Refining Irrigation Scheduling During and After Crop Establishment

Andre Biscaro,
UC ANR, Ventura County

University of California
Agriculture and Natural Resources

Assessing Drip vs Micro-sprinkler Irrigation During Strawberry Establishment – 2nd Season

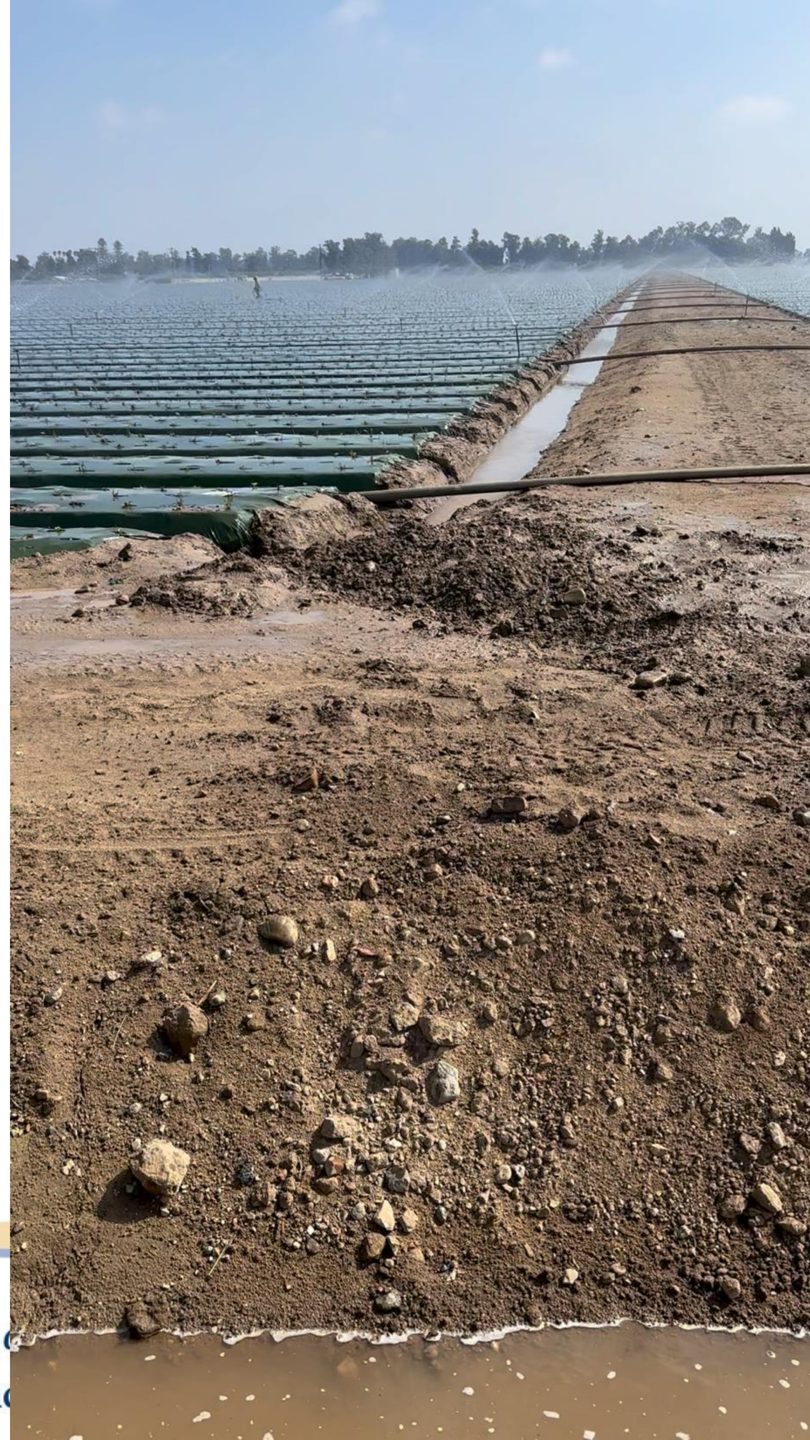
Andre Biscaro,
UC Cooperative Extension, Ventura County

Project collaborators:
Gina Ferrari, Oleg Daugovish, UCCE Ventura
Raul Coronado, GoodFarms

University *of* California
Agriculture and Natural Resources

Strawberry Establishment

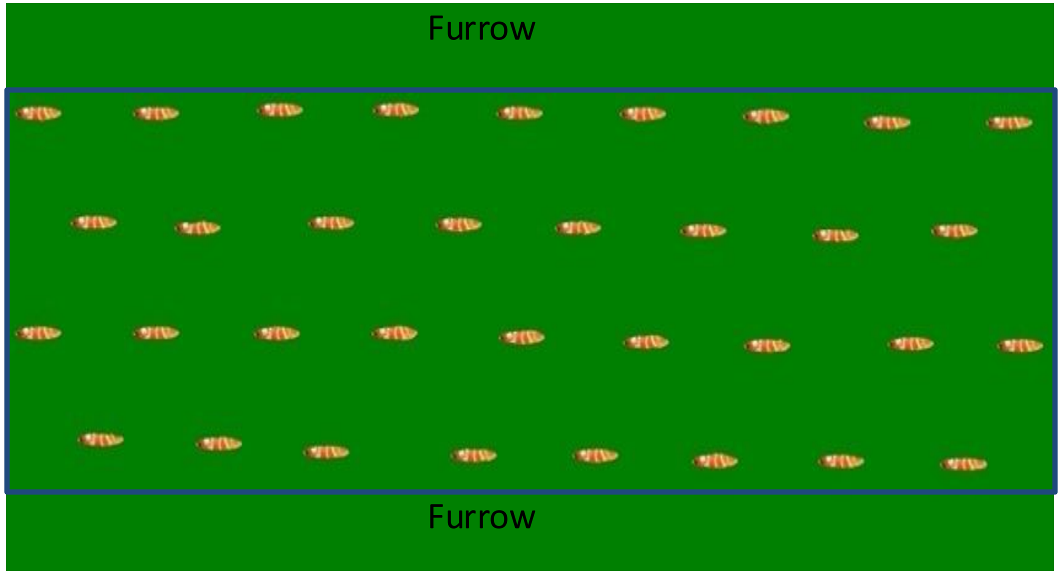
- Lasts between 4 and 6 weeks after planting
- Crop water use is very low
- There is a lot of room to conserve water



University
Agriculture and

Limited Efficiency of Overhead Irrigation

Aerial view of a strawberry bed section



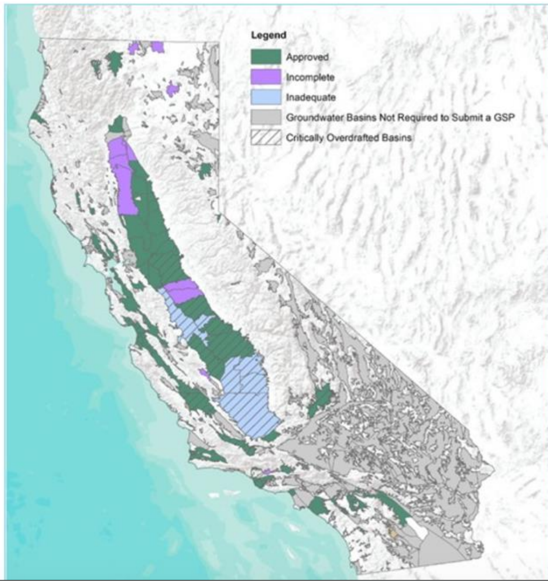
- The majority (~ 80-90%?) of the sprinkler-applied water is lost through runoff, deep percolation and evaporation.

- Planting holes (elliptical orange shapes) represent 2.3% of the total area of this image
- Five images from the same field resulted on an average of 2.4% of planting hole area

CALIFORNIA DEPARTMENT OF WATER RESOURCES

Water Basics | What We Do | Programs | Work with Us | News | Library | Search

Groundwater Sustainability Plans



The Sustainable Groundwater Management Act (SGMA) requires local Groundwater Sustainability Agencies (GSAs) in the state's high and medium priority basins to develop and implement Groundwater Sustainability Plans (GSPs) or Alternatives to GSPs. These GSPs and Alternatives provide roadmaps for how groundwater basins will reach long-term sustainability.

On January 18, 2024, the Department completed the initial GSP reviews for all basins that were required to submit plans by January 31, 2022. The Department's determinations can be viewed on the SGMA Portal. The current status of California's groundwater basins is:

- 71 approved basins
- 13 incomplete basins
- 6 inadequate basins

GSAs are required to begin implementing their GSPs upon their submittal to the Department. If a basin's GSP is

GSP

GSP Reporting System

Contact Us

General Inquiries:
sgmps@water.ca.gov

Regional Inquiries:
sgmp_rc@water.ca.gov

Basin Points of Contact:
Northern Region
North Central Region
South Central Region
Southern Region

Previous study results and other regions

- ➢ A series of field trials conducted in Oxnard, Santa Maria and Watsonville between 2009 and 2014 (Daugovish et al., 2016):

- ✓ Water use reduction of 24 to 78% with the use of drip tape compared to overhead sprinklers during strawberry establishment

- ✓ Plant size, root biomass and yield were similar between the two irrigation systems, suggesting great suitability for adoption of such method

- ➢ Many operations in Baja and other regions in California don't use sprinklers/microsprinklers

Objective:

Quantify differences in yield, water use and plant growth between drip tape and micro-sprinkler irrigation methods during crop establishment

University *of* California
Agriculture and Natural Resources

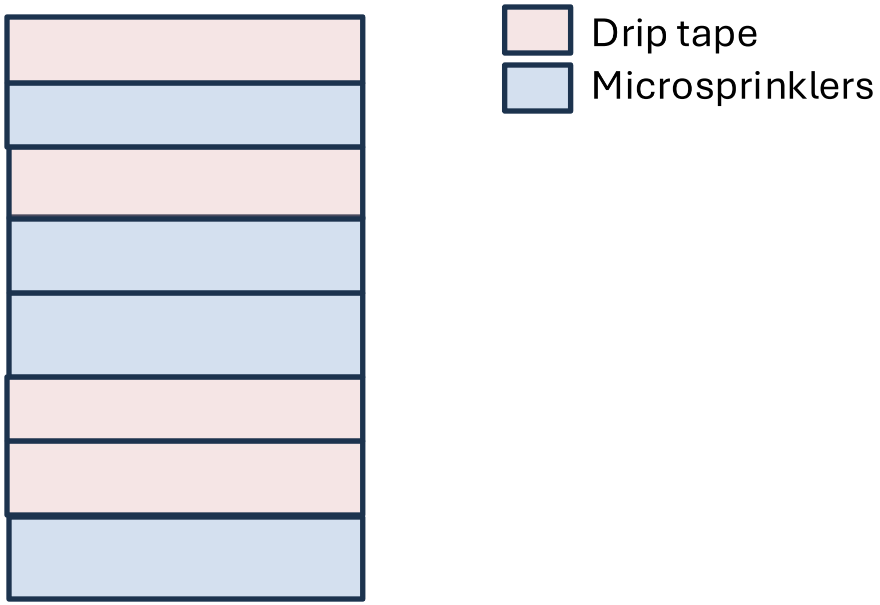
Treatments (42 DAP):

1. Drip tape
2. Micro-sprinkler (grower standard)

Parameters assessed:

Yield, water use, canopy coverage and root depth

Experimental Design



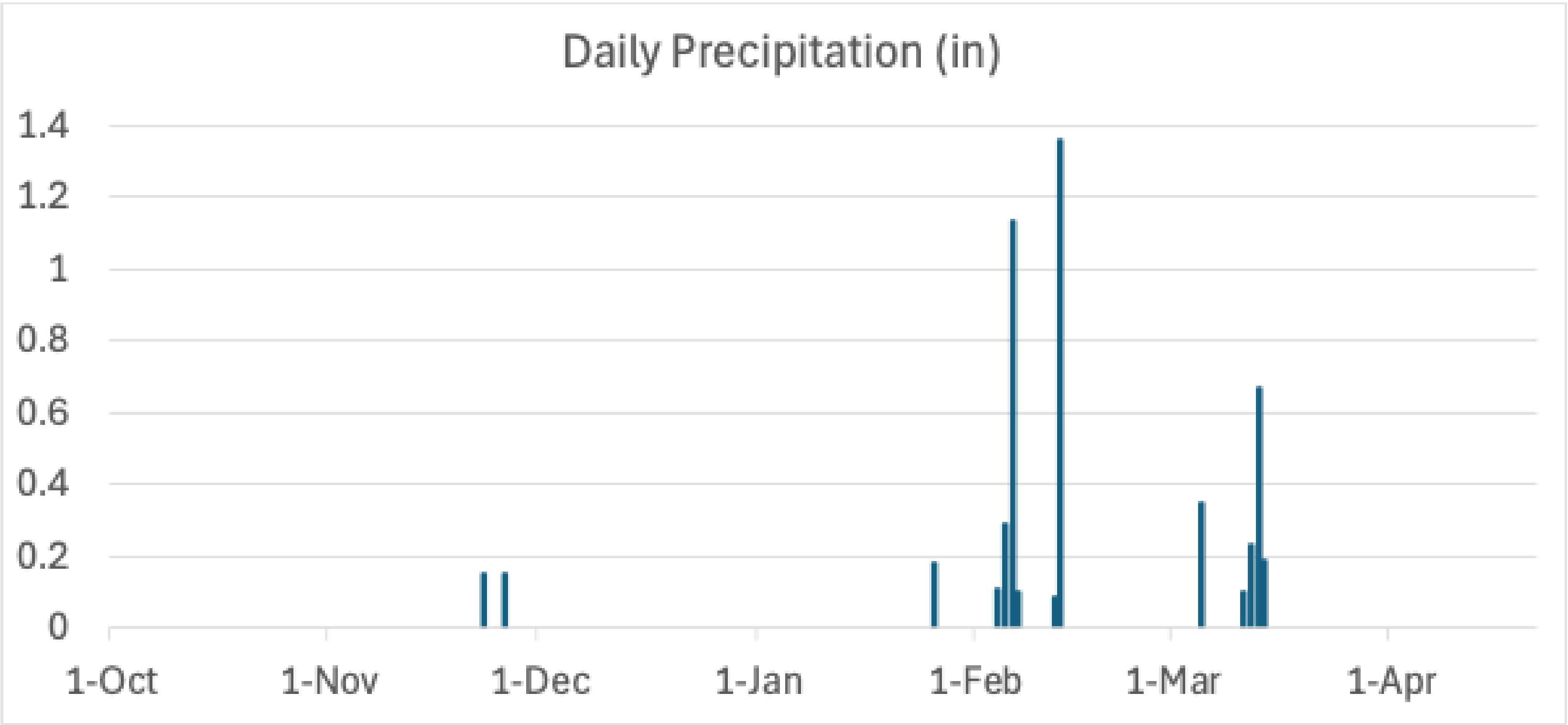
Each plot: 7 beds wide (37.3ft) x 175ft long

Details

- Treatments were applied during the first 6 weeks after planting, after which drip irrigation became the only irrigation method. All other cultural practices remained the same.
- Experimental design: randomized complete block, replicated four times (0.15-acre plots).
- 64-in bed, three medium flow tapes, Plant Sciences cultivar planted on Oct 1.
- Soil: Hueneme sandy loam.
- 800 lb/acre of 22-8-13 pre-plant fertilizer banded in plant row.

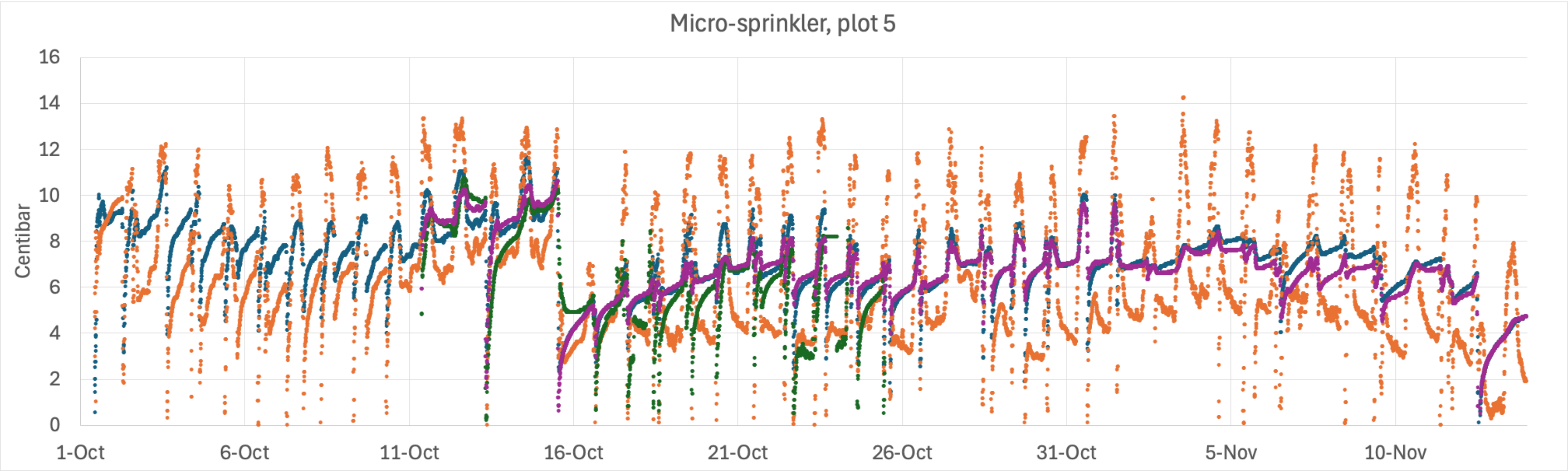
Details (cont.)

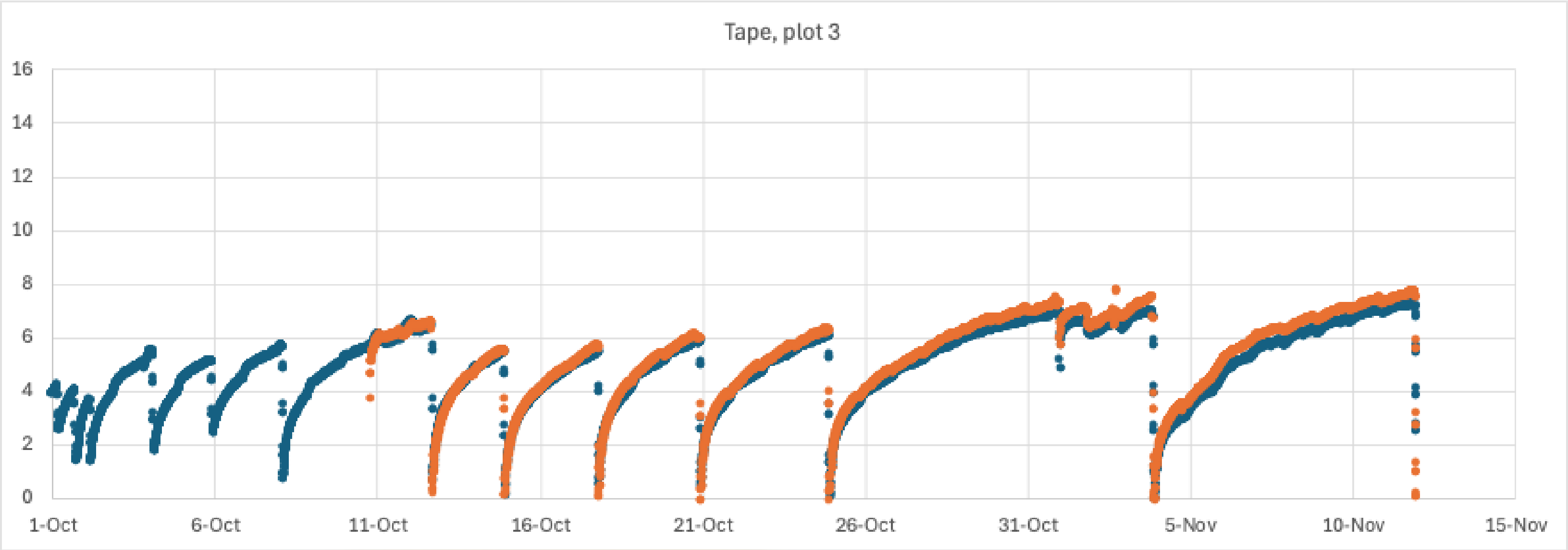
- Irrigation of the drip tape treatment was guided by soil moisture measured with Hortau® tensiometers installed at 4-in depth under the plants, in addition to field observations.
- The irrigation of the micro-sprinkler treatment was determined by the irrigator as usual.
- Total precipitation: 5.1 inches total, with no precipitation during establishment.



Establishment (42 days)

Tensiometer installed at 4in depth





University of California
Agriculture and Natural Resources

Results Summary Table

Treatments	Yield (boxes/acre) Jan 14-Mar 31	Water use during crop establishment (acre-in)	Canopy Size (% of ground cover) measured at: 1mo – 6mo after planting	Root depth (in) at 5 weeks after planting	Soil salinity (ECe) at 0-6in, 1 mo after planting	Avg soil moisture at 4-in depth during establishment (centibars)
Drip tape	2,408	3.3	10.7 – 56.0	6.9	4.1	5.9
Micro-sprk	2,427	5.8	11.6 – 62.1	7.0	4.0	7.1
p-value	0.9517	NA	0.5504 and 0.1223	0.9496	0.7158	NA

40 days after planting

University of California
Agriculture and Natural Resources

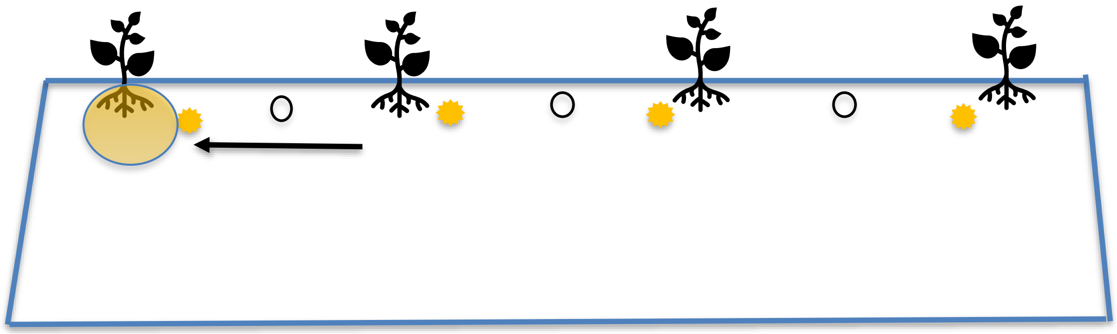





Root Depth

2024/2025

2023/2024



'Perfect storm':

- Crop sensitive to salinity
- High amount of pre-plant placed right next to the bare roots
- Sandy soil
- Warm days during establishment = higher soil temperature at 2in depth = much sooner release of the controlled-release fertilizer
- High N in NH_4^+ form
- Irrigation water from drip tape pushing high ECw water directly to the plant rows.

Soil Chemical Analysis

	Calcium, Sol	Chloride	Salinity (ECe)	Magnesium, Sol	Sodium, Sol	pH
	meq/l	meq/l	dS/m	meq/l	meq/l	units
Soil around healthy plants	44.4	9.30	5.03	15.4	15.7	6.3
Soil around stunted plants	67.0	14.6	9.92	31.7	18.6	5.4

beds	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30	31 32	33 34	35 36	37 38	39 40	41 42	43 44	45 46	47 48
reps	1						2						3						4					
irrig	drip			sprinkler			sprinkler			drip			drip			sprinkler			sprinkler			drip		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
fert	np	bc	ban	bc	ban	np	np	bc	ban	bc	ban	np	np	bc	ban	bc	ban	np	bc	ban	np	np	bc	ban

np = no pre-plant
bc = broadcast
ban = banded

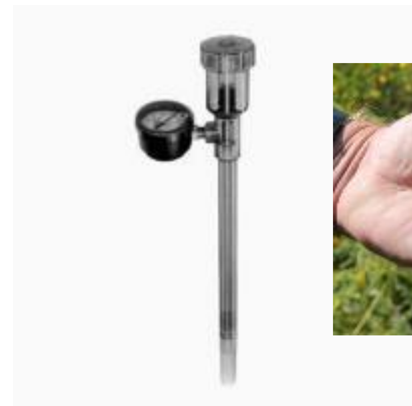
20ft harvest section, bar code

Summary

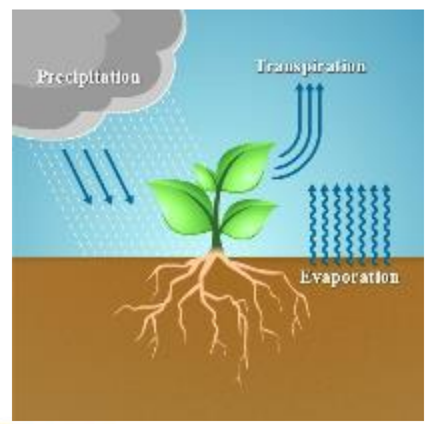
- ✓ Start monitoring soil moisture at 4in depth immediately after planting;
- ✓ Strawberries can be established with drip tape only, but it needs a step up in management: soil moisture monitoring and production practices like fertilization and planting;
- ✓ Slowly introduce drip irrigation during establishment (once a week?);
- ✓ Beware of the salinity effect of fertilizers and do not apply high concentrations too close to the roots.

Irrigation Scheduling

1. Deciding when to irrigate



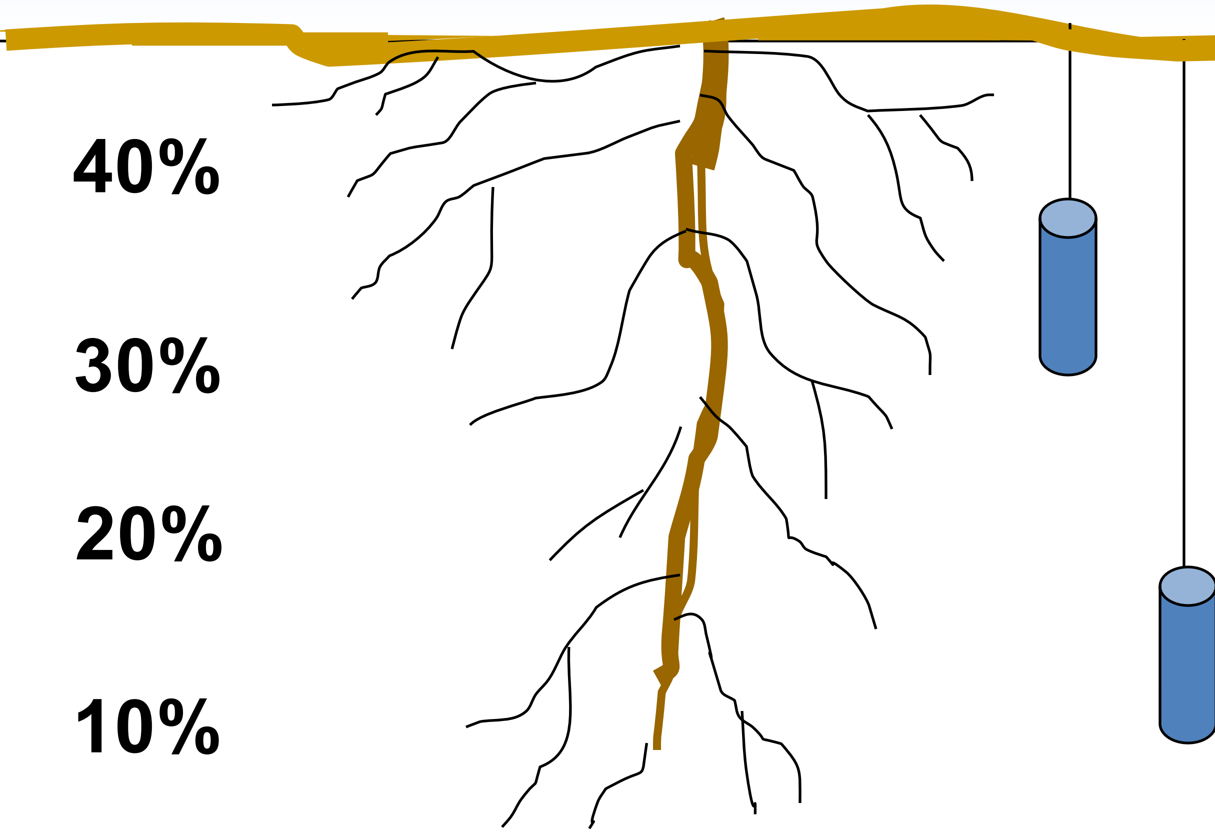
2. Deciding how much to irrigate



Soil Moisture Monitoring

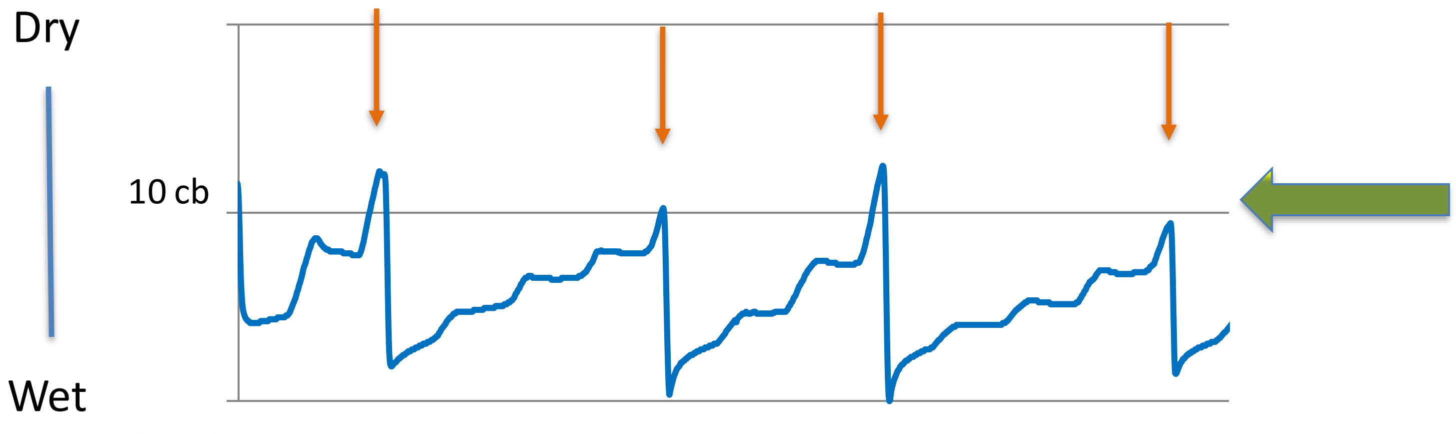
- Sensor type: Tensiometer
- Depths: 6 and 12in;
- Actionable depth = 6in

Sensor Depth and Installation are Key



Soil Moisture Threshold

at 6in depth



Agricultural Water Management 161 (2015) 102–113

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Matric potential-based irrigation management of field-grown strawberry: Effects on yield and water use efficiency

Guillaume Létourneau*, J. Caron, L. Anderson, J. Cormier

Department of Soil and Agrifood Engineering, Laval University, Pavillon de l'Envirotron, 2480 boul. Hochelaga, Québec G1 V 0A6, Canada

ARTICLE INFO

Article history:
Received 3 February 2015
Received in revised form 9 July 2015
Accepted 12 July 2015
Available online 10 August 2015

Keywords:
Strawberry
Irrigation management
Water use efficiency
Soil matric potential
Tensiometer

ABSTRACT

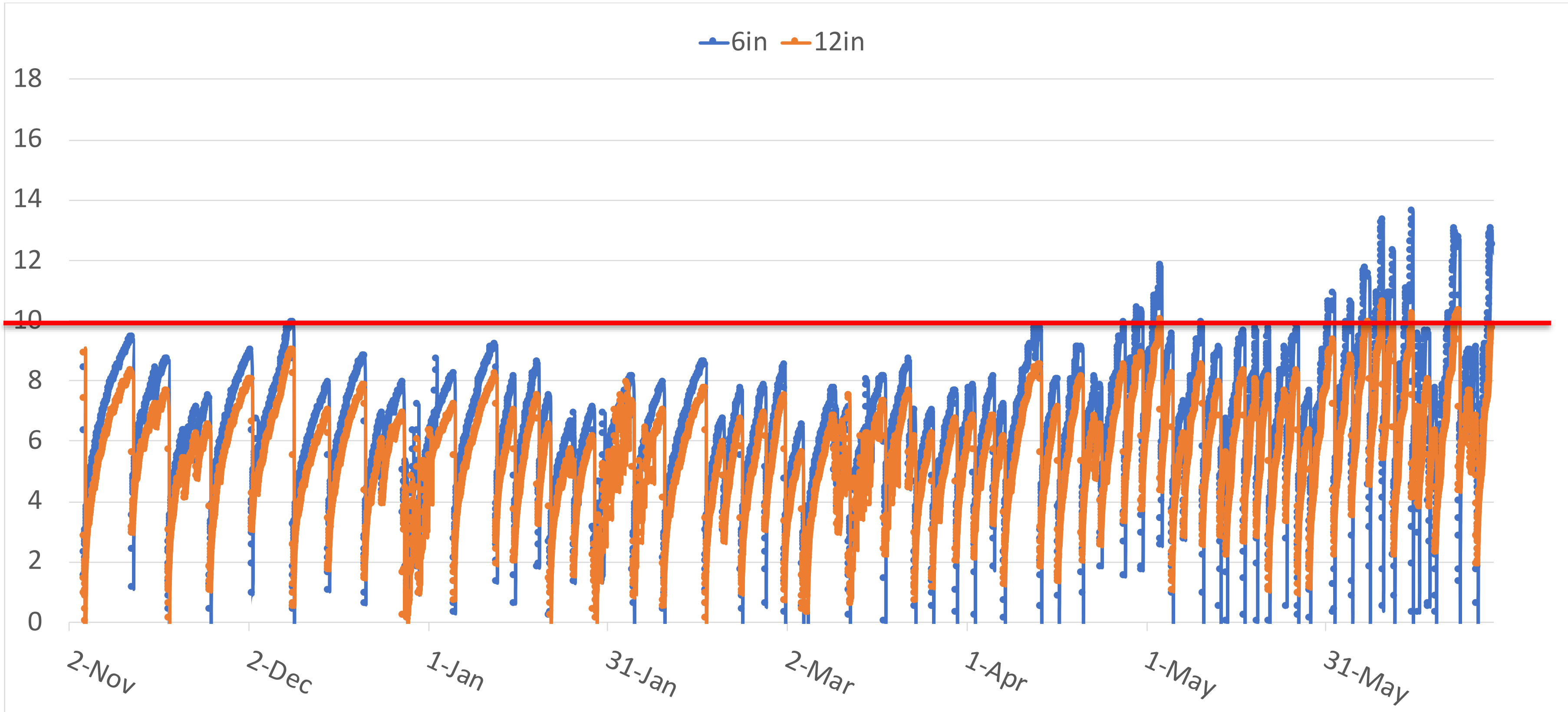
Effective and adapted criteria for irrigation scheduling are required to improve yield and water use efficiency (WUE) and reduce the environmental impacts associated with water and nutrients losses by runoff and leaching. In this study, field-scale experiments were conducted at four commercial strawberry production sites with contrasting soil and climatic conditions. Within each site, the influence of different soil matric potential-based irrigation thresholds (IT) on yield and WUE was evaluated. Matric potential-based irrigation management was also compared with common irrigation practices used by producers in each site's respective areas. At Site 1 (silty clay loam; humid continental (Dfb) climate), an IT of −15 kPa improved yields by 6.2% without any additional use of water relative to common irrigation practices. At Site 2, with similar soil and climatic conditions, the irrigation treatments did not affect yield and the matric potential-based management decreased WUE relative to common practices. However, the results suggested that maintaining the soil matric potential lower than −9 kPa could induce stressing conditions for the plants. At Site 3 (sandy loam; Mediterranean (Cs) climate), the best yield and WUE were obtained with an IT of −8 kPa and suggested that WUE could be further improved by implementing high-frequency irrigation. At Site 4 (clay loam; Mediterranean (Cs) climate), results suggested that an IT between −10 and −15 kPa could optimize yield and WUE, and matric potential-based irrigation considerably reduced leaching under the root zone relative to common practices. Considering the results from all sites, an IT of −10 kPa appears to be adequate as a starting point for further optimizing irrigation under most field conditions.

1. Introduction

Irrigation management is of primary importance for the profitability and sustainability of field strawberry production because it affects yield, water use efficiency and diffuse pollution of ground and surface water. These issues are of great importance in some areas, such as coastal California, Spain and Australia, where water availability is a growing concern. In recent decades, the increased implementation of more efficient water management practices, mainly subsurface drip irrigation (SDI) and the use of plastic mulch,

Many studies have shown that evapotranspiration (ET)-based irrigation management could be efficient for strawberry production (Hanson and Bendixon, 2004; Krüger et al., 1999; Yuan, 2004). However, this method is also criticized for its inability to account for rapid changes in climatic conditions and because it generally does not account for differences in the water requirements of different strawberry cultivars (Giné Bordonaba and Terry, 2010; Klamkowski and Treder, 2008; Krüger et al., 1999). The availability of locally determined crop coefficients that account for the wetting patterns resulting from the combined effects of SDI system configuration

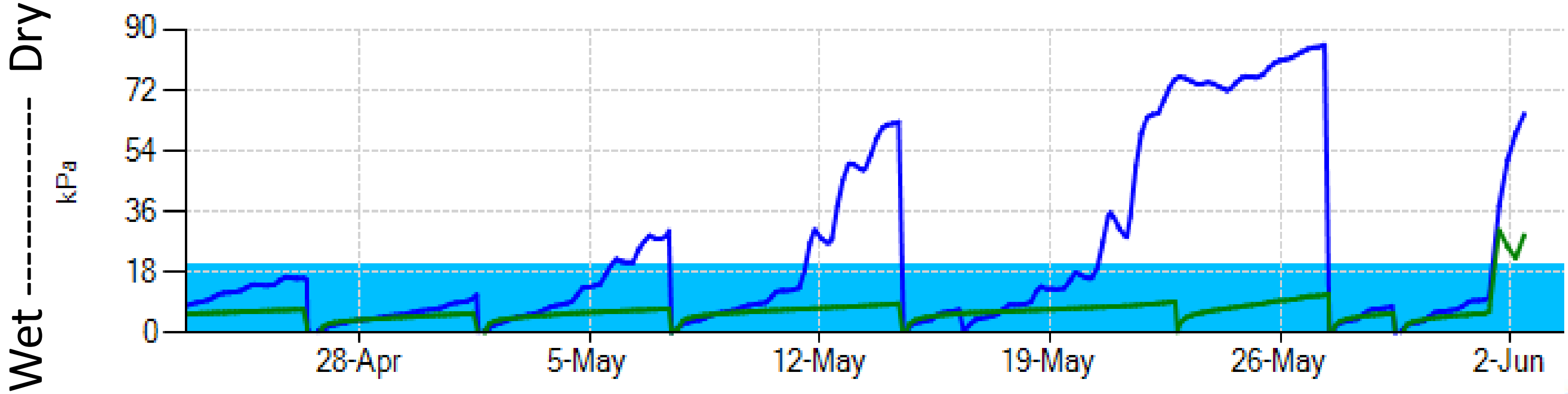
Soil Moisture (cbars)



University *of* California
Agriculture and Natural Resources

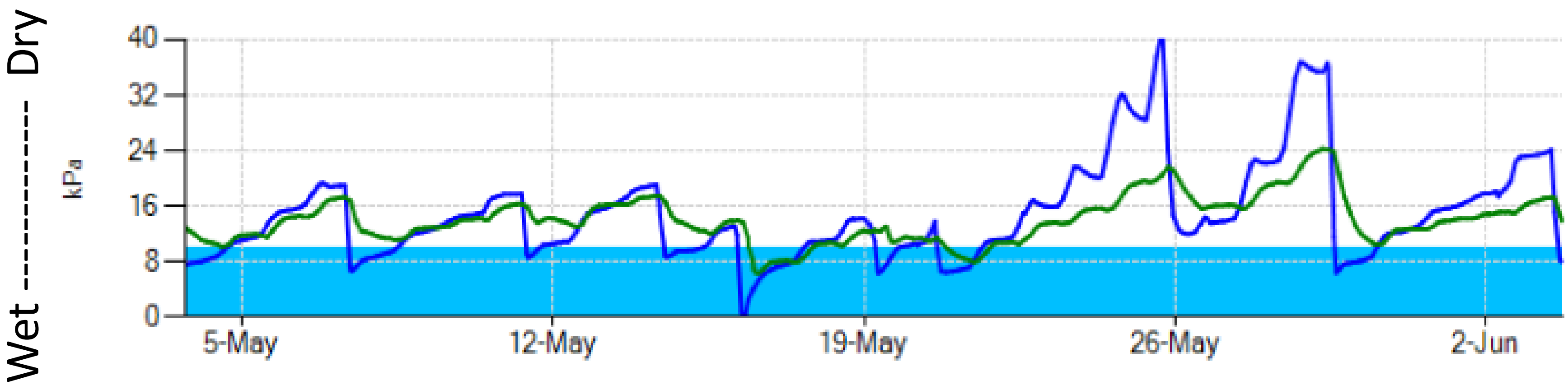
Irrigation Management Context

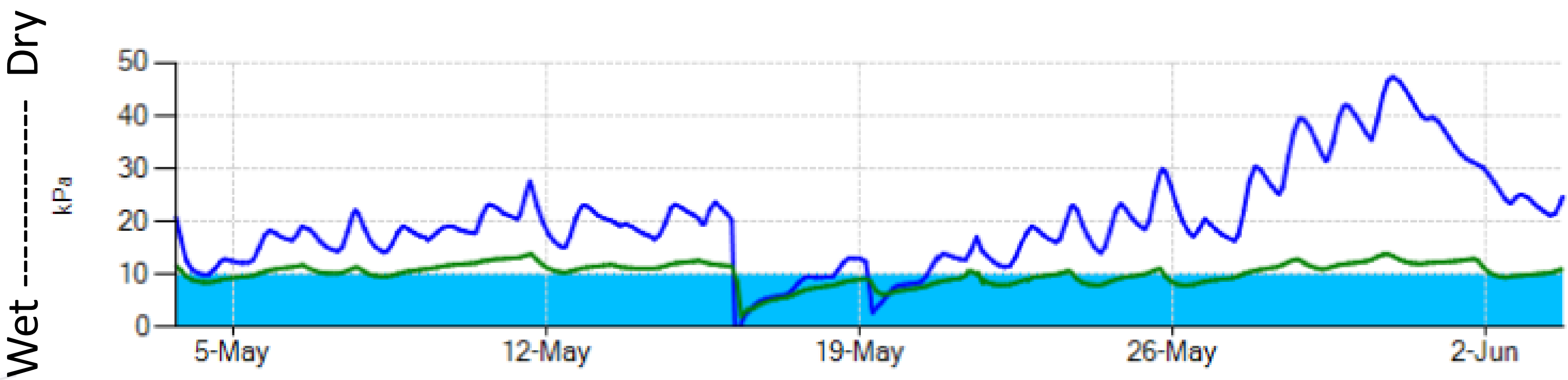
- Overall, most irrigators over-irrigate early in the season and under-irrigate later
- Why? Mostly lack of information



University *of* California
Agriculture and Natural Resources

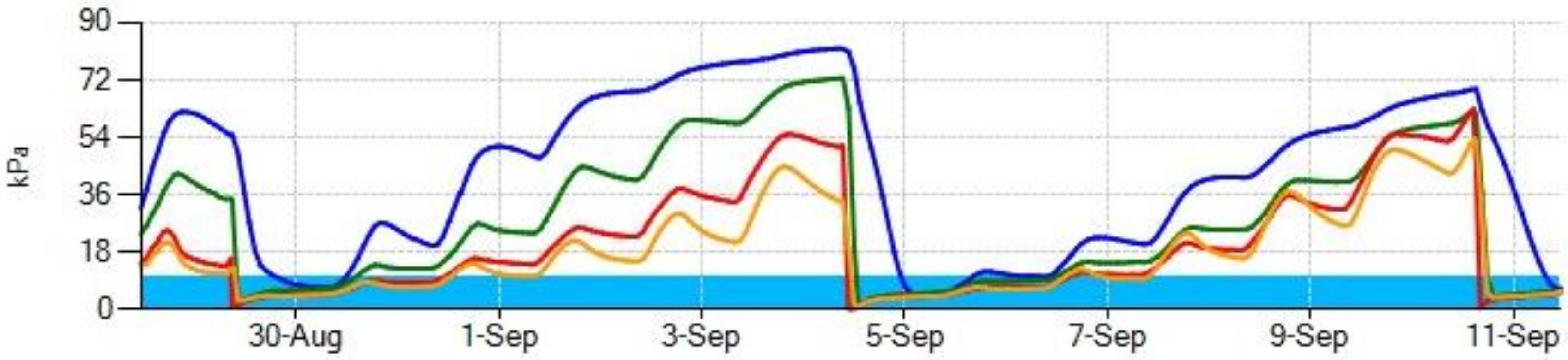
Soil Moisture (Centibars, kPa)





University of California
Agriculture and Natural Resources

Soil Moisture (Centibars, kPa)



Plant Disease • 2025 • 109:1268-1279 • https://doi.org/10.1094/PDIS-05-24-1131-RE

Role of Soil Moisture in Disease Development of Charcoal Rot of Strawberries Caused by *Macrophomina phaseolina*

Lindsey Pedroncelli,[1] Andre Biscaro,[2] and Alexander I. Putman[1,†]

[1] Department of Microbiology and Plant Pathology, University of California, Riverside, CA 92521, U.S.A.
[2] University of California, Division of Agriculture and Natural Resources, Cooperative Extension Ventura County, Ventura, CA 93003, U.S.A.

Abstract

Charcoal rot, caused by the soilborne fungus *Macrophomina phaseolina*, is one of the most economically important diseases affecting strawberry (*Fragaria × ananassa*) production in California. Previous studies on nonstrawberry hosts have shown that proper soil moisture management can limit pathogen colonization of plants and decrease disease severity. We performed field and greenhouse studies for two seasons with the objective of investigating the role of soil moisture in disease development and management of charcoal rot of strawberries. Bare-root transplants of cultivars Monterey and Fronteras were inoculated or not inoculated and maintained at a high, optimal, or low soil moisture level using tensiometers. Randomly selected plants from each treatment were sampled for pathogen colonization every 4 weeks after planting, and all plants were visually rated for disease severity every 2 weeks after symptom onset. In both seasons, low soil moisture significantly increased charcoal rot mortality among inoculated plants compared with optimal soil moisture by 16 and 24 percentage points, respectively. In the first season, mortality was significantly lower in the high- compared with the optimal-soil-moisture treatment. Colonization of crowns was increased by low soil moisture among inoculated plants in the first season, but soil moisture did not influence root colonization in either year of the study. In the greenhouse, charcoal rot severity was highest in the low-soil-moisture treatment. These results indicate that soil moisture has a limited influence on colonization of strawberries by *M. phaseolina* and that maintaining optimal soil moisture can help prevent excess charcoal rot mortality.

Keywords: cultural control, fungal pathogens, plant stress and abiotic disorders

Strawberry (*Fragaria × ananassa*) is an important crop in California. Production acreage averaged 15,419 ha and the farm gate value averaged $2.4 billion annually from 2020 to 2023 (CDFA 2020, 2021, 2022, 2023) California accounts for nearly 90% of domestic strawberry production, and from 2020 to 2023 exports averaged $441.5 million annually, making California a global leader in strawberry production (CDFA 2020, 2021, 2022, 2023).

In 2006, California strawberry growers observed an increase in the number of plants collapsing and dying. Plants were stunted and the older, outer leaves of the plant wilted and became necrotic while the inner, younger leaves of the plant remained green and alive. When the crown of the plant was cut open, dark orange to brown discolored decay was observed (Koike 2008). These are symptoms of charcoal rot, a disease that began to affect California strawberry production following the phaseout of methyl bromide as a preplant fumigant (Koike et al. 2013). Since the first report in Orange County, California, in 2005 to 2006 (Koike 2008; Koike et al. 2013), charcoal rot has been reported in all major strawberry production regions throughout the state, as well as Florida and several other countries, making charcoal rot of strawberries a global concern (Avilés et al. 2008; Hajlaoui et al. 2015; Koike et al. 2013; Mertely et al. 2005; Qamar et al. 2019; Sánchez et al. 2013; Zveibil and Freeman 2005).

There are very few widely effective strategies to manage charcoal rot. Crop rotation, anaerobic soil disinfestation, and biological controls are promising approaches but often do not suppress disease below economic thresholds and can be difficult to implement on a large scale. Planting disease-resistant cultivars is a strategy to manage many plant diseases; however, susceptibility of strawberry cultivars to charcoal rot varies greatly, and there are currently no highly resistant cultivars (Holmes et al. 2020). Strawberry growers throughout the state need new ways to manage this disease.

†Corresponding author: A. I. Putman; aiputman@ucr.edu

Author contributions: Conceptualization: L.P. and A.I.P.; Methodology: L.P., A.B., and A.I.P.; Formal Analysis: L.P. and A.I.P.; Investigation: L.P.; Resources: A.I.P.; Data Curation: L.P. and A.I.P.; Writing – Original Draft Preparation: L.P.; Writing – Review and Editing: L.P., A.I.P., and A.B.; Supervision: A.I.P.; Project Administration: L.P. and A.I.P.; Funding Acquisition: A.I.P.

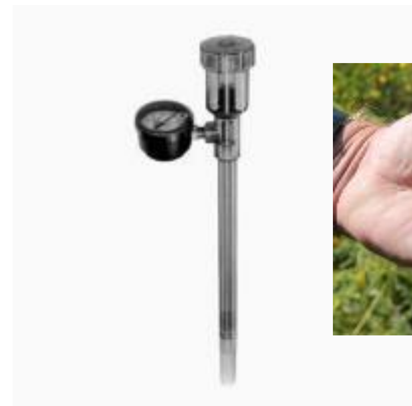
University of California
Agriculture and Natural Resources

Summary

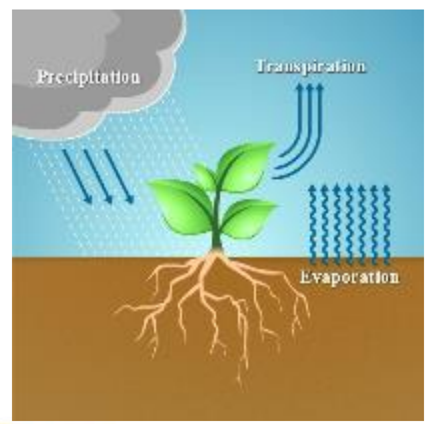
- ✓ Start monitoring soil moisture at 4in depth immediately after planting;
- ✓ After establishment, use 6 and 12in depths;
- ✓ Use tensiometers along with soil probe;
- ✓ Irrigation threshold for best results = 10cb at 6in depth;
- ✓ Excessively dry conditions usually trigger plant mortality from Macrophomina.

Irrigation Scheduling

1. Deciding when to irrigate

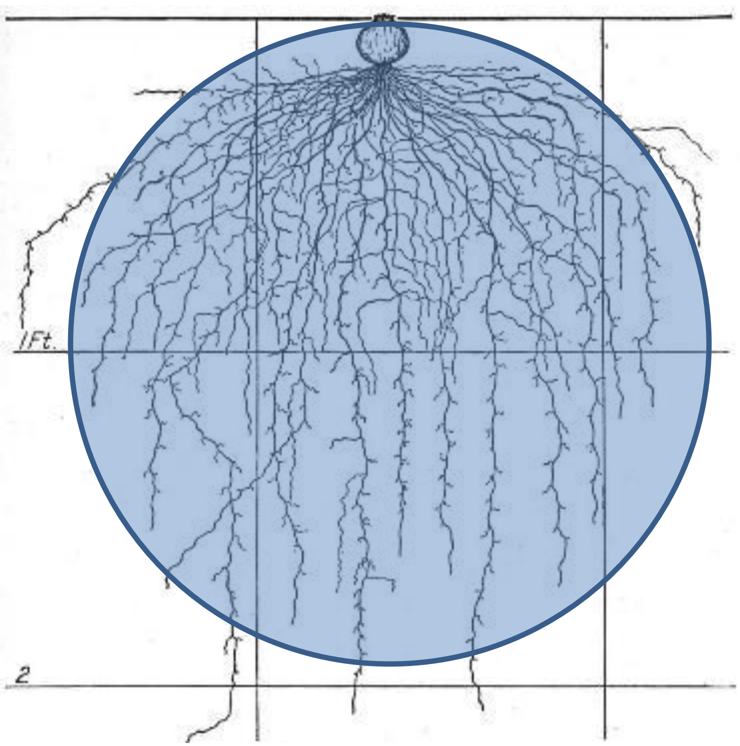


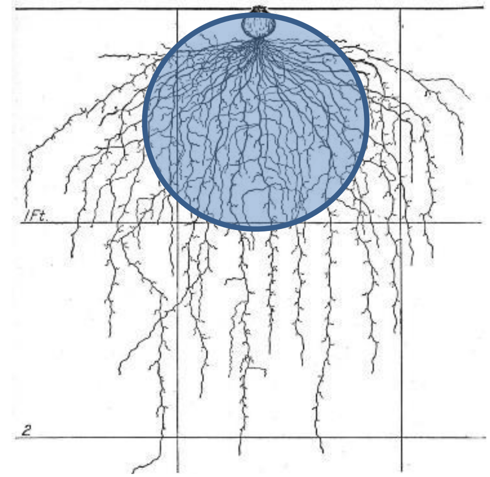
2. Deciding how much to irrigate

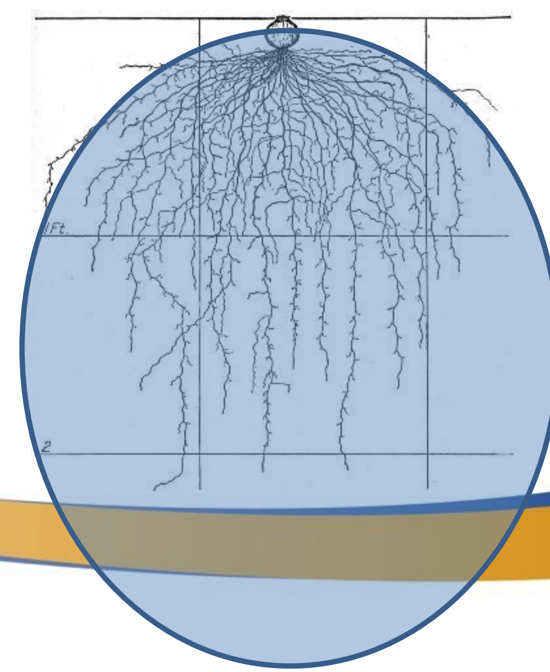


Inefficient irrigation

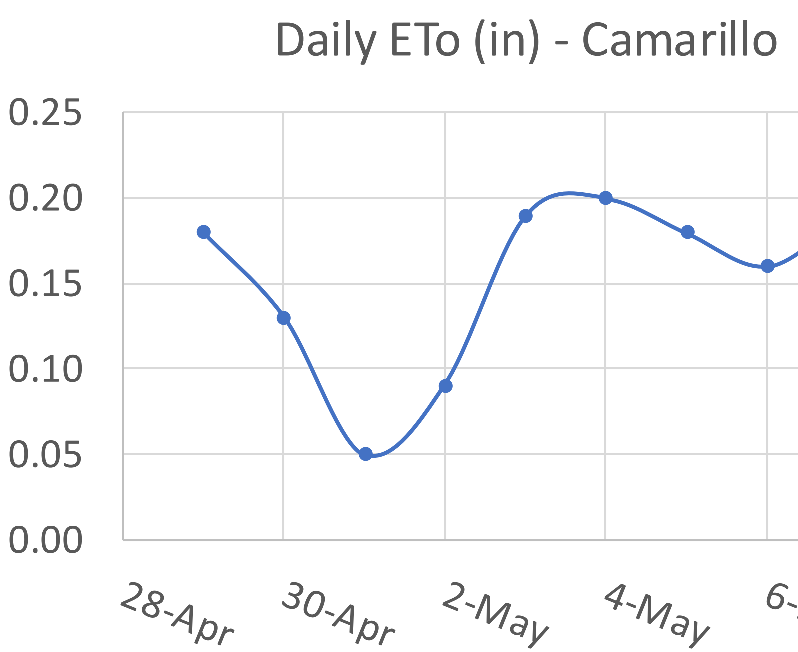
Ideal irrigation

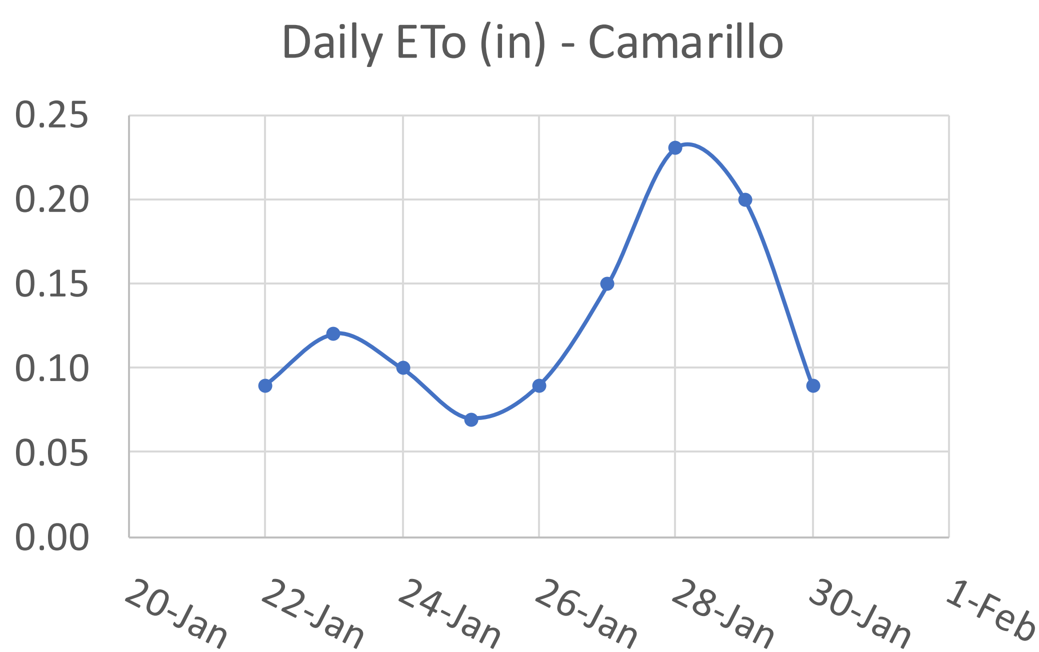






Why is irrigation scheduling challenging?





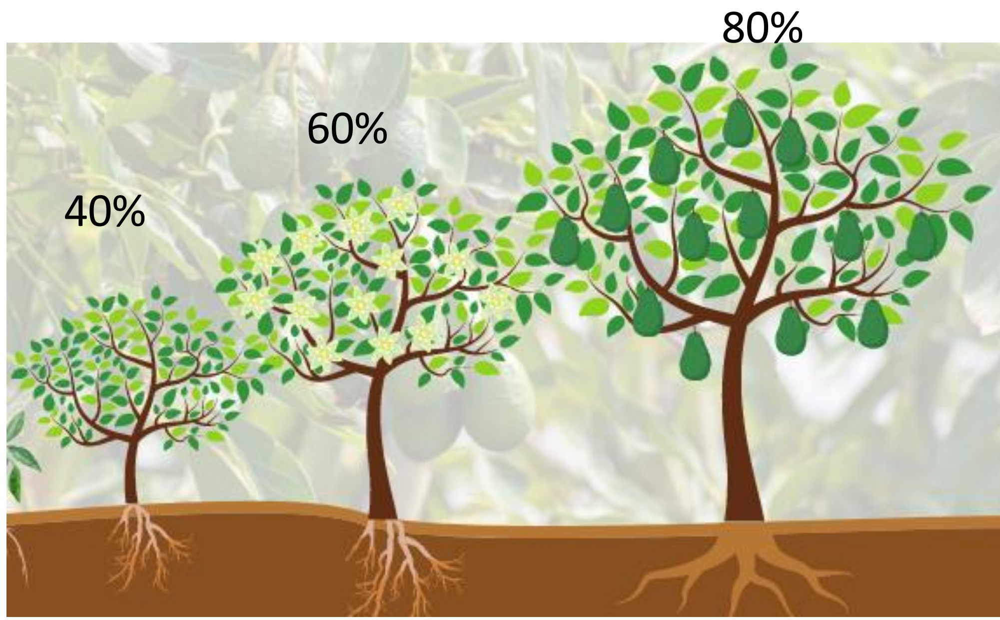
University of California
Agriculture and Natural Resources

ET-Based Irrigation

Kc (varies with different canopy cover)

ETo

x



Water Recomme-ndation

Basic equation: ETc = ETo * Kc

ETc = Crop evapotranspiration
ETo = Reference evapotranspiration
Kc = Crop coefficient

Accounting for distribution uniformity and leaching fraction:
ETc = ((ETo * Kc)/(DU/100))/(1-LF/100)

DU = Distribution uniformity
LF = Leaching fraction

Example:

Kc = 0.2 Kc = 0.8

Last irrigation on May 27

Date	ETo (in)
5/28/24	0.14
5/29/24	0.10
5/30/24	0.15
5/31/24	0.14
6/1/24	0.05
6/2/24	0.06
6/3/24	0.13

Total ETo = 0.77 in

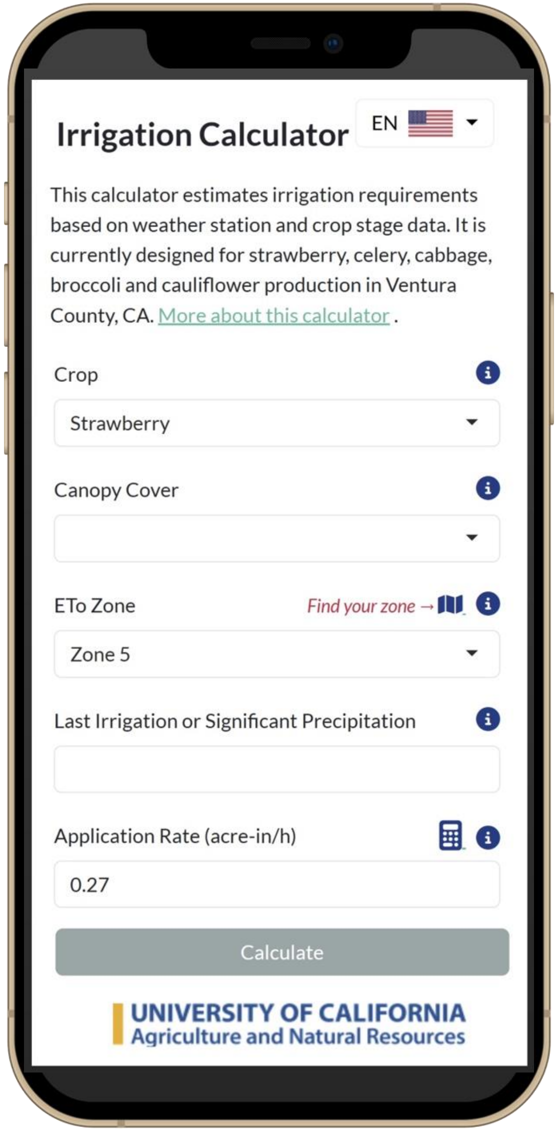
Young orchard:
ETc = 0.77*0.2 = 0.15 in

Mature orchard:
ETc = 0.77*0.8 = 0.62 in

DU= 80%
LF = 10%

ETc = ((0.15)/0.8)/0.9
= 0.21 in

ETc = ((0.77)/0.8)/0.9
= 0.86 in

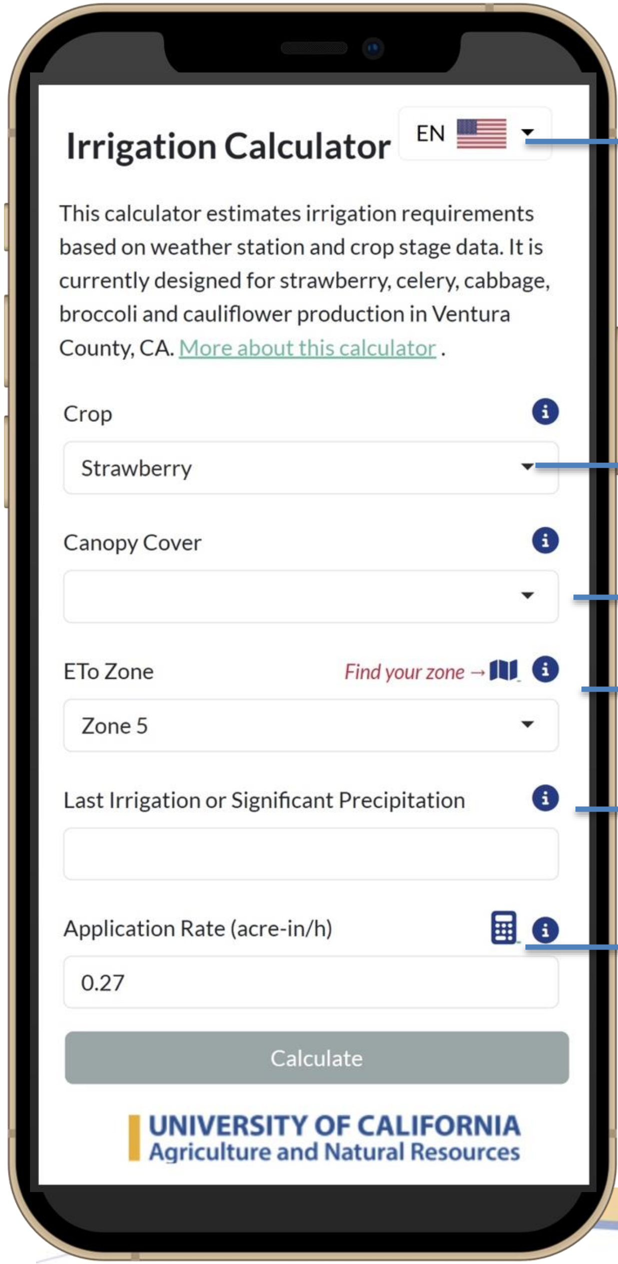


Irrigation App to Increase Data-Driven Decisions

Andre Biscaro,
Irrigation and Water Resources Advisor,
UC ANR

Andy Lyons,
IGIS, UC ANR

University *of* California
Agriculture and Natural Resources



English and Spanish

Crop

Adjusts the crop coefficient

Chooses weather station

Collects ETo data since last irrigation

Converts volume to time

✓ Distribution Uniformity: 85%

✓ Leaching Fraction: 10%

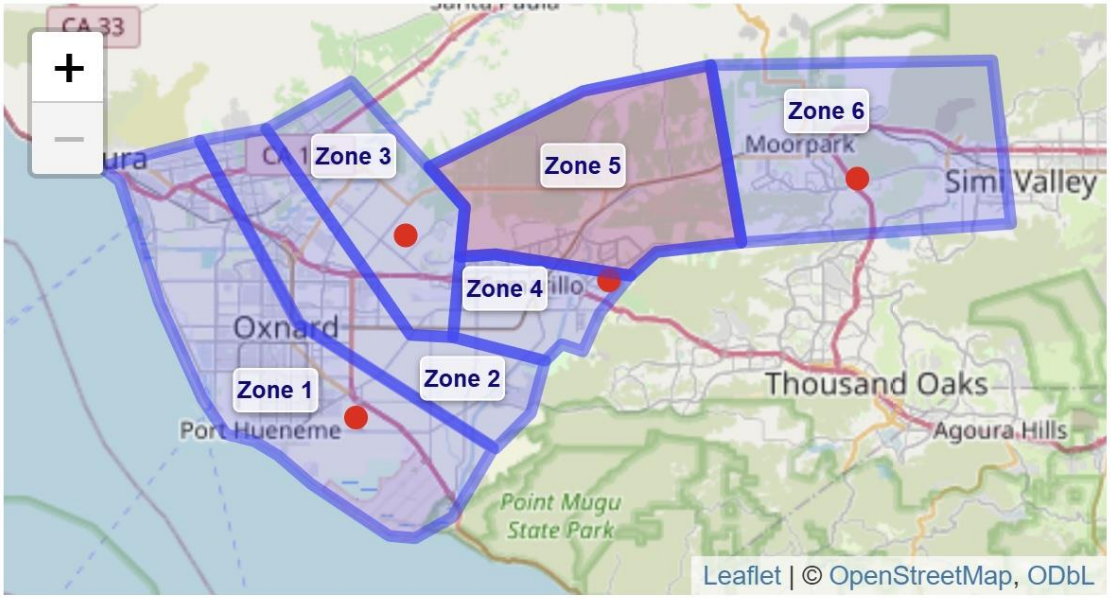
Strawberry, celery, cabbage, broccoli, cauliflower

Avocado

University *of* California
Agriculture and Natural Resources

ETo Zones Map

Below are the ETo Zones for Ventura. Click on a zone to use it. The red dots are weather stations.



Cancel

Use this zone

University *of* California
Agriculture and Natural Resources

Example:

- Strawberry
- Canopy: 50-60%
- ETo Zone 3
- Last irrigation: Sept 9
- Application rate: 0.18 in/h

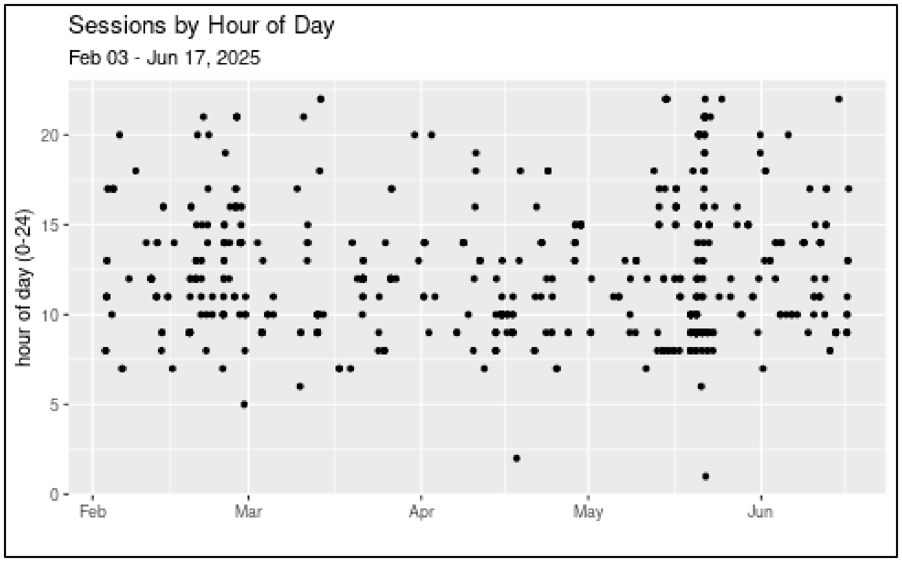
February 01 - June 17, 2025

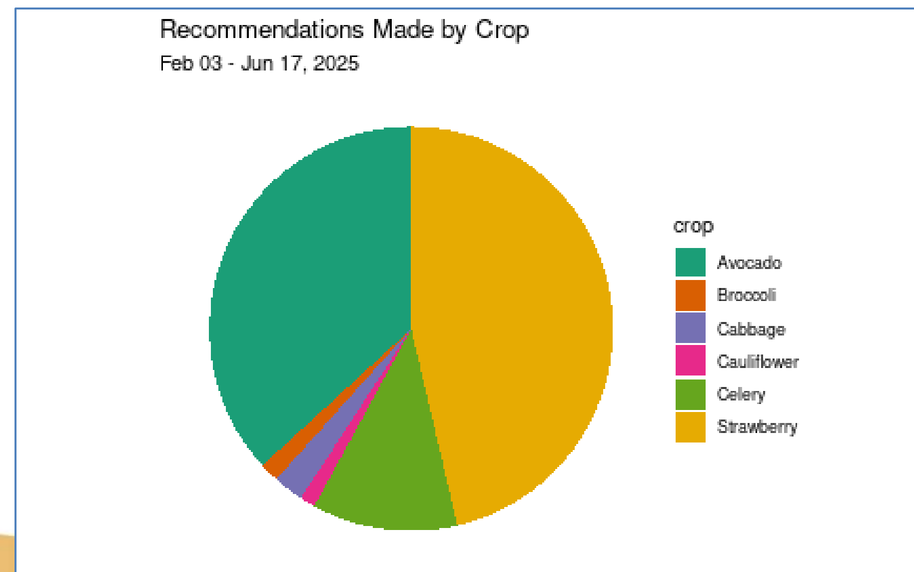
544 Sessions

407 Return visits

326 Recommendations

106 Rate calculated



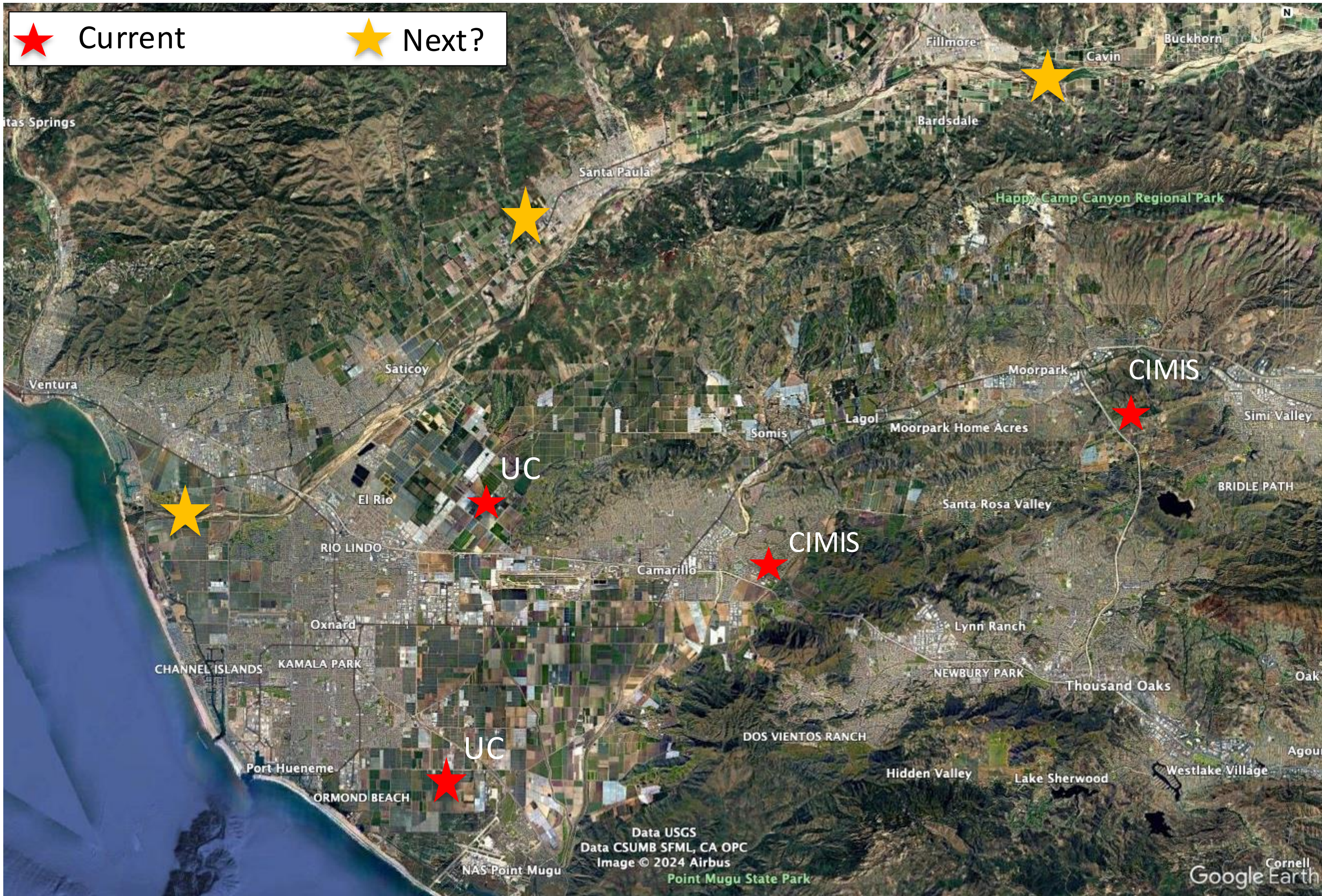


University *of* California
Agriculture and Natural Resources

Summary

- ✓ App is fully functional
- ✓ Beta-testing
- ✓ Anticipated outcomes:
  - Increased adoption of data-driven management
  - Improved yield and crop health
- ✓ Your feedback is important

Ventura County ETo Stations

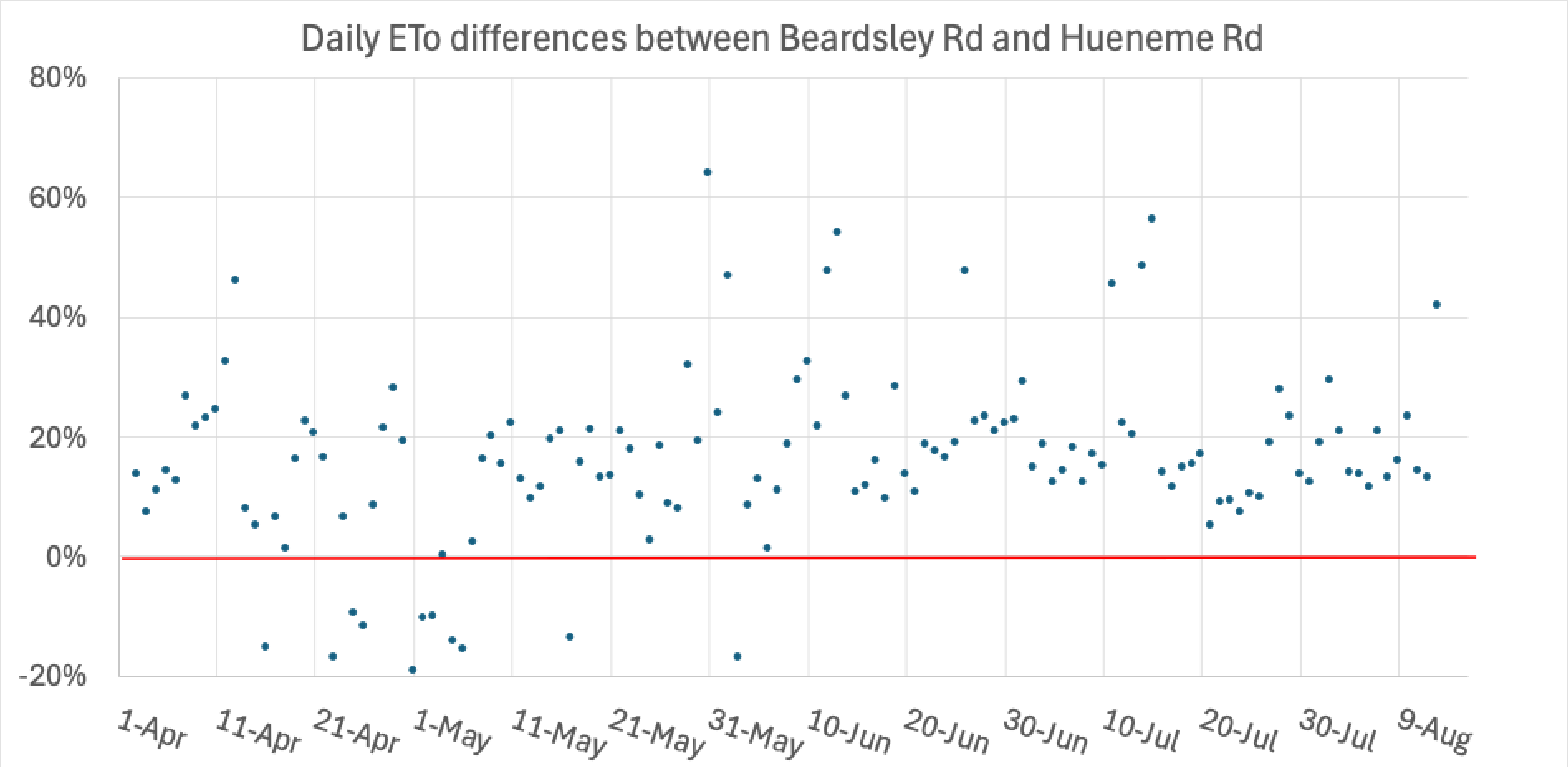


University *of* California
Agriculture and Natural Resources

UC ANR Ventura Weather Stations

https://ucanrventura.westernweathergroup.com/

University *of* California
Agriculture and Natural Resources



- Average: Beardsley is 16% greater
- Beardsley is greater than 20% in 33.8% of the time
- Beardsley is greater than 40% in 7.5% of the time
- Hueneme is greater in only 8.3% of the days

Thank you!

Questions/comments?

asbicaro@ucanr.edu
(805)645-1465