis.edu/PMG/r604700111.html

Daugovish et al. 2011. Year–round IPM Program for peppers. Worked as a part of crops team to develop this IPM publication. Available on Line at : http://www.ipm.ucdavis.edu/PMG/C604/m604yi01.html

Le Strange. M., M. Cahn, S. Koike, R. Smith. O. Daugovish, S. Fennimore., E. Natwick, S. Dara, E. Takele and M. Cantwell. 2010. Broccoli Production in California (ANR Publication 7211), Available on line at http://anrcatalog.ucdavis.edu/pdf/7211.pdf

Daugovish et al. 2007. Vegetable Crops: Planting and harvesting dates. UC ANR Pub. #2282

Smith R. and O. Daugovish,. 2007. UC Pest management guidelines for pepper. UC ANR Pub. #3460.

Daugovish O. et al. IPM for Cole crops. 2007. Weed IPM UC ANR Pub. #3442.

Daugovish O. and others participating Weed Workgroup members. 2004. (S. Fennimore – Editor.) UC Weed Susceptibility chart. ANR Publication, updated annually. Available on-line at: http://ucce.ucdavis.edu/specialsites/weed%5Fsept/

Daugovish et al. 2007. Celery production in California. UC ANR. Pub. #7220

Daugovish et al. 2008. Cabbage production in California Pub. UC ANR #7208.

Smith et al. 2008. Leaf lettuce production in California. UC ANR Pub.#7216 (co-authored)

Daugovish et al. 2008. Strawberry year-around IPM program. 2007. Available on-line http://www.ipm.ucdavis.edu/PMG/C734/m734yi01.html

Book chapters (peer-reviewed)

Daugovish et al. 2014. 'Vegetable crops'. (Author of four sections, contributed references, and images. *In* Principles of Weed Control. ISBN: 978-0-692-30482-2. This electronic book is the most comprehensive textbook for weed control the Western United States. Available at: http://ucanr.edu/filevault/fileview.cfm?filenum=45996&password=YORBGX

Daugovish, O. et al. 2014. Increased number of drip tapes to enhance efficacy of fumigation and irrigation. *In* Moving the needle – accomplishments of the national strawberry sustainable initiative. Pp.38-40. Available on-line at http://strawberry.uark.edu/nssiweb.pdf

Daugovish O. 2007. "Mustard-Derived Biofumigation for Soil Borne Pests: A Review and Case Studies in California", *In:* AGRICULTURA SUSTENTABLE: Técnicas y Productos de Bajo Impacto Ambiental (International Symposium of Sustainable Agriculture).

Non-peer reviewed

Web site postings

More than **60** (*including eight in English and two in Spanish during review period*) of my slide shows/presentations and videos have been posted to http://ceventura.ucanr.edu/ under three of my web pages (strawberry, vegetables and caneberry). More than **300** postings from guest speakers that contributed to my collaborative outreach program have been posted to that site. The site receives ~3,000 hits/annually.

During 2016-2019 only:

Daugovish O. and S. Fennimore 2018. Can herbicides applied under TIF cause strawberry phytotoxicity? http://ceventura.ucanr.edu/Com_Ag/Strawberry/Recent_Meetings/

Daugovish O. et al. 2018. Progress in Anaerobic Soil Disinfestation (ASD) posted to my strawberry website under 'recent meetings' (in addition to four guest speaker presentations) http://ceventura.ucanr.edu/Com_Ag/Strawberry/Recent_Meetings/

Daugovish, O, B. Faber and J. Whiteford. BMPs for managing runoff from plastic-covered tunnels. 2019. On-line guidelines available in English: http://ceventura.ucanr.edu/files/304038.pdf and Spanish http://ceventura.ucanr.edu/files/304039.pdf

Daugovish, O., M. Bolda and S. Dara. Sulfur damage to strawberry plants. Added to bi-lingual Strawberry Disorder website on 11/9/18. Available on line at: https://ucanr.edu/sites/sdim/Chemical_Injury/Sulfur_Damage_to_Strawberry_Plants/

Daugovish. O. 2018. Nutsedge management in strawberry and four presentations of guest speakers were added to UCCE-Ventura website under "Strawberry recent meetings' on 10/8/18; available on line at: http://ceventura.ucanr.edu/Com_Ag/Strawberry/Recent_Meetings/17th_Annual_Strawberry_Growers_Meeting/

Daugovish. 2018. 'Organic fatty acid herbicide' posting added to UC ANR 'Strawberry Disorders' web site on Feb 10, 2016. Available on-line at: http://ucanr.edu/sites/sdim/Chemical_Injury/Fatty_acid_organic_herbicide/

Daugovish O. et al. Strawberry disorder identification and management. Two new entrees during 2014-2016. Available at: http://ucanr.edu/sites/sdim/

Daugovish, O. 2018. Guidelines to water quality for strawberry (bilingual publication) had been posted on my web sites under 'strawberry-water' and all hard copies has been distributed acquired and used in Ventura and S. Barbara counties. Available on-line at : http://ceventura.ucanr.edu/files/154573.pdf (English) and http://ceventura.ucanr.edu/files/154574.pdf (Spanish)

Blogs

During 2016-2019:

Daugovish. O. Drip-applied Kerb (Pronamide) in lettuce. 2019. UC Weed Science Blog, available at: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=29259).

Daugovish. O. 2017. Spreading mulch or spreading weeds? UCD blog , Jan 17, available at: http://ucanr.edu/blogs/blogcore/createpost/postedit.cfm?postnum=22969

Bolda, M. S. Koike and O. Daugovish. A Review on Anthracnose Disease Caused by Colletotrichum acutatum in Strawberry. Available on line at: http://cesantacruz.ucanr.edu/Strawberry_Nursery_Plant_Production/Blog_In_Spanish/?blogpost=20250&blogasset=41579. I contributed content and images.

Daugovish O. 2016. Continuation of organic herbicide 'Suppress' story in Southern California. UC Davis Weed Science blog, Feb 9., Availbale on –line at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=20169

Daugovish, O. 2016. Cover cropping tunnel post rows helps in soil and weed management. UC Davis Weed Science blogs, Feb 8th , 2016. Available in –line at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=20056

Daugovish. O. 2014. Yellow nutsedge control with drip fumigation and S-metolachlor in strawberry. Available on line at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=15494

Daugovish O. 2015. Using organic herbicides in production fields and non-crop areas. Topics in Subtropics. UC ANR publication. Nov 2015. Available on-line at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=19372

Daugovish O. 2015. ASDoing the weeds. UC Weed Science blog on line at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=19242

Daugovish. O. 2014. Separating herbicide injury symptoms from other problems in strawberry. UC Weed Science blog on line at: http://ucanr.edu/sites/wric3/?blogpost=13983&blogasset=32026

This blog is #5 most read ANR blog and has ~170,000 hits or page views/year

Daugovish. O. 2011. "Can herbicides be activated with drip-only irrigation? UC-Davis Weed science blog. Available on-line at http://ucanr.org/blogs/UCDWeedScience/

Posts to Ventura County UCCE blogs based on my program (>120, not listed, available upon request) generate 5,367 direct and 42,219 indirect hits per year

Blogs that I authored for others or provided information that highlighted my collaborative programs:

Daugovish O. S. Fennimore and M. Bolda. 2013. Chateau herbicide use in strawberry. UCCE Santa Cruz blog.
Daugovish. O. Separating herbicide injury symptoms from other problems in strawberry. UC Davis Weed Science Blog.
Weed management in caneberry tunnels http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=10987
Partners of the Americas- Dominican Republic. Ventura UCCE blog. http://ceventura.ucanr.edu/

New way to manage weeds in caneberry growing tunnels – Caneberries Pest Management Guidelines update- UC-IPM blog 6/3/2013
O. Daugovish. 2011. "Can herbicides be activated with drip-only irrigation? I was invited to post to UC-Davis Weed science blog and made a post on Aug 29, 2011. Available on-line at http://ucanr.org/blogs/UCDWeedScience/
O. Daugovish. 2011. Yellow nutsedge growth in plasticulture systems. Nov 3. Available on-Line at: http://ucanr.org/sites/wric3/?blogpost=6121&blogasset=32026

'Highlights of the 8th North American Strawberry Symposium'- Ministry of Ag., Food and Rural Affairs, Ontario, Canada. On-line at: http://www.omafra.gov.on.ca/english/crops/hort/news/allontario/ao0315a1.htm

Researchers join forces in a new project. 2014 Hansen REC blog. Posted by S. Bruzzone-Miller on 7/9/14, available on line at: http://ucanr.edu/blogs/Hansen/

Other non-peer publication including printed articles, UC ANR and industry publications with state, national and international circulation

During 2016-2019:
Daugovish O. and S. Fennimore. 2019. Is oxyfluorfen safe in strawberry when impermeable film is used? CAPCA Applicator Alerts IV (2):6-7
Daugovish, O., M. Bolda, A. Howell, G. Ferrari and P. Henry. 2018. Chemigation with metam at the end of strawberry season can help reduce infestations of nutsedge and soilborne pathogens. CAPCA Adviser XXI (6): 58-62. Available on line at: https://capca.com/publication/december-2018-adviser-magazine/

O. Daugovish. 2018. Herbicide limits planting following cilantro. California Ag today. On line at: https://californiaagtoday.com/

Bolda, M. S. Koike and O. Daugovish. 2017. Antracnosis de la fresa. Production guideline in Spanish, published by CSC (#14) and reaches over 800 clientele.

Bolda, M. S. Koike and O. Daugovish. 2017. Anthracnose of strawberry. Production guideline published by CSC (#14) and reaches over 800 clientele.

Daugovish, O., B. Faber, E. Takele, J. Whiteford and L. Wu. 2018. Stormwater runoff from plastic tunnels: What can be done to improve runoff quality and help meet regulations? CAPCA Advisor XXI (5): 58-60. Available on line at: https://capca.com/publication/october-2018-adviser-magazine/

Daugovish O. A, Howell, S. Fennimore and J. Rachuy. 2017. Effects of prometryn applied in cilantro on four following vegetable crops. CAPCA Briefs. Aug 2017.

Daugovish O. 2016 . 2018. Reducing stormwater runoff from plastic tunnels. Farm Bureau Newsletter. VOLUME XLX, No. 3:2-3; Available on -line at: http://files.constantcontact.com/46f67aab001/df1bd63a-3502-41ea-a30d-40bcc0cd836e.pdf

Daugovish O. 2016 . Recycled coffee grounds show promise as soil amendment. Farm Bureau Newsletter. VOLUME XLVIII, No. 6 Dec 2016.

Daugovish O. 2015 Organic herbicides in production fields and non-crop areas. Farm Bureau newsletter column article. Available on-line at: http://origin.library.constantcontact.com/download/get/file/1102643162980-212/Farm+Bureau+Newsletter+11-15.pdf

Daugovish O. J. Muramoto, and R. Smith. 2015. Organic pest management options: Anaerobic soil disinfestation and control with new organic herbicide. CAPCA advisor XVIII no. 4:44-46

Caron , J., O. Daugovish et al. 2015. Improving Irrigation Management through Scientifically-Proven Results. Hortau brochure, an industry publication on irrigation efficiency.

Daugovish O. 2015. Primocane blackberry management provides flexibility in fruit production. REC Highlights (Hansen REC).

Daugovish. O. 2014. Ventura to host international strawberry conference. Farm Bureau newsletter column, available on line at: http://origin.library.constantcontact.com/download/get/file/1102643162980-212/Farm+Bureau+Newsletter+11-14.pdf

Cahn M., O. Daugovish and M. Bolda. 2014. Drip establishment of strawberries on the Central Coast. Central Coast UCCE newsletter Nov 2014. Extension publication based on collaborative trial that we carried out with Wal-Mart grant funding.

Howell A. and O. Daugovish. 2014. Biocontrol of Lewis and two –spotter spider mites. UC IPM, available at http://www.ipm.ucdavis.edu/PDF/PMG/AnnaHowell.pdf

Daugovish O. 2014. Primocane blackberries can provide flexibility in fruit production. Farm Bureau. XLVI 3-5

Howell A. and O. Daugovish. 2014. Management of Lewis spider mite in strawberry. CAPCA Adviser. XVII 1:26-29

Daugovish O. et al. 2014. Irrigation field day proceedings booklet. (Oxnard, 80 copies distributed, Santa Maria, 95 copies distributed).

Takele E., O. Daugovish and M. Vue. 2013. UC ANR Cost of production studies for fresh market peppers.

Takele E., O. Daugovish and M. Vue. 2013. UC ANR Cost of production studies for processed peppers.

Takele E., O. Daugovish and M. Vue. 2013. UC ANR Cost of production studies for cabbage.

Takele E., O. Daugovish and M. Vue. 2013. UC ANR Cost of production studies for celery.

Mochizuki. M., L. Corkidi, O. Daugovish, J. Newman, D. Merhaut and D. Haver. 2012. Best Management Practices to Protect Water Quality. A guide for California strawberry growers. I worked with SRA (who led he project) and a team of colleagues to secure funding, develop an illustrated bi-lingual guide, provided materials for the guide, including images.

Daugovish O. 2012. Proceedings of the 2012 field day on fumigants and alternatives: Evaluation of non-fumigant alternative in a filed infested with Macrophomina and Fusarium. pp. 3-7.

Daugovish. O. 2012. Recycled plastic mulch shows promise. Farm Bureau publication 8:2.

Daugovish. O. 2012. Bird control with falconry. CAPCA Advisor. 4:36-38

Daugovish O. 2012. Not all salts are created equal. Farm Bureau publication. 6:2.

Daugovish O. and A. Howell. 2011. Spider mites require new control strategies. Farm Bureau newsletter column. XLIII 12:3.

Koike S., T. Gordon, O. Daugovish and H. Ajwa. 2013 Production Guidelines: Fusarium Wilt of Strawberry. California Strawberry Commission Publication.

Koike S., T. Gordon, O. Daugovish and H. Ajwa. 2013 Production Guidelines: Charcoal Rot of Strawberry. California Strawberry Commission Publication.

Corkidi L., Donald J. Merhaut, Maren Mochizuki, Toan Khuong, Julie P. Newman, Oleg Daugovish, Ben Faber, José de Soto, Arturo A. Keller, María E. Sánchez-Coronado, Jeff Bohn, and Mike Evans. 2013. Plant Selection for Vegetated Buffers: Plant Size vs Nutrient Uptake Efficiency. UC NFA News 17(2) 1-4.

Daugovish. O. 2013. Herbicide resistant weeds in your neighborhood. Farm Bureau publication 7:2-3. Publication reaches about 2400 subscribers

Daugovish. O. 2013. Herbicide resistance in weeds. In Topics in Subtropics - a UC ANR publication. Vol 12.

Caron. J. , S. Gumiere, J. Gallichard, S. Pepin, S, Jutras, S. Allaire, J. Fortin, R. Harbut, W. Bland and O. Daugovish. 2012. A new approach to irrigation. International Innovation-North America, Jan. 84-87.

Daugovish. O. 2011. Lygus Monitoring and Management in Strawberries in Ventura County, an article for Vegetable West magazine: June issue.

Daugovish O. E. Takele, K. Klonsky and R. De Moura 2011. Sample costs to produce strawberries (South Coast region – Ventura County). Available on-line at: http://coststudies.ucdavis.edu/files/Strawberry_SC_VC_2011.pdf

Daugovish O. 2010. 'Strawberry plants can be established with less water and minimal runoff'. An article for the Santa Barbara County newsletter

Daugovish. O., S. Koike, T. Gordon. M. Bolda, and K. Subbarao. 2010. Strawberry plant collapse investigation in California. California Fresh Fruit & Raisin News Magazine. May issue 2010.p.7-9.

Daugovish. O. 2010. Strawberry plants can be established with less water. Farm Bureau newsletter April 2010: p 4.

Daugovish. O. 2011. Anaerobic soil disinfestation: a non-fumigant alternative shows promise. Farm Bureau newsletter. XLIII- 2

M. Mochizuki and O. Daugovish. 2010. Coordination is key for spotted wing drosophila management. Farm Bureau newsletter XLII 10:2-4

Muramoto et al. (I'm co-author) Webinar highlighting our ASD work had 77 participants from 9 countries on March 30, 2011. The webinar is available online through Youtube at http://www.youtube.com/watch?v=9TQmVQdaOVI and had over 700 hits by Sept 30 2011.

Epstein, L., D. Marcum. M. Bolda and O. Daugovish. 2007. Control of anthracnose in strawberry nurseries by conversion to drip irrigation. UC ANR Core issues grant report http://ucce.ucdavis.edu/cig/annualreportview.cfm?propnum=106

Daugovish O. and S. Fennimore. 2007. Control tactics for difficult weeds in strawberry. CAPCA Adviser 5:64-67

Daugovish O. and S. Fennimore. 2007. Control tactics for difficult weeds in strawberry. CAPCA magazine.

Lanini, T. S. Fennimore, M. LeStrange, O. Daugovish, R.Smith, K. Hembree and J.Rachuy. 2007. Current Weed Control Research in Vegetable Crops. California Weed Science Society Publication.

Daugovish O. and W. Gubler. 2006. Pre-plant dipping of strawberry transplants for control of *Colletotrichum acutatum*. California Strawberry Commission Annual Research Report, 2006.

Daugovish O., S. Koike, K. Subbarao, and M. Mochizuki. 2006. Sclerotinia spp. survey in Lettuce in Ventura County. California Lettuce Research Board Report. p. 102-105

S. Fennimore, Z. Kabir, H. Ajwa ,O. Daugovish, K. Roth, and J. Valdez. 2004. Chloropicrin and Inline dose-response under VIF and HDPE film: Weed control in California. USDA Methyl bromide alternatives newsletter 10:12-15.

S. Fennimore, Z. Kabir, H. Ajwa , O. Daugovish, and K. Roth. Chlorpicrine and InLine dose effects on yellow nutsedge and knotweed propagule viability under impermeable film. Proceeding of MBAO International Conference, San Diego, 2005

Daugovish et al. Biofumigation for vegetable crops. Proceedings of the Organic production short course, Ventura, CA, 4 Aug 2005.

Larson K. D. Shaw, J. Esparza and O. Daugovish. Yield performance of strawberries using protected culture in Southern California, 2002-2004. 'The Pink Sheet' Strawberry Commission publication. February 2006.

Larson K. D. Shaw, J. Esparza and O. Daugovish. Qualitative evaluation and estimated costs and returns for protected culture of strawberry in Southern California. 'The Pink Sheet' Strawberry Commission publication. February 2006.

Daugovish et al. Cover crops performance evaluation in Ventura County : 4 –year summary. Proceedings of the Organic production short course, Ventura, CA 4 Aug 2005.

Fennimore S. and O. Daugovish, and H. Ajwa. Weed control in strawberries with fumigants. Proc. of the "Strawberry production with alternative fumigants: cost-effective management of soil-borne pests and weeds" short course, Camarillo and Watsonville, CA June 7-9 , 2005. pp.1-5

Ajwa, H., S. Fennimore, S. Shem-Tov, O. Daugovish and S. Klose. Fumigant volatilization and strawberry production under various tarps. Proc. of the Oxnard MBr Alternatives Field day. p.2-6. Oxnard , CA, 24 March, 2005.

Shem-Tov S., S. Fennimore, H. Ajwa, and O. Daugovish. Demonstration of weed control with drip-applied Methyl Bromide fumigants at Oxnard, CA. Proc. of the Oxnard MBr Alternatives Field day.p.12. Oxnard , CA, 24 March, 2005

Videos

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Daugovish O. 2015. Primocane blackberry production in southern Califiornia. California Fresh Fruit web-site on-line video. Available at http://calfreshfruit.com/

Daugovish. O. 2014. Doubling number of drip tape for strawberry irrigation. UCCE video , available at: http://www.youtube.com/watch?v=K2TNXAGK_TM

Daugovish O. 2014. Anaerobic soil disinfestation applied to strawberry beds, an extension video for bed-applied ASD technology. Available at: https://www.youtube.com/watch?v=wR_JdJuRdiI&feature=youtu.be

Daugovish O. 2104. Saving Water with More Drip: Doubling the number of drip tapes in strawberry beds, NSSI video, available at https://www.youtube.com/watch?v=G_e3q_v6jYU&feature=youtu.be

Daugovish. O. 2010.'Yellow nutsedge management in strawberry' was recorded by the American Society of Agronomy and is available at: http://a-c-s.confex.com/crops/2010am/webprogram/Paper57457.html

Stories about my work in industry/UC/other publications:

My work used in other publications: San Francisco Chronicle /SF Gate: Organic Removal of Nut Grass by Deborah Green, Demand Media refers to my work published in Weed Technology. Available on line at: http://homeguides.sfgate.com/organic-removal-nut-grass-21649.html

Article about the $ 2. 6 mln. USDA Grant (Shannon, PI, I'm a co-PI) on which I collaborate was highlighted at Santa Cruz Sentential, available athttp://www.santacruzsentinel.com/community/ci19195156

UC estimates costs for growing strawberries on coast, An ANR Headline article, highlighting our recently developed production cost publication in strawberry. Available at: http://ucanr.org/news/?blogpost=7443&blogasset=44546

Sample costs to produce strawberries are also highlighted in a Western Farm press article (May 9, 2012, Available on line at: http://www.calstrawberrynews.com/?p=20475

New cost studies for bell peppers, celery and cabbage production in Ventura County ANR Headline article, highlighting four of our recently developed production cost publication in vegetable crops Available at: http://ucanr.edu/?blogpost=12808&blogasset=60503

Koike S. T, C.T. Bull, M. P. Bolda and O. Daugovish. 2012. Organic Strawberry production manual. UC ANR PUB 3531. 160 pp. Available on line for purchase at: http://anrcatalog.ucdavis.edu/Items/3531.aspx. The manual has been translated into Mandarin in 2014

Ontario Berry grower – a publication of the Ministry of Agriculture of Ontario, Canada: Highlights of the 8th North American Strawberry Symposium Available on line at: http://www.omafra.gov.on.ca/english/crops/hort/news/allontario/ao0315a1.htm

White, H. 2016. At Hansen Agricultural REC, better blackberries and soil disinfestation alternative. Cal Agriculture 70 (3): 104-106. I provided information, images and edited the story multiple times. Available on-line at: http://ucanr.edu/calagfiles/fullissues/CAv070n03.pdf

Hise, P.2016. Why does a strawberry grown down the road cost more than one grown in California? Washington Post. 6/22/2106, Available on –line at : https://www.washingtonpost.com/lifestyle/food/why-local-food-costs-more-a-strawberry-case-study/2016/06/20/c7177c56-331f-11e6-8ff7-7b6c1998b7a0_story.html I provided information for the story.

Hulse. J. 2015. Newer, better blackberries gain a foothold. Central Coast Farm and Ranch. 26 Sept. I provide information via interviews, research data, images and corrections prior to publication. The story reached >3000 people and generated a lot of interest among clientele.

UC-delivers stories

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Koike. S and O. Daugovish. 2010. Research on new celery virus identifies control measures.

Koike, S., Daugovish, O., Gordon, T., Ajwa, H., Bolda, M., and Subbarao, K. 2010. UC research identifies new emerging soilborne diseases of strawberry.

Converting urban yardwaste for avocado root rot management. Co-author of the story along with UCCE advisors B. Faber and J. Downer. Available on the web at :http://ucanr.org/delivers/impactview.cfm?impactnum=577

Daugovish O. and S. Fennimore. NEW WEED CONTROL STRATEGIES IN STRAWBERRY ARE EFFECTIVE. Available on the web at: http://ucanr.org/delivers/impactview.cfm?impactnum=614

Project reports to granting agencies and industry:

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Fennimore S. and O. Daugovish. 2019. Weed Management in Strawberries 2017 and 2018. CSC production Research Report

Gordon, T. S. Koike and O. Daugovish. 2017. Management of diseases caused by Fusarium oxysporum and Verticillium dahliae. CSC production Research Report pp. 13-25.

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Qin, R., O. Daugovish, H. Ajwa and J. Gerik. 2014. Fumigation efficiency improvement with TIF mulch at reduced rates and additional lines placements. National Strawberry Sustainability Initiative Program (funded by Wal-Mart foundation) Final report.

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Martin F., S. Fennimore, A. Putman, M. Martin, M. Matson, F. Melton, R. Goodhue, P. Henry, S. Vougioukas, N. Dorn, C. Greer, O. Daugovish, A. Biscaro and M. Stanghellini. 2019. Site specific pest management in strawberry and vegetable cropping systems. Proceedings of MBAO Intl. Conference. 24:1-4; San Diego, CA

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Daugovish O., T. Gordon, A. Pastrana-Leon, K. Elfar. P. Henry and G, Ferrari. 2019. Effect of Fusarium inoculum density on strawberry performance. Proceedings of MBAO Intl. Conference. 12:1-2. San Diego, CA.

Daugovish. O., A. Howell, S. Fennimore and J. Rachuy. 2018. Effects of Caparol applied in cilantro on four following vegetable crops. Proceeding of the 70th Annual conference of eth California Weed Science Society.

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Martin, F. S. Fennimore, A. Putman, O. Daugovish, A. Biscaro, S. Koike, T. Gordon, F. Melton, L. Johnson, R. Goodhue, M. Stanghellini and N. Dorn. 2017. Site-specific soil pest management in the strawberry production system. MBAO proceedings. 37:1-2. San Diego Nov. 13-15 2017.

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Biscaro. A. M.Cahn, T. Hartz, R. Smith, O. Daugovish and N. Bradford. 2015. Developing wed-based irrigation and nitrogen management software for celery production. Proceedings of the VIII International Symposium on Irrigation of Horticultural Crops. Lleida, Spain; June 08-11).

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08-Oct-2019

Dear Dr. Daugovish:

It is a pleasure to accept your manuscript entitled "Stormwater runoff management from plastic tunnels" in its current form for publication in the California Agriculture journal. The comments of the reviewer(s) who reviewed your manuscript are included at the foot of this e-mail.

Thank you for your fine contribution. On behalf of the Editors of the California Agriculture journal, we look forward to your continued contributions to the Journal.

Sincerely,

Jim Downing
Executive Editor, California Agriculture journal jdowning@ucanr.edu

CALIFORNIA STRAWBERRY COMMISSION

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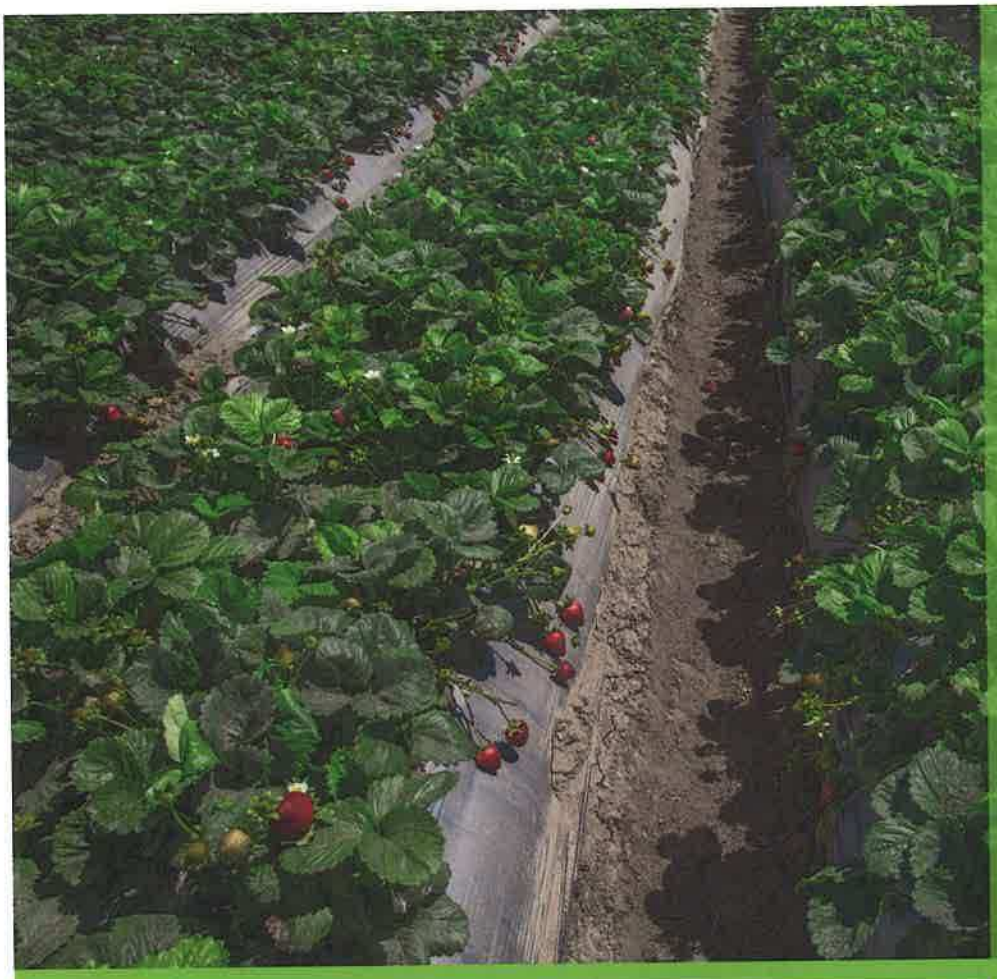


Production Guideline

The California Strawberry Commission Production Guidelines are produced in cooperation with scientists who conduct research related to strawberry production. These guidelines are a tool for growers, providing critical scientific background information on diseases and pests common to strawberry production in California. For copies of this guideline or others in the series, visit www.CalStrawberry.com.

Anthracnose of Strawberry

Anthracnose is a disease that occurs wherever strawberries are produced. In California, the disease occurs sporadically and its importance can vary greatly. In some seasons the disease is very destructive, resulting in plants with reduced productivity, unmarketable fruit with lesions, and even plant death. In other years, anthracnose is a minor issue and may be hard to find in the field. Historically the disease is of little concern in California's central coast fruit production fields but may be more damaging to crops in the south coast region. The severity of anthracnose is dependent on the extent to which transplants are contaminated with the pathogen and the amount of overhead irrigation and rain that falls on the planted crop.

Symptoms

The pathogen can infect many different parts of the strawberry plant, though some infections are more common and important than others.

In This Issue

- Anthracnose incidence varies among California strawberry production regions and years and is dependent upon nursery stock cleanliness and environmental conditions.
- Moderate and warm temperatures and wet, humid conditions encourage pathogen spread and disease development.
- Sanitation during strawberry multiplication in the nurseries, pre-plant treatment of transplants, minimizing the use of sprinklers to establish transplants, and application of post-plant foliar fungicides can help manage anthracnose disease.

Root infections, though not commonly seen, result in rotted, non-functional roots that cause the plant to wilt. On occasion, the fungus can also infect the inner tissues of the crown, resulting in an internal red brown discoloration and again, plant wilting. Therefore, root and crown anthracnose disease (Table 1) may resemble symptoms caused by soilborne pathogens such as *Phytophthora.*

On strawberry leaf petioles, runner stolons, and flower peduncles, the anthracnose pathogen causes oval to elongated lesions that range in color from brown to gray to black (Table 1; Figure 1). If conditions are suitable for development of the fungus, the lesions will contain numerous tiny orange masses of spores (Figure 2). Infected leaves can form round, oval, or irregularly shaped brown spots which likewise may produce the orange spore masses.

Strawberry flowers can also become infected, turn brown, and bear the orange spore masses (Figure 3). In some cases, the flower may be killed. Green immature and red ripe fruit show perhaps the most readily identified symptoms. Such fruit develop round to oval shaped, sunken, brown lesions (Figure 4). Lesions are usually firm in texture and may be surrounded by a dark border. As disease develops, the orange spore masses form extensively in the fruit lesions (Table 1; Figure 5).

Pathogen

Anthracnose on strawberry in California is primarily caused by the fungus *Colletotrichum acutatum,* though strawberry is also host to additional species including *C. gloeosporoides* and *C. fragariae. Colletotrichum acutatum* is found worldwide on strawberry and many other crop and weed hosts. Some of these other hosts include almond, celery, delphinium, pepper, pine, tomato, walnut, zinnia, chickweed, fiddleneck, and vetch. It is unclear to what extent *C. acutatum* from non-strawberry hosts can infect and cause damage to strawberry.

Strawberry tissue	Symptoms	Orange spore masses?
root	discolored, rotted roots, causing leaves to wilt	no
crown	discolored internal crown, causing leaves to wilt	no
leaf petiole	dark brown, elongated lesions	yes
leaf blade	gray to brown circular spots	yes
runner	dark brown, elongated lesions	yes
flower peducle (stem)	dark brown, elongated lesions	yes
flower	discolored tissue, causing flower to shrivel	yes
fruit	brown, oval to round, firm, dry sunken spots	yes

Table 1. Anthracnose can cause varying symptoms on different strawberry tissues. Orange spore masses may or may not be visible depending upon the tissue type.

Figure 1. Anthracnose causes oval, elongated lesions on petioles, runners, and other stem tissue.

Figure 2. Lesions often contain numerous tiny fungal bodies and orange masses of spores.

For example, researchers have found that strawberry isolates of *C. acutatum* are more aggressive and damaging to strawberry than isolates from other hosts. *Colletotrichum acutatum* populations from different hosts show genetic relatedness but are not identical groups, indicating that they are distinct from one another. Therefore, *C. acutatum* is likely composed of diverse strains or sub-types that have some degree of host specialization.

Disease Cycle

Colletotrichum acutatum is not a true soil inhabitant and does not survive for long periods of time in the soil. Studies show that this pathogen, under California conditions, can remain viable on bits of strawberry crop residue in the soil for about nine months. Based on limited survival capability and the pattern and sporadic distribution of disease when it does develop, disease occurrence in fumigated production fields is primarily due to infested or diseased strawberry transplants. Disease outbreaks in production fields occur when an infected transplant develops symptoms and the pathogen produces fungal fruiting bodies and spores on the infected tissues. Spores form in a sticky orange ooze and are almost exclusively spread by splashing water, so there must be rain or overhead sprinkler irrigation taking place for the spores to be splashed from the initially diseased plant to surrounding healthy ones. With continued favorable weather (moderate temperatures of 60 to 85 degrees F and wet, humid conditions) the spores germinate and infect the surrounding plants, resulting in disease outbreaks. Therefore, if there are no rains during the fruit production period, significant levels of anthracnose disease on strawberry fruit are rare. To a lesser extent, spores can also be spread through physical contact (such as from passing equipment that brushes against the wet, infected foliage). The anthracnose fungus is not spread via airborne spores, which is the case for powdery mildew and Botrytis gray mold.

Figure 3. Infected flowers can turn brown and bear orange spore masses.

Figure 4. Infected fruit develop round to oval, sunken brown lesions.

Figure 5. If weather conditions are suitable, fruit lesions will contain mycelium and orange spore masses.

Disease Management

Pre-plant control measures: Because anthracnose—resistant strawberry cultivars are not yet available, the most essential step in preventing this disease in production fields is the use of pathogen-free plants. Therefore, integrated disease management strategies in nurseries are critical. Mother plants should be maintained pathogen-free at every step of multiplication. Irrigating nursery plants using drip systems will decrease disease spread and development. Alternatively, using micro-sprinklers instead of high impact sprinklers could minimize conditions that favor anthracnose, though field research has not yet demonstrated this advantage of micro-sprinkler systems. The use of fungicides as plant dips or foliar sprays is an important tool for minimizing anthracnose. If symptoms develop on transplants, removing diseased plants may also help reduce disease spread to other parts of the transplant field. Transplants coming out of cold storage for planting into nursery fields (and not for fruit production purposes) can be treated with hot water to reduce, though not eradicate, *C. acutatum.* However, if not conducted properly, hot water treatments can damage the plants. See Integrated Pest Management for Strawberries (UC ANR Publication 3351) and other information sources for guidelines on hot water treatments.

Pre-plant soil fumigants likely can reduce *Colletotrichum* populations remaining in soil following disking and incorporating a previously diseased strawberry crop. However, the extent of pathogen survival following the application of materials like chloropicrin and 1,3-dichloropropene + chloropicrin (InLine) has not been well documented for California fruit production fields. Broadcast applications are likely to provide a greater level of control than bed-only fumigation or drip applied materials.

If a strawberry crop is planted into non-fumigated soils that had anthracnose-infected plants the previous season, the subsequent crop is subject to infection from soilborne inoculum. Therefore, crop rotation is recommended and back-to-back strawberry plantings should be avoided. Judicious crop rotation is especially important for organic strawberry since a fumigation step is not possible. Second-year strawberry fields, if infected with anthracnose in year one, will likely have higher levels of disease in year two.

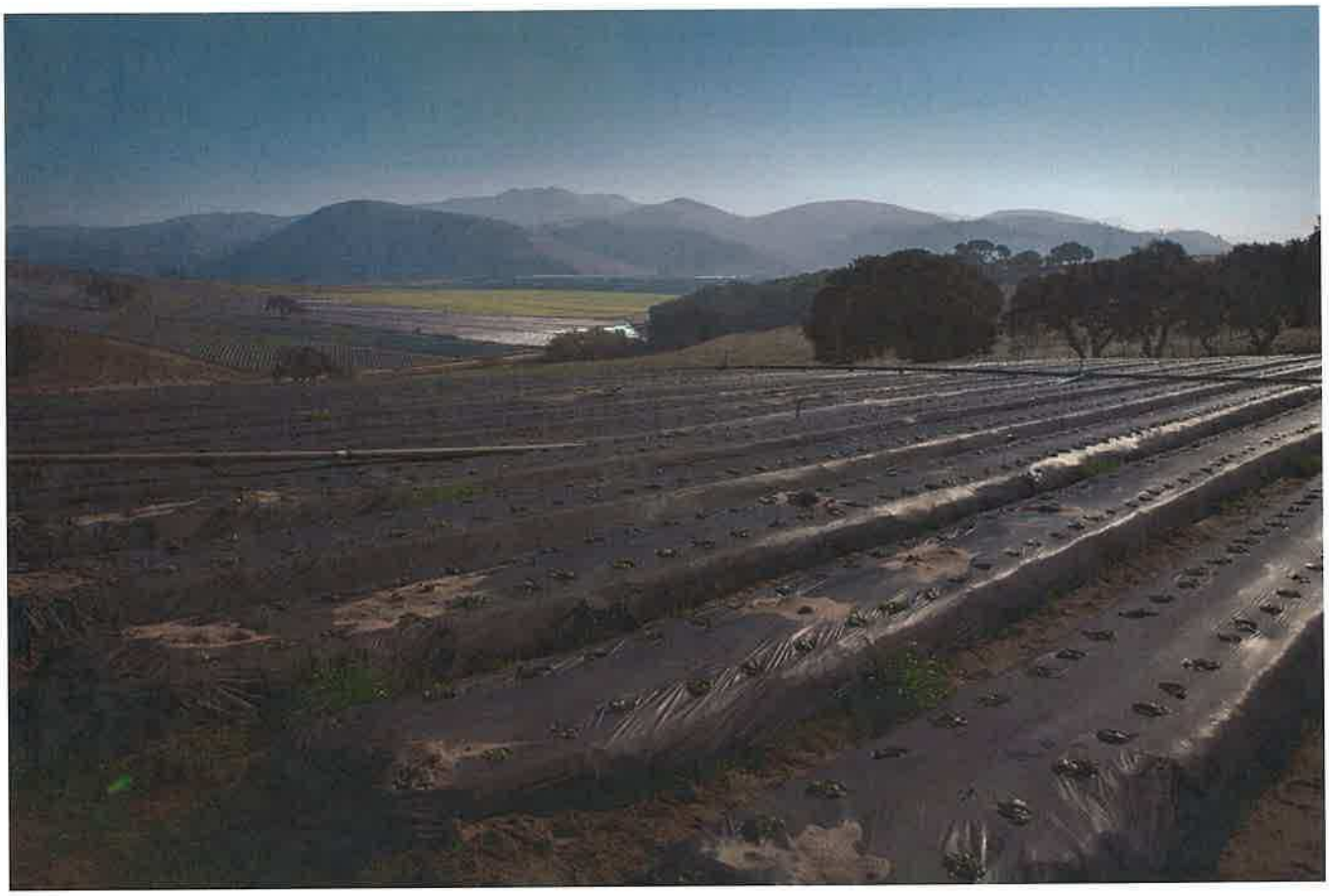
For fruit production fields, treating transplants prior to planting can reduce the level of anthracnose. Thoroughly washing transplants in plain water to remove soil has demonstrated some reduction in anthracnose, likely due to the washing off of fungal inoculum present on the transplants. However, such a treatment could increase the incidence of other diseases, such as angular leaf spot caused by the bacterium *Xanthomonas fragariae.* Dipping transplants in the fungicides Abound (azoxystrobin) or Switch (cyprodinil + fludioxonil) can reduce the incidence and severity of anthracnose. Switch is an effective fungicide with no reports of resistance associated with its use for anthracnose control in California.

Current manufacture recommendations state that plants should be dipped in the fungicide solution for no longer than five minutes and then not stored longer than 12 hours before planting. Abound can also be effective, though there is evidence that some *Colletotrichum* isolates may be resistant to this fungicide. Care should be taken when treating transplants with fungicides, because failure to adhere to treatment recommendations could result in damaged transplants. Before implementing transplant treatments, check with your transplant supplier for guidelines and consult your local Agricultural Commissioner's office and product labels for current status of product registration, restrictions, and use information.

Post-plant control measures: If transplants are established with the use of overhead sprinklers, such irrigations should be ended as soon as possible. Spores produced on infected plants will spread by the splashing water from sprinkler irrigations.

The mechanical spread of spores by equipment passing through the field is of secondary importance. Nevertheless, growers should be aware of the potential of moving spores around on machinery and crews when there are symptomatic plants in the field and the foliage is wet.

A key part of the management strategy is to accurately detect anthracnose in the field. Fruit and stem infections may be readily identified due to the formation of the orange spore masses on lesions. However, if the orange masses are absent, symptoms may look like other diseases or appear to be physical damage. *Colletotrichum*-infected roots and crowns cannot be diagnosed without laboratory tests. Therefore, carefully investigate possible anthracnose cases and consult appropriate professionals and laboratories as needed.



Timely foliar application of the fungicides Captan (captan), Abound (azoxystrobin), and Switch (cyprodinil + fludioxonil) is warranted if wet conditions from rain or extensive fog are anticipated and especially if anthracnose symptoms have been observed and the disease is confirmed. These fungicides are protectants and should be applied prior to extensive disease development.

Currently, there are no organically acceptable fungicides that are effective against anthracnose. Because fungicides are used to manage this disease at both transplant and fruit production stages, it is advisable to develop a comprehensive integrated disease management system that takes into account the fungicide products used in all phases of the strawberry industry.

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Guía de Producción

Las guías de producción se publican por parte de la Comisión de la Fresa de California en cooperación con los científicos que hacen investigaciones relacionados con la producción de fresa. Estas guías son herramientas para agricultores y proveen información científica indispensable sobre enfermedades y plagas comunes en la producción de fresa en California. Para copias de esta guía u otros en la serie, por favor visite www.CalStrawberry.com.

Antracnosis de la fresa

La antracnosis es una enfermedad que ocurre en las regiones productoras de fresa. En California, la enfermedad ocurre esporádicamente y su importancia puede variar. En algunas estaciones, esta enfermedad es muy destructiva, resultando en la reducción de la productividad, fruta con lesiones que no puede ser comercializada, e inclusive mortalidad de plantas. En otros años, la antracnosis es un problema menor que apenas puede encontrarse en el campo. Históricamente esta enfermedad no es una de las principales preocupaciones en la costa central de California, pero puede ocasionar más daños a los cultivos en la región costera Sur. La severidad de la antracnosis depende del grado en el que las plantas están contaminadas con el patógeno y la cantidad de riego por aspersión y de lluvia que cae sobre el cultivo.

Síntomas

El patógeno puede infectar diferentes partes de la planta de fresa, aunque algunas infecciones son más comunes e importantes

Contenidos

- Incidentes de antracnosis varían entre regiones e años de producción de fresas en California y depende de la higiene de las plantas desde los viveros ("nurserias") y condiciones ambientales.
- Las temperaturas moderadas y cálidos además de condiciones húmedas y mojadas promueve la propagación del patógeno y el desarrollo de la enfermedad.
- Desinfección durante el proceso de multiplicación en los viveros, tratamiento de los trasplantes antes de sembrar, minimizar el uso de los rociadores elevados para establecer trasplantes y aplicación de fungicidas foliar después de plantar puede ayudar manejar la enfermedad de antracnosis.

que otras. Las infecciones de las raíces no son generalmente visibles, pero pueden resultar en pudrición y pérdida de funcionalidad que, en última instancia, resulta en la marchitez de la planta. En algunas ocasiones, el hongo también puede infectar los tejidos internos de la corona, resultado en una descoloración de color marrón-rojizo, que también puede desarrollarse en marchitez. Por lo tanto, la enfermedad de antracnosis de la raíz y la corona (Tabla 1) puede tener síntomas similares causados por otros patógenos del suelo como *Phytophthora.*

El patógeno de la antracnosis causa lesiones ovaladas a elongadas de color marrón, gris y negro en los pecíolos de las hojas, los estolones, y los pedúnculos florales (Tabla 1; Figura 1). Si las condiciones son apropiadas para el desarrollo del hongo, las lesiones contienen numerosas masas pequeñas de esporas anaranjadas (Figura 2). Las hojas infectadas pueden formar manchas marrones circulares, ovaladas o irregulares, que también pueden producir las masas de esporas anaranjadas.

Las flores de fresa pueden también pueden ser infectadas, volverse marrones y llevar las masas de esporas anaranjadas (Figura 3). En algunos casos, las flores pueden morir. La fruta verde inmadura y la madura de color rojo quizás muestra los síntomas más fáciles de identificar. Estas frutas desarrollan lesiones de forma circular u ovalada, hundidas, de color marrón (Figura 4). Las lesiones son generalmente firmes en textura y pueden estar rodeadas por un borde oscuro. A medida que la enfermedad se desarrolla, las masas de esporas anaranjadas se forman extensivamente en las lesiones en la fruta (Tabla 1; Figura 5).

Patógeno

La antracnosis de la fresa en California es principalmente causada por el hongo *Colletotrichum acutatum,* aunque la fresa también es huésped de otras especies incluyendo *C. gloesporoides* y *C. fragariae. C. acutatum* se encuentra presente en todas las regiones productoras de fresa, como así también en otros cultivos y malezas. Algunos otros huéspedes

Tejido	Síntomas	¿Masa de esporas anaranjadas?
Raíz	Podredumbre y descoloración de raíces podridas; causa la marchitez de las hojas	No
Corona	Descoloración de la corona interna; causa la marchitez de las hojas	No
Pecíolo de la hoja	Lesiones elongadas marrón oscuro	Sí
Lámina foliar	Manchas circulares gris-marrón	Sí
Estolón	Lesiones elongadas marrón oscuro	Sí
Pedúnculo (tallo) floral	Lesiones elongadas marrón oscuro	Sí
Flor	Tejido descolorido, genera el secado de la flor	Sí
Fruta	Manchas hundidas firmes, secas, circulares a ovaladas, y marrones	Sí

Tabla 1. Antracnosis puede causar varios síntomas en diferentes partes del tejido de la fresa. Masas pequeñas de esporas anaranjadas puede o no puede ser visible dependiendo en el tipo de tejido.

Figura 1. La antracnosis produce lesiones ovales alargadas en los pecíolos, estolones, y otros tejidos del tallo.

Figura 2. Las lesiones producen cuerpos fungosos microscópicos y masas de esporas anaranjadas.

incluyen almendras, apio, Delphinium, pimiento, pino, tomate, nueces, zinnia, tripa de pollo (Stellaria media), Amsinckia menziesii y habas (Vicia spp.). No es claro en qué grado *C. acutatum* puede infectar y causar daño a la fresa desde otros huéspedes. Por ejemplo, investigadores han encontrado que los aislamientos de fresa de *C. acutatum* son más agresivos y dañinos para las fresas, que muestras aisladas de otros huéspedes. Las poblaciones de *C. acutatum* de diferentes huéspedes muestran una relación genética, pero no son grupos idénticos, indicando que son distintos uno del otro. Por lo tanto, *C. acutatum* estaría compuesto por una serie diversa de cepas o sub-tipos que tienen algún grado de especificidad con el huésped.

Ciclo de la enfermedad

Colletotrichum acutatum no es un habitante verdadero y no sobrevive por períodos prolongados en el suelo. Los estudios muestran que este patógeno, bajo las condiciones de California, puede mantenerse viable en porciones del residuo del cultivo de fresa en el suelo por 9 meses. Debido a la limitada capacidad de supervivencia y al patrón y la distribución esporádica de la enfermedad cuando se desarrolla, la ocurrencia en campos fumigados es principalmente debida a la existencia de plantas infestadas o enfermas. El brote de enfermedades en los campos de producción ocurre cuando las plantas desarrollan síntomas y el patógeno produce cuerpos fructíferos y esporas en los tejidos infectados. Las esporas forman un exudado pegajoso naranja que casi exclusivamente se propaga por la salpicadura de agua, por lo tanto, debe haber lluvia o riego por aspersión para que las esporas sean salpicadas desde la planta inicialmente enferma hacia las plantas saludables que la rodean. Mientras el clima continúe favorable (temperaturas moderadas de 60-85 grados F y condiciones húmedas), las esporas germinan e infectan las plantas circundantes, resultando en el brote de la enfermedad. Por lo tanto, si no hay lluvias durante el período de producción de frutas, es difícil encontrar niveles significativos de antracnosis en la fruta. En menor medida, las

Figura 3. Las flores infectadas se vuelven de color pardo (café o marrón) y producen masas de esporas anaranjadas.

Figura 4. Lesiones ovales o circulares y profundas se desarrollan en la fruta infectada.

Figura 5. En condiciones climáticas favorables micelio y masas de esporas anaranjadas se desarrollan en las lesiones del fruto.

esporas también pueden propagarse a través del contacto físico (como en equipos que rozan contra las hojas húmedas infectadas). El hongo causante de la antracnosis no se propaga a través del viento, como en el caso del mildiú polvoriento y la podredumbre de *Botrytis.*

Manejo de la enfermedad

Medidas de control previo al trasplante:
Debido a la falta de cultivares resistentes a antracnosis, el paso esencial en la prevención de la enfermedad en los campos de producción es el uso de plantas libres del patógeno. Por lo tanto, la aplicación de estrategias de manejo integrado de enfermedades en los viveros ("nurserias")es crítica. Las plantas madre deben mantenerse libres de patógeno en cada paso de la multiplicación. La utilización de riego por goteo en los viveros ("nurserias") reducirá la difusión y el desarrollo de la enfermedad. Alternativamente, la utilización de micro-aspersores en vez de aspersores de alto impacto podría minimizar las condiciones que favorecen la antracnosis, aunque las investigaciones en el campo aún no han demostrado esta ventaja. El uso de fungicidas en inmersión o aplicaciones foliares es una herramienta importante para reducir los niveles de antracnosis. Si los síntomas se desarrollan en los trasplantes, la remoción de las plantas infectadas también puede ayudar a reducir la propagación de la enfermedad a otras partes del campo. Las plantas que provienen del almacenamiento frío para su trasplante en viveros ("nurserias") (y no para la producción de fruta) pueden ser tratadas con agua caliente para reducir, pero no erradicar, C. acutatum. Sin embargo, si este tratamiento no es conducido en forma apropiada, el agua caliente puede dañar a las plantas. Para más información consulte *"Integrated Pest Management for Strawberries"* (PublicaciónUC ANR 3351).

Las fumigaciones del suelo previas al trasplante también pueden reducir las poblaciones de *Colletotrichum* que permanecen en el suelo luego del disqueado y la incorporación del cultivo enfermo previo. Sin embargo, el nivel de supervivencia del patógeno luego de la aplicación de materiales como cloropicrina y 1,3-dicloropropina+cloropicrina (InLine) no ha sido bien documentado para los campos de producción de fruta en California. Las aplicaciones en todo el campo proveen mayor nivel de control que las fumigaciones en las camas, o los materiales aplicados a través del sistema de riego por goteo.

Si un cultivo de fresa es plantado en suelos no fumigados que han tenido plantas infectadas con antracnosis en la temporada anterior, el cultivo siguiente se encuentra sujeto a infección desde el inóculo en el suelo. Por lo tanto, se recomienda la rotación del cultivo y evitar el cultivo sucesivo de fresa sobre fresa.

La rotación de cultivos es especialmente importante en la producción orgánica ya que la fumigación no es posible. En los campos de fresas de segundo año, si en el primero se han observado infecciones con antracnosis, es esperable que se registren mayores niveles durante el segundo. Para los campos de producción de fruta, el tratamiento de las plantas previo al trasplante puede reducir el nivel de antracnosis. La remoción del suelo a través del lavado cuidadoso con agua ha demostrado tener un efecto sobre la reducción de la antracnosis, posiblemente debido a la eliminación del inóculo presente en los trasplantes. Sin embargo, este tratamiento puede incrementar la incidencia de otras enfermedades, como las manchas angulares foliares causadas por *Xanthomonas fragariae.* La inmersión de las plantas en los fungicidas Abound (azoxystrobin)

o Switch (cyprodinil + fludioxonil) puede reducir la incidencia y severidad de la antracnosis. Switch es un fungicida efectivo que no presenta registros de resistencia asociada a su uso para el control de antracnosis en California. Las recomendaciones actuales del fabricante establecen que las plantas deben ser sumergidas en la solución fungicida por no más de 5 minutos y posteriormente no deben ser almacenadas por más de 12 horas antes del trasplante. Abound también puede ser efectivo, aunque hay evidencia que algunas cepas de *Colletotrichum* pueden ser resistentes a este fungicida. El tratamiento de las plantas con fungicidas debe ser de extremo cuidado porque la falla en el seguimiento de las recomendaciones puede resultar en plantas dañadas. Antes de implementar tratamientos en los trasplantes, consulte con su proveedor de plantas sobre los pasos a seguir y también con la Oficina del Comisionado Agrícola del Condado (County Agricultural Commissioner) y las etiquetas de los productos por el estado actual de registración del producto, restricciones, e información de uso.

Tratamientos posteriores al trasplante: Si el establecimiento de las plantas utiliza riesgo por aspersión, los mismos deben finalizar lo antes posible. Las esporas producidas en las plantas infectadas pueden propagarse por el salpicado del agua de los aspersores.

La propagación mecánica de las esporas por el equipo que pasa a través del campo es de importancia secundaria. Sin embargo, los productores deben estar atentos al riesgo de transportar esporas a través de máquinas y trabajadores cuando hay plantas sintomáticas en el campo y las mismas se encuentran húmedas.

Un aspecto clave en la estrategia de manejo es la detección precisa de antracnosis en el campo. Las infecciones en la fruta y en el tallo pueden ser identificadas fácilmente debido a la formación de las masas anaranjadas de esporas en las lesiones. Sin embargo, si las masas anaranjadas están ausentes, los síntomas pueden parecerse a otras enfermedades o ser confundidas con daño físico. Las raíces y coronas infectadas con *Colletotrichum* no pueden ser diagnosticadas sin ser evaluadas

en el laboratorio. Por lo tanto, investigue cuidadosamente los casos posibles de antracnosis y consulte con profesionales y laboratorios adecuados cuando sea necesario.

Las aplicaciones foliares a tiempo de los fungicidas Captan (captan), Abound (azoxystrobin), y Switch (cyprodinil + fludioxonil) están justificadas cuando se anticipan condiciones húmedas debidas a la lluvia o a la presencia extendida de niebla, especialmente si los síntomas de antracnosis han sido observados y la enfermedad ha sido confirmada.

Estos fungicidas son protectores y deben ser aplicados antes de que la enfermedad se desarrolle en forma extensiva. Actualmente, no hay fungicidas orgánicos aceptables que sean efectivos contra la antracnosis. Como los fungicidas son utilizados para el manejo de la enfermedad tanto en los trasplantes como durante el período de producción de fruta, se recomienda desarrollar un comprensivo sistema de manejo integrado de la enfermedad que tenga en cuenta que los fungicidas son utilizados en todas las fases de la industria de la fresa.

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UC CE University of California Cooperative Extension

Chemigation with metam at the end of strawberry season can help reduce infestations of nutsedge and soilborne pathogens

Oleg Daugovish, Mark Bolda, Anna Howell, Gina Ferrari (UC-ANR) and Peter Henry, UC-Davis

At the end of fall-planted strawberry season many problems surface, including pathogen related plant collapse and unrestricted weed growth. Soil-borne pathogens *Fusarium oxysporum* f. sp. *fragariae* (causing Fusarium wilt) and *Macrophomina phaseolina* (causing charcoal rot) like warm soil as much as yellow nutsedge (*Cyperus esculentus*). Strawberry plants stressed with heavy fruit loads try to cool off by transpiring water, but pathogens colonize and block their vascular systems and nutsedge competes for water and resources while producing new tubers for future.

It certainly would be nice to do a 'clean-up' instead of just burying these problems back in the ground and see them reappear during the next season.

MITC (methyl isothiocyanate) generating fumigants can be applied in many troubled fields via existing drip lines at the end of season accompanied by sprinkler irrigation to mitigate potential emissions. These fumigants are short lived, can be very effective and are considerably cheaper than chloropicrin.

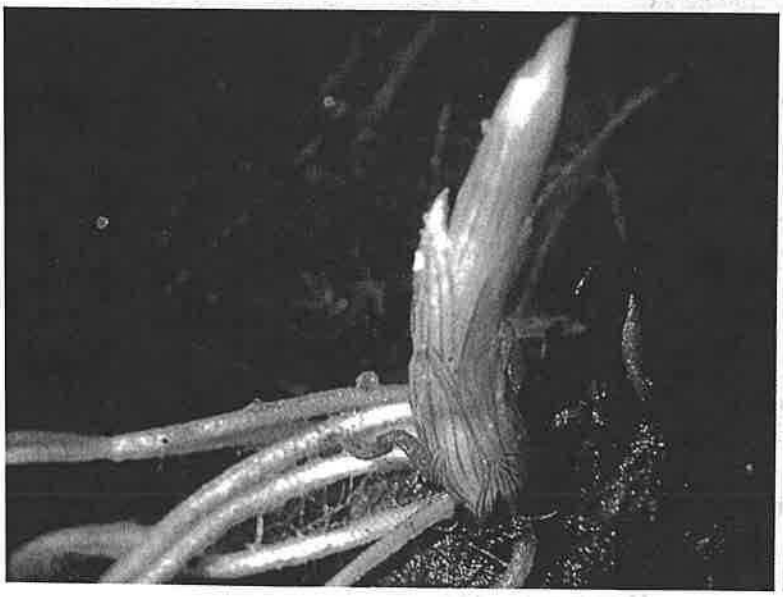
Ventura county projects:
We conducted two trials in 68-inch Oxnard beds with end-season injections via two drip lines per bed in 2015 (213 lbs/acre of metam sodium) and in 2018 (174 lbs/acre of metam potassium). The collaboration included Advisors and staff from UC ANR and California Strawberry Commission and help from Crop Production Services and cooperating growers.

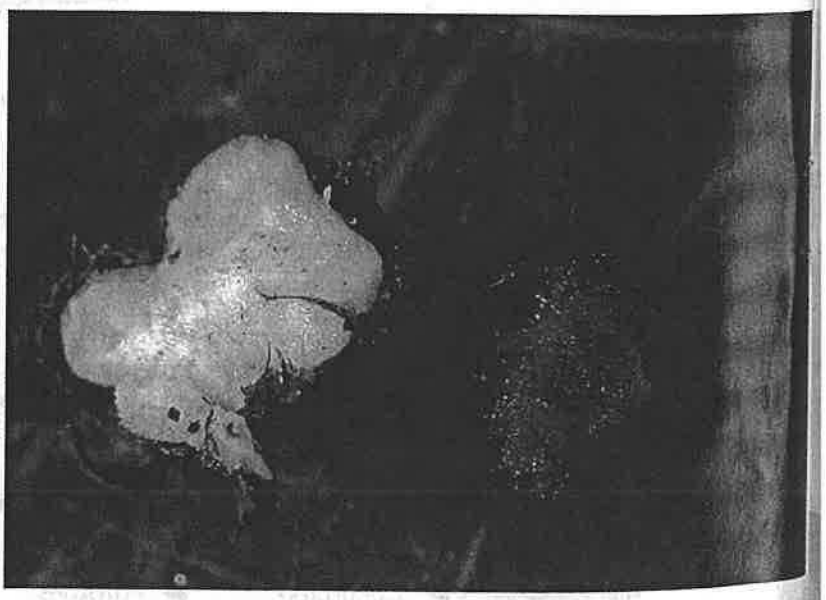
At 2 depths (6 and 12 inches) and 2 locations in strawberry beds (under drip lines and between them) we buried permeable bags containing locally collected nutsedge tubers and sand-mixed Fusarium inoculum and pathogen-infested strawberry crowns with roots. The bags were excavated 12 days after metam fumigation and contents of bags analyzed for viability.

Here is what we found out:

- Nutsedge tubers germinated 80-100% in untreated soil but after chemigation with metam sodium or metam potassium shoot number was significantly reduced in both years. Nutsedge shoot production was similar at 6 and 12-inch depths but varied among locations in bed. Fumigants reduced shoot production from tubers under drip lines to 0-5% in both years, but between drip lines only to 35% (2015) and 53% (2018). Reduction in efficacy with increased distance from drip emitters is something we observed in several studies with this and other fumigants. Lack of efficacy in bed centers (between drip lines) was also observed above ground in

Figure 1. Tubers of yellow nutsedge germinated readily in untreated soil (left) and failed to germinate near drip lines used for metam sodium application (right)





established nutsedge compared to nutsedge above drip lines used for fumigation (Figure 2).

- Fusarium microsclerotia in sand bags were an easy target and fumigants provided nearly compete (>99%) control compared to untreated soil. As with nutsedge, pathogen mortality was consistently lower in soil between drip lines compared to locations under drip lines. Fusarium-infested crowns and roots are known to harbor pathogens from fumigants and that was the case in these trials. Viable Fusarium recovery from infested plant material was 50-90% in fumigated soil generally not different from untreated soil.

Santa Cruz County Projects:
We conducted two trials, one in 2016 and the other in 2017 in a field heavily infested with Fusarium. Beds were 56" wide and metam potassium was injected through the drip irrigation system at 273 lbs/acre at the end of the season. The collaboration included the growers and personnel from AMVAC and SoilFume in Watsonville.

In 2016, following end-season fumigation of the beds, plants were mowed, plastic mulch and drip tape removed, bed tops chiseled to loosen soil and new drip tape and mulch installed in reshaped beds. Subsequently, six varieties: Cabrillo, Fronteras, Monterey, Petaluma and San Andreas were planted in fumigated and untreated beds in in a randomized complete block arrangement. Plant canopy growth and fruit yields were evaluated from December 2016 until the end of June of 2017.

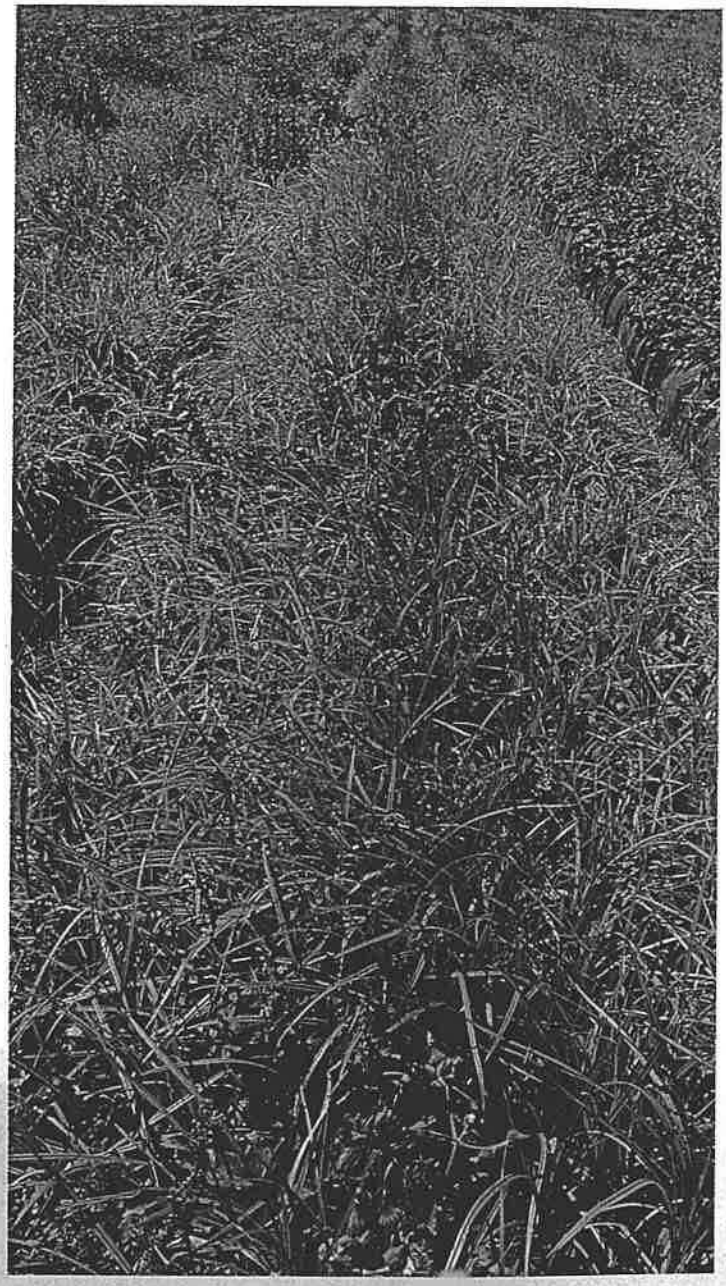
In 2017, a 5-acre block heavily infested with Fusarium was treated with drip-applied metam potassium at 273 lbs/acre at the end of the season, and an untreated area was included in evaluation. After two weeks, once the re-entry interval was over, 20 plant crowns were collected for pathogen analyses from four locations in both treated and untreated beds. As in in 2016, plants were mowed, the bed tops chiseled and in renewed beds six strawberry varieties were planted: Portola, Sweet Ann, Monterey, San Andreas, Radiance and Fronteras.

Here is what we found out:

- Plant performance following the post crop application of metam potassium was remarkable. In the season following the 2016 application, all six tested varieties significantly outperformed the untreated check. Fruit yield increases in the treated plots over the untreated were as follows: 127% in Fronteras, 630% in Cabrillo, 52% in Monterey, 75% in Petaluma and 166% in San Andreas.

- In the 2017 metam potassium application for crop termination significantly improved fruit production of Monterey (26%) compared to untreated control. However, yield increases for Sweet Ann (13%), Portola were (17%), Fronteras (35%) and in San Andreas (44 %), were not sufficient to statistically separate (at P=0.05) fumigated plots from untreated control for these varieties. In the 2017 trial, Fusarium incidence was reduced in treated strawberry crowns by 75%. This finding is extremely important for our continuing approach to managing Fusarium in strawberry since the bulk of this disease is found in plant material and reductions of this magnitude will be very important in reducing disease.

Figure 2. Established yellow nutsedge turned yellow above drip lines used for metam potassium end-season injection and remained green in bed centers most distant from drip lines.



RESEARCH ARTICLE

Cover crop and mulch practices reduce agricultural pollutant loads in stormwater runoff from plastic tunnels

Results from a trial with two raspberry growers in coastal California suggest that using a barley cover crop or mulch can reduce potential groundwater pollutants in soil and leachate.

by Oleg Daugovish, Ben Faber, Eta Takele, Jamie Whiteford and Laosheng Wu

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Abstract

Macrotunnel production systems contribute over $1 billion to California's economy, but despite increased use, guidance to help macrotunnel growers limit agricultural pollutant loads in rainfall-induced runoff is sparse. Using raspberry as a model crop, we evaluated four runoff management practices during two rainy seasons of the normal 3-year raspberry production cycle: barley cover crop seeded at 500 pounds per acre, weed barrier fabric, yard waste mulch spread 2 to 3 inches thick, and polyacrylamide (PAM). Treatments were applied to 300-foot-by-6-foot-wide post rows. Barley cover crop and mulch reduced combined nitrate and nitrite nitrogen in runoff by 21% to 48% at some runoff events and reduced nitrate nitrogen in soil and leachate to groundwater by 52% to 90%. All treatments reduced turbidity and phosphorus levels in runoff and had 75% to 97% less sediment accumulation compared with bare soil. Additionally, all treatments except PAM reduced weed densities by 48% to 87% compared with bare ground, which reduced the costs of weed management. Barley cover crop had the lowest estimated costs (~$60.00 per tunnel period), while PAM and mulch were highest (~$193.00 per tunnel period).

Macrotunnel production has been increasing in coastal counties of California and is poised for expansion due to its recent adoption as a standard practice by the U.S. Department of Agriculture (USDA NRCS 2019). In high tunnel production, crops are grown within plastic-covered structures to enhance crop performance, extend production seasons and to protect crop quality. While most caneberries, some strawberries, cut flowers, herbs and leafy greens are widely grown under plastic in California, contributing $1 billion to the state's economy, in other states small fruits, melons and nuts are also grown in high tunnel systems. This interest in plasticulture tunnels is driven by many factors: increased production due to season expansion; reduced exposure to deleterious weather events; consumer demand for fresh, local produce; and national interest in reducing transportation-related greenhouse gas emissions, amongst other concerns. Unfortunately, it comes at a time when climate-induced weather pattern changes, particularly shorter-duration, higher-frequency storm events, are expected to become the norm (Westra et al. 2014).

The plastic covering hoop structures can reduce the available permeable surface of a field's production area by over 90%, which increases the volume of water likely to run off a field in a storm event (RCDMC 2014). During rains, water intercepted by plastic covers

In coastal California, most caneberries, some strawberries, cut flowers, herbs and leafy greens are grown in plastic-covered structures like the ones shown here.

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is channeled into post rows (furrows with tunnel-supporting posts), accelerating soil erosion, especially on slopes, which ultimately degrades surface water quality. In California, surface water quality is regulated by the State Water Resources Control Board through the Irrigated Lands Regulatory Program (ILRP 2017). To protect water quality, California regional water quality control boards have adopted different measures to regulate pollutants in water from agricultural operations, including implementation of best management practices (BMPs) (Lu et al. 2008). Typical pollutants in areas with exceedances of total maximum daily loads (TMDLs) include nitrogen, sediment, phosphorus and pesticides, such as chlorpyrifos. Many surface water TMDL exceedances occur during the rainy season, indicating the need for practices that address stormwater runoff. In some areas, management practices that reduce rain-induced leaching of soluble pollutants into groundwater may also be needed.

Stormwater management treatments

In this project we compared treatment efficacies and costs of untreated tunnel post rows with rows treated under four different practices in plastic-covered raspberry operations at Somis (Ventura County) and Santa Maria (Santa Barbara County), California. Both sites were on moderate slopes (2% to 10%), but the beds were planted on the contour to reduce runoff and were on a 1% slope at both sites. The post row treatments were selected based on previous work (M. Cahn, personal communication) and potential feasibility for caneberry operations. Each treatment was applied to 6-foot-by-300-foot post rows (each row is an 1,800–square foot plot) in an experiment with randomized complete block design with three replications at both sites. Site conditions are described in table 1. The project focused on the rainy seasons of 2016–2017 and 2017–2018.

The four treatments were as follows:

A *barley cover crop* ('U.C. 476') was seeded in 2016 (July at Somis and November at Santa Maria) at 500 pounds per acre with a seed spreader, lightly raked into the soil and established with sprinkler irrigation used for delivering overhead water to newly planted raspberry roots (a standard propagation approach). At both locations we reseeded barley at the same rate during the second rainy period of the project (January 2017) to increase cover crop density in areas lacking ground cover.

Weed block fabric (DayBlack/Premium Weedmat, Dewitt) is commonly used in organic and hydroponic production systems. Fabric was unrolled and pinned by hand to cover the post-row surface between raspberry beds prior to post installation. The fabric remained in place during the experiment and was unpinned and rolled up at the end of the project for potential reuse.

Yard waste mulch from local suppliers (Agromin for Somis and Santa Barbara County Public Works Green Waste for Santa Maria) was delivered to the project sites. Mulch was a woody < 2-inch screened material with < 20% fine components. Different mulch sources at the two sites were used because the distance between sites and volume requirements for each site were prohibitively large to source from a single supplier. Mulch was delivered by tractor to post rows, where it was spread with rakes to cover the entire post row with a 2- to 3-inch thick layer. At both locations mulch was applied once prior to post installation and persisted throughout the trial period.

Polyacrylamide (PAM; Soil Binder DC, J.R. Simplot Company), a nontoxic soil-binding polymer, was applied prior to rain events (or as needed based on efficacy) at a rate of 2 pounds per acre. In 2016–2017, PAM was mixed with water and applied with a backpack sprayer, but due to plugging of nozzles we dispersed dry PAM to post rows instead in 2017–2018 and observed similar efficacy and increased ease of application.

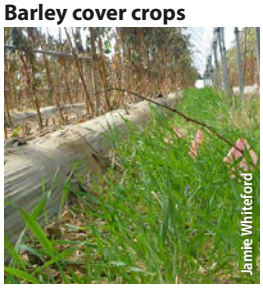
Runoff and soil collection, data analyses

In the 2016–2017 season, we collected runoff samples by hand (grab samples) within 30 min from the beginning of the runoff generation, approximately 25 feet away from the ends of each of the treatment post rows (to prevent potential runoff mixing from adjacent post rows). About 250 milliliters of runoff water in each sample were brought from field sites to the UC Cooperative Extension (UCCE) Ventura County lab and immediately tested for turbidity using a turbidimeter (Model 2100P, Hach Company, Loveland, Colo.), acidified with sulfuric acid to reach pH 3 and either shipped immediately to the ANR analytical lab at UC Riverside or stored at 4°C until shipment. Levels of nitrogen forms (nitrate [NO_3], nitrite [NO_2] and ammonium [NH_4]) and total nitrogren and phosphorus were determined using a Discrete Analyzer AQ2 (Seal Analytical Inc., Mequon, Wis.).

TABLE 1. Site characteristics in raspberry tunnel runoff management project

Experimental site	Soil type	OM	pH	Slope, %	Rainfall, total in inches, 2016–2017	Rainfall, total in inches, 2017–2018	Plastic cover on tunnels
Somis	Mocho loam	1.8	7.8	5	16.63	6.74	Duration of the project
Santa Maria	Oceano sand	2.3	6.1	9	18.84	6.48	Feb–May each year

Barley cover crops



Weed block fabric

Yard waste mulch

Polyacrylamide

Untreated

Treatments applied to raspberry tunnel post rows at Somis and Santa Maria.

In 2017–2018, we collected grab samples as described above. We also collected runoff in 5-gallon buckets installed at 25 feet from the end of post rows (passive samplers) to intercept first flush of runoff at soil surface level. Additionally, we installed suction lysimeters (AGQ Labs, Oxnard, Calif.) about 30 feet away from the ends of the post rows at 8-inch depth at Santa Maria and 8- and 24-inch depths at Somis and collected leachate (water that has percolated through soil) after rains.

In 2017–2018 we also collected sediment from the buckets after runoff occurred, and the sediment samples were dried and weighed at the UCCE Ventura County lab. In April 2018, we took soil samples (15 cores per plot at 0- to 6-inch and 6- to 12-inch depths) that were analyzed for soil moisture, nitrate nitrogen (NO_3-N) and phosphorus content.

Weed densities and raspberry shoots

Weed numbers were determined by counting all germinated weeds in each 1,800–square foot plot at each site on three dates. Predominant weed species at Somis were little mallow (*Malva parviflora*) and annual sowthistle (*Sonchus oleraceus*), and horseweed (*Conyza canadensis*) and annual bluegrass (*Poa annua*) at Santa Maria. Additionally, in April 2018 at Somis we counted the numbers of volunteer raspberry shoots (suckers) in all plots.

Runoff, weed and cane data were analyzed using the GLM Procedure in SAS (SAS version 9.0, SAS Institute, Cary, N.C.) with the overall error rate controlled by Tukey-Kramer adjustment.

Economic analyses

We calculated the costs of each treatment for the 1,800–square foot experiment plot and then extrapolated the costs into a per acre basis for one tunnel use period. A tunnel use period covers a 3-year production cycle of raspberry from establishment until termination. Costs of treatments included materials, labor and equipment when applicable. Granular dry PAM formulation application to soil was used in the analyses. We also adjusted the treatment's costs if it provided weed control benefit. In addition, some treatments can serve for more than one tunnel use period. Therefore, we distributed the costs accordingly.

Treatment effects on runoff and water retention

Not all treatments had runoff during light rains. Barley cover crop and yard waste mulch likely interfered with low flows and aided water retention in post rows. We observed slower flows and greater puddling in post rows with barley or mulch than in other treatments or untreated soil (data not shown). Soil sampled 3 days after rain in March 2018 at Somis had 8% to 12% (w/w) greater moisture content at both sampling depths under mulch compared with other treatments (table 2). Mulch also conserved more soil moisture than fabric at Santa Maria (table 2).

Bare ground allows erosion and weeds, which then move into crop beds.

Nitrogen in runoff

Combined nitrite and nitrate (NOx) levels in runoff samples ranged from 0.29 to 6.48 milligrams per liter (mg/L) over two seasons of sampling. This variability is due to the intensity and frequency of the rains during this period, which also affected the accumulated fertigated nitrogen that occurred between rain events.

Fabric and PAM did not reduce nitrate or nitrite in runoff compared with untreated soil at any of the sampling dates at both locations and sampling seasons (data not shown), while mulch was equally ineffective in 2016–2017 in reducing NOx in runoff at both locations. During one out of five runoff events in 2016–2017, barley reduced NOx levels in runoff by 48% ($P = 0.023$) compared with untreated soil, but not significantly during other rain events of that season (data not shown).

During two out of five runoff events (March 10, 2018 and March 13, 2018) at Somis in 2017–2018, barley reduced NOx levels in runoff by 71% and 82% ($P < 0.05$) and mulch reduced them by 67% and 91% ($P < 0.1$) compared with untreated soil, but reductions were not significant at other sampling events. At Santa Maria, none of the treatments had significant impact on NOx

TABLE 2. Soil moisture and nitrate nitrogen in 0- to 12-inch soil profile three days after rain (3.25 inches) under raspberry post row treatments, March 29, 2018

Treatments	Somis		Santa Maria	
	Moisture	Nitrate nitrogen	Moisture	Nitrate nitrogen
	%	*ppm*	*%*	*ppm*
Untreated	18.5 b	28 a	8.7 ab	11.2 a
Fabric	18.4 b	22 a	7.6 b	2.3 b
Mulch	20.8 a	7.8 b	8.9 a	9.8ab
Barley	19.6 ab	4.4 b	8.7 ab	4.7 b
PAM	18.3 b	35 a	8.4 ab	8.4 b

Treatment means with the same letter in each column are not significantly different at $P = 0.05$.

in runoff when compared with untreated soil ($P > 0.1$) (data not shown).

TABLE 3. Average ammonium concentrations of five runoff events (grab samples in 2016–2017) and passive samples (2017–2018) at Somis

Treatments	Ammonium, mg/L	
	2016–2017	2017–2018
Barley	0.04 b	0.47 b
Fabric	0.04 b	3.59 ab
Mulch	0.06 b	0.57 ab
PAM	0.05 b	1.30 ab
Untreated	0.24 a	5.94 a

Treatment means with the same letter in each column are not significantly different at $P = 0.1$.

All treatments at Somis were effective in reducing ammonium in runoff in 2016–2017 compared with untreated soil (table 3), but only barley was effective in 2017–2018. The overall greater average levels of ammonium in 2017–2018 were likely due to use of passive samplers that intercepted the first flush of runoff, which may have had a greater concentration of pollutants than runoff collected later (such as with grab samples in 2016–2017). Ammonium is typically carried on sediments, so lower ammonium would indicate less sediment movement.

This suggests that barley cover crop and yard waste mulch can reduce both the concentration of dissolved ammonium nitrogen in runoff and the volume of runoff, leading to potential reductions in nitrogen losses to the environment compared with untreated soil.

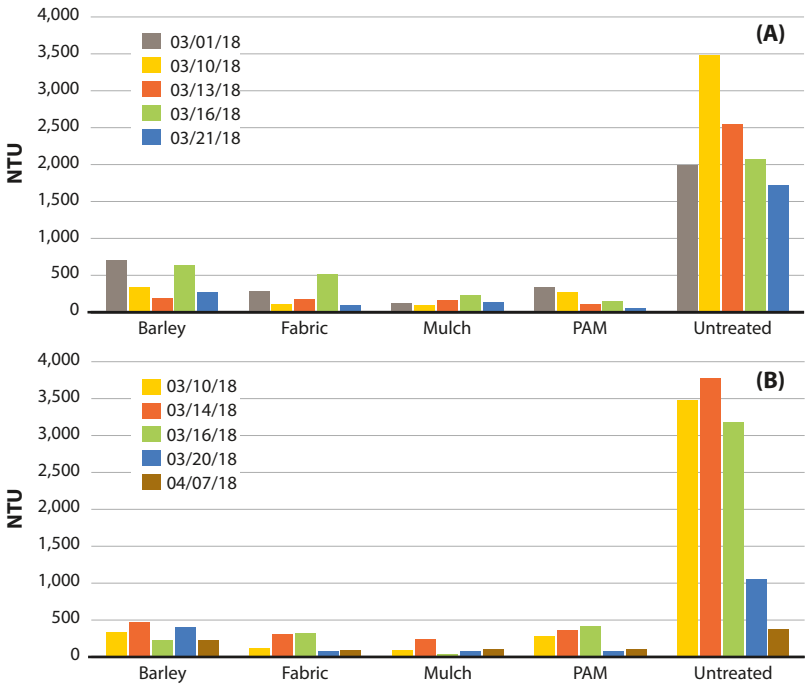


FIG. 1. Turbidity (in Nephelometric Turbidity Units, NTU) in first flush of runoff in 2018 at Somis (A) and Santa Maria (B). Untreated > rest (at $P = 0.05$) at all dates.

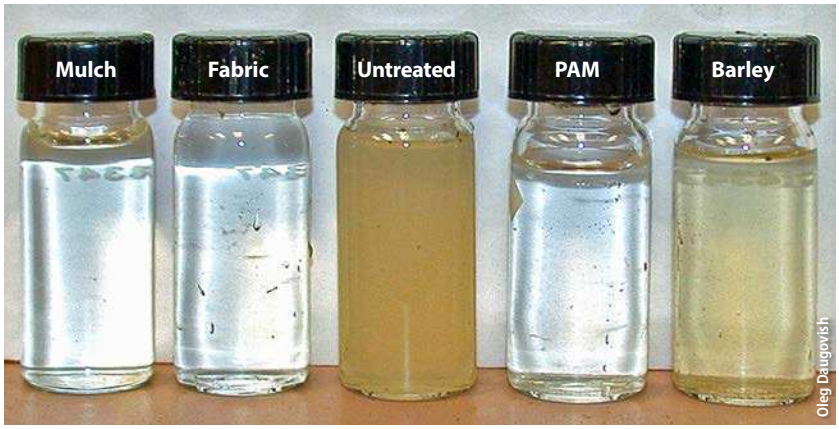


FIG. 2. Turbidity of runoff water in first flush of runoff from raspberry post rows with different treatments and untreated bare soil at Somis on March 10, 2018.

Nitrate nitrogen in soil and leachate

Soil under barley and mulch had significantly less nitrate nitrogen compared with other treatments in March 2018 at Somis (table 2). At Santa Maria, all treatments except for mulch had 25% to 81% less nitrate nitrogen than that of untreated soil, although mulch was also similar to all other treatments. Mulch deterioration might have reduced its efficacy at Santa Maria.

At Santa Maria, nitrate nitrogen levels in leachate collected at 8-inch depth on all sampling dates ranged from 12 to 27 parts per million (ppm) in PAM and untreated plots, which was 52% to 80% greater ($P < 0.05$) than those in other treatments (data not shown). At Somis a similar trend was observed: nitrate nitrogen levels in leachate under PAM and untreated soil were 7 to 22 ppm, which was 80% to 90% greater ($P < 0.01$) than those under barley or mulch. Leachate nitrate concentrations under fabric were not different ($P = 0.8$) from those in untreated soil (data not shown).

These results suggest that barley and mulch can reduce nitrate nitrogen in soil and leachate. Mulch and cover crop (including straw and stubble) act as a barrier to runoff water with dissolved nitrogen and sediment and may retain nitrogen to be used for cover crop growth and for residue and mulch decomposition.

Turbidity, sediment and phosphorus in runoff

Turbidity (a measure of suspended sediment loads) in first flush of runoff was reduced 5- to 10-fold by all treatments compared with untreated soil at both locations in 2018 (figs. 1 and 2). These results were similar to turbidity in grab samples taken in 2017 and 2018 (data not shown), which suggests that all treatments were effective in reducing waterborne sediments on site.

Additionally, 75% to 97% less sediment was collected from passive samplers in all treated post rows compared with those in untreated soil, as shown for March 10, 2018 (fig. 3). Relatively high sediment load in fabric treatment resulted from deposits of soil on top of the fabric during removal of plastic from raspberry beds. Similar to the March 10 rain event, we observed significantly lower sediment levels after other rains in all treated post rows compared with untreated rows (data not shown). We also observed fewer erosion

channels in treated post rows compared with untreated plots at both sites during the trial.

Besides the agronomic benefits, retaining soil in the field is also a good pesticide management practice because soil-adsorbed pesticides will stay in the field and not end up in receiving bodies of water. In a previous study, Mangiafico et al. (2009) showed that concentrations of the harmful insecticide chlorpyrifos in runoff were linearly related to sample turbidity. This suggests that retaining waterborne sediments on-site is an effective method for mitigating runoff of this pesticide. Preventing soil movement with these post row treatments may also reduce the costs of sediment removal from receiving waterways and associated environmental impacts (Tundu et al. 2018).

Phosphorus levels in the first flush of runoff samples were reduced by 24% to 85% in all treatments compared with untreated soil at Somis in 2018, except for PAM on Feb. 27, 2018 (fig. 4). Lack of efficacy of PAM on that date may have resulted from deterioration of the PAM seal due to soil disturbance (foot traffic during cane pruning) after PAM application and before runoff sample collection. At Somis in 2016–2017 and Santa Maria in 2018, we observed a similar reduction in phosphorus by all post row treatments compared with untreated soil (data not shown). Since phosphorus is normally adsorbed to soil particles (Zhang et al. 2016), reduction in turbidity and phosphorus in runoff samples from treated post rows followed a similar trend. Reducing losses of phosphorus from production fields may help prevent eutrophication in receiving waterways when this microelement is limiting for algal growth (Correll 1996).

Control of weeds, raspberry shoots

Since tunnel post rows receive water and retain soil moisture, conditions are favorable for weed growth. At both locations weed barrier fabric provided nearly complete weed control (table 4) with only occasional weed germination in areas where soil was deposited on the top of the fabric. Application of PAM did not provide control, and weed densities in PAM-treated rows were similar to those in untreated plots. Yard waste mulch provided 81% to 90% weed control at Somis but did not control weeds in two out of three evaluation dates at Santa Maria (table 4). Mulch at Santa Maria was much finer compared with the one at Somis, and likely decomposed more rapidly, allowing weed growth.

Barley cover crop provided 86% and 42% weed control on two evaluation dates at Somis, but after barley was reseeded, high germination of little mallow occurred (Jan. 17, 2018, table 4). Incorporation of barley during reseeding likely disturbed hard-coated weed seeds sufficiently to break dormancy; however, mallow was controlled before seed production when barley was mowed in spring. Barley cover crop at Santa Maria provided 87% and 43% weed control at two out of three evaluation dates.

At Somis in 2018, we observed 3.5 more volunteer raspberry shoots ($P = 0.001$) in post rows with mulch compared with other treatments or untreated plots (data not shown). Unlike weeds, raspberry shoots

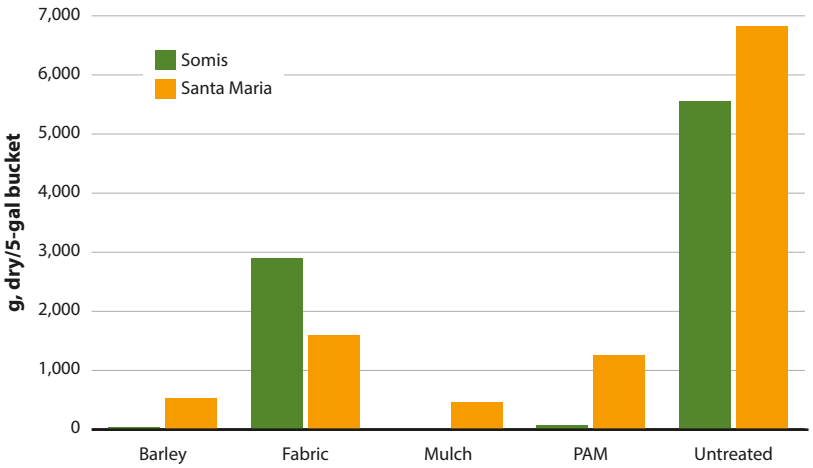


FIG. 3. Sediment collected after 3.25 inches of rain on March 10, 2018, in passive samplers in treated and untreated raspberry post rows. Untreated > rest (at $P = 0.05$).

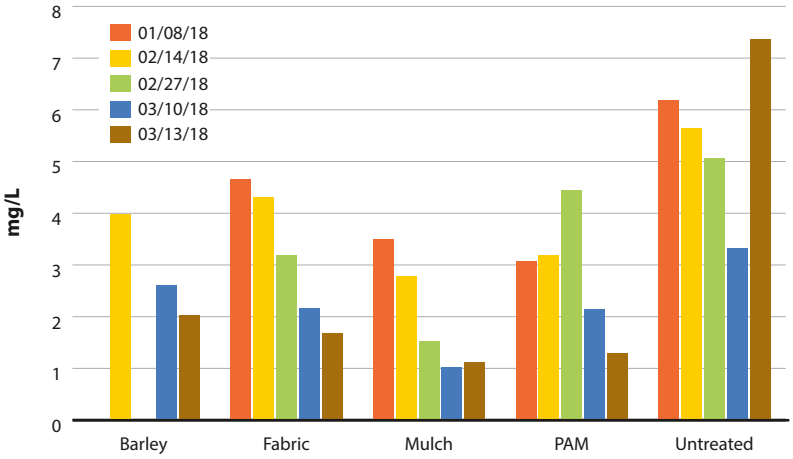


FIG. 4. Total phosphorus in first flush of runoff in 2018 at Somis. Untreated > the rest ($P = 0.05$), except PAM on 02/27/2018 (similar to untreated, $P = 0.23$).

TABLE 4. Weed densities in post rows (plants per 1,800 ft^2–post row) at Somis and Santa Maria

	Somis			Santa Maria		
Treatments	11/23/2016	02/15/2017	01/17/2018	02/01/2017	04/06/2017	02/16/2018
Untreated	206 a	651 a	625 a	7 a	76 a	244 a
Fabric	4.3 b	10 d	2 b	0 b	1 b	11 c
Mulch	21 b	126 cd	90 b	5 a	65 a	99 b
Barley	27 a	338 bc	1,686 a	1 b	42 a	138 b
PAM	173 a	487 a	610 a	3 ab	52 a	136 b

Treatment means with the same letter in each column are not significantly different at $P = 0.05$.

were able to penetrate mulch and establish, likely benefiting from the greater soil moisture content under it (table 2).

These results show that weed barrier fabric, mulch and barley (when adequately applied and managed) can effectively reduce weed control costs in raspberry tunnel post rows, but greater volunteer raspberry shoot management may be required if mulch is used.

Costs of post row treatments

To estimate the costs of the barley cover crop, we obtained machine use and labor hours for seeding, raking and mowing from cost studies for raspberry production (Bolda et al. 2017). Cover crop treatment at 500 pounds per acre costs $29.42 for the treatment area minus the weed control benefit of about $18.60, resulting in the net cost approximates of $10.83 for the treatment, or $59.55 per acre per tunnel period (table 5).

The amount of weed block fabric required for the experimental plot area (1,800 square feet) was 0.22 roll, priced at $349.31 per roll. Ninety metal pins were used to pin the 1,800–square foot fabric area at a cost of $0.12 per pin. The labor needed for spreading and pinning the fabric in the experiment plot was 1 hour (two workers at 0.5 hour each) at $15 per hour. Assuming the fabric serves two tunnel periods, only half of

TABLE 5. Sample costs of raspberry tunnel post row treatments based on a study at Somis and Santa Maria

Materials and labor	Costs/tunnel cycle/treatment area*	Costs/tunnel cycle/ acre†
	$	$
Fabric		
Fabric cost (one roll covers 8,071 ft^2) at $349.31/roll	77.90	428.47
Pins (90 for treatment area of 1,800 ft^2) at $0.12/pin	10.80	59.40
Labor (two people at 0.5 hour each) at $15.00/hour	15.00	82.50
Total cost for fabric treatment	103.70	570.37
Reuse of fabric for another planting:		
Unpinning cost (two people at 0.5 hour each)	15.00	82.50
Pinning back for the planting (two people at 0.5 hour each)	15.00	82.50
Total cost with fabric reuse (two tunnel cycles)	133.70	735.37
Total cost per tunnel cycle	66.85	367.68
Less weed control cost in post rows at $300/ac/year (100% weed control)	–37.19	–204.55
Total fabric treatment cost	**29.66**	**163.14**
Mulch		
Mulch cost (90 ft^3 for 1,800 ft^2) at $15/$yd^3$ ($0.56/$ft^3$): 495 ft^3/ac	50.00	275.00
Delivery and spreading: 0.74 hours at $15/hour	11.10	61.05
Total cost for mulch treatment	61.10	336.05
Less weed control in post rows at $300/ac/year (70% weed control)	–26.03	–143.18
Total mulch treatment cost	**35.07**	**192.87**
Cover crop		
Cover crop planting:		
500 lbs/ac (43,560 ft^2) at $20/50 lbs (two times)	8.26	45.45
Labor hours for light tilling with hand rototiller:		
Two people (20 min each) at $15/hour (two times for two seedings)	10.00	55.00
Mowing (two times): Two people (20 min/each) (two times for two seedings)	10.00	55.00
Machine cost: mowing at $14/acre (from cost studies)	0.58	3.18
Weedwacker (same as mowing)	0.58	3.18
Less weed control in post rows at $300/ac/year (50% control)	–18.60	–102.27
Total cover crop treatment cost	**10.83**	**59.55**
Polyacrylamide (PAM)		
PAM cost (application at 2 lbs/ac at $4/lb (six times application)	1.98	10.91
Labor at 250 min/ac and wage rate $15/hour (six times application)	15.50	85.23
Total PAM cost	17.48	96.14
Less weed control cost in the post rows	0.00	0.00
Total PAM treatment cost	**34.96**	**192.27**

* The treatment area consists of one post row (1,800 ft^2); one tunnel cycle = 3 years.

† One acre = 5.5 post rows; one tunnel cycle = 3 years.

the cost of the fabric material is applied to one tunnel period. Fabric also provides 100% weed control in post rows. Therefore, the cost of fabric treatment per tunnel period is $29.66 for the treatment area, or $163 per acre for one tunnel period.

The volume of applied yard waste mulch should be sufficient to cover the entire post row with a 2- to 3-inch thick layer. Ninety cubic feet of mulch, priced at $0.56 per cubic foot ($15 per cubic yard), was applied to the 1,800–square foot treatment area. Delivery and spreading on flat ground with a front end loader and spreader costs $270 per acre. In cases where smaller equipment is used, it would take more labor — at least a day for two people to spread an acre, as it is a slow process and depends on how well the mulch spreads out in the field. In terms of weed control, mulch controlled 70% of the weeds in post row areas. Mulch treatment cost is one of the highest at $35.07 for the treatment area, or $192 per acre per tunnel period.

The PAM product (Soil Binder DC) was applied at 2 pounds per acre (0.083 pounds for the 1,800 square feet) and was priced at $4.00 per pound. PAM was applied six times per tunnel period; hence, the total PAM cost for this treatment is $1.98 for the treatment area. The labor cost for applying PAM was calculated at 250 minutes per acre (10.33 minutes for the 1,800–square foot treatment area) per time at a wage of $15 per hour. Therefore, the PAM treatment cost became $34.96 per post row, or $192.27 per acre.

The costs of the treatments in this study were very low: 0.7% to 2.4% of the total cultural costs of raspberry production (Bolda et al. 2017). This suggests that little investment in soil and runoff management can be cost-effective over time for sustainable plasticulture crop production.

Next steps

During this trial, California was experiencing the drought of 2011–2019, and these treatments were used in periods when lower runoff and sediment movement would have been expected. However, we observed similar treatment efficacy during low (< 0.2 inches) and high (> 1 inch) rainfall events in these trials, which suggests the treatments were resilient during wet periods. The four treatments in the study all reduced runoff flows and sediment transport (and consequently phosphorus movement) compared with the untreated rows. However, additional work on runoff flow rates and the effect of infiltration on soluble nitrogen forms is needed to more fully quantify the treatment effects with respect to nitrogen balance in these systems.

Our treatment cost analysis serves as a template for tunnel users to assess the feasibility of inputs and costs in their production systems, which may be different from those in this study. During the project we conducted several outreach events for growers and field workers where we displayed the treatments and discussed the in-progress results. At the end of the project, we developed bilingual guidelines for runoff management to facilitate treatment adoptions. These guidelines are available online at https://ucanr.edu/sites/ucceventura/files/304038.pdf (English) and https://ucanr.edu/sites/ucceventura/files/304039.pdf (Spanish). These resources enable tunnel users to select best management practices to protect their fields from soil and nutrient losses and to comply with runoff regulations aimed at protecting the environment. CA

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Summary of publication examples

1. Daugovish, O., B. Faber, E. Takele, J. Whiteford and L. Wu. 2019. Stormwater runoff management from plastic tunnels. Accepted to Cal. Agriculture on 8 Oct. 2019. Acceptance letter on file.

This article summarizes findings of a 3-year project and provides guidelines for runoff management in plasticulture systems that are essential to production of several CA crops contributing > $1 bln to ag economy. Since plastics are impermeable, intensification of runoff is a target of regulations and information on improving runoff quality in these systems was previously lacking. Outcomes of the projects were widely communicated via non-peer reviewed outlets and already reached > 1000 clientele. The Cal Ag Article will reach even greater audience and is a deliverable supported by CDFA competitive grant. This collaborative effort that I led exemplifies successful information delivery and cooperation of UCCE, UCR and RCD with industry and stakeholders.

2. Daugovish, O., M. Bolda, A. Howell, G. Ferrari and P. Henry. 2018. Chemigation with metam at the end of strawberry season can help reduce infestations of nutsedge and soilborne pathogens. CAPCA Adviser XXI (6): 58-62. Available on line at: https://capca.com/publication/december-2018-adviser-magazine/

This publication reaches several thousands of PCAs and others in pest management industry with findings of multi-site research (Ventura and Santa Cruz Counties) conducted in grower fields infested with yellow nutsedge and soil-borne pathogens. It discusses the efficacy of end-season fumigation, which can be 2-3 less expensive alternative to pre-plant chloropicrin fumigation. Even though it did not provide control of pathogens in infested strawberry crowns the approach was cost-effective since nutsedge densities and Fusarium survivorship in soil were greatly reduced. The story discuses it as one of key components in planning IPM in infested strawberry.

3. Bolda, M. S. Koike and O. Daugovish. 2017. Anthracnose of strawberry. Production guideline published by CSC (#14). On line at: https://www.calstrawberry.com/Portals/2/Reports/Research%20Reports/Production%20Guidelines/English/Anthracnose%20of%20Strawberry_Final.pdf?ver=2018-01-15-205356-027 or in Spanish: https://www.calstrawberry.com/Portals/2/Reports/Research%20Reports/Production%20Guidelines/Spanish/Antracnosis%20de%20la%20fresa_Final.pdf?ver=2018-01-15-125623-553

   I have worked with C. acutatum (anthracnose of strawberry) for over 8 years and have published industry and peer-reviewed papers about its management in the past. However, this timely publication led by UCCE advisors was developed as a response to industry needs resulting from severe outbreaks of the pathogen in recent seasons and is a concise summary, guiding fruit and nursery growers to established management strategies. California strawberry commission expedited publication preparation and helped to deliver it to over 800 clientele. Publication is also available in Spanish, reaching clientele that lacked the information previously.