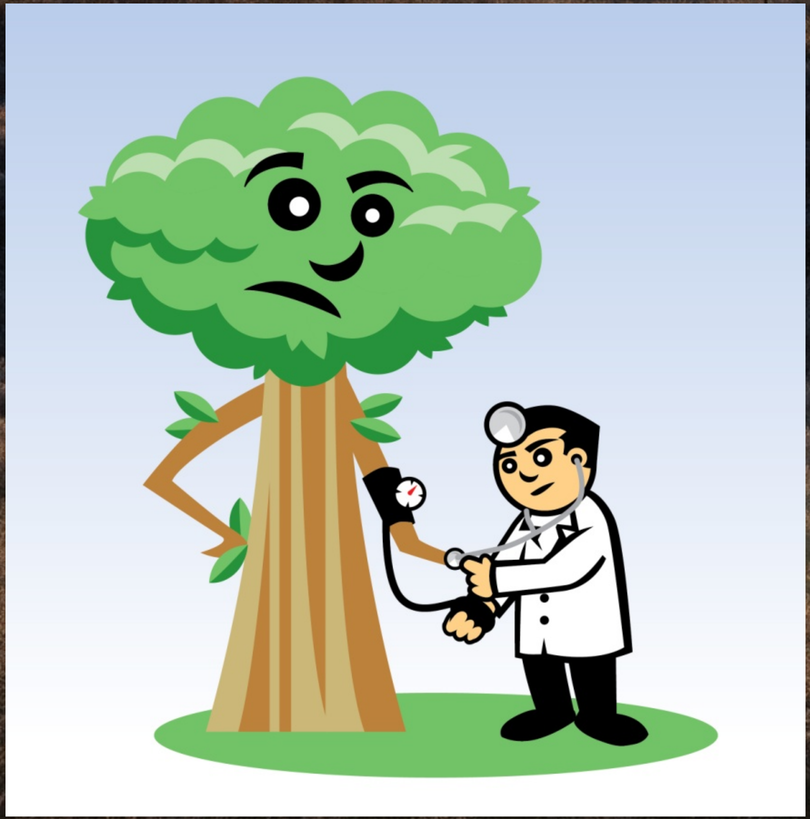
Rooted IN SUCCESS 2021
the almond conference

PRECISION ORCHARD MANAGEMENT: IRRIGATION AND PESTS

Moderators: Sebastian Saa (ABC), Tom Devol (ABC), Drew Wolter (ABC)
Speakers: Ken Shackel (UC Davis), Nicolas Bambach (UC Davis), Pat Biddy (Vanguard Ag), Lynn Sosnoskie (Cornell University)

california almonds
Almond Board of California



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Water stress sensors and what they have taught us about almond irrigation.

12/9/21 / Ken Shackel

california almonds
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The quest for the 'Holy Grail' of plant water stress sensors…

Diagnosing plant physiological activities and drought stress effects

*In the TV series Star Trek, a tricorder is a handheld scanning and analysis diagnostic device

What would a plant "tricorder"* measure?

•Plant water potential

•Stress-responses: hormones, transcripts, metabolites

•Growth rate

•Growth direction and orientation

What is the ‘Perfect’ sensor?

Predicts if profit ($) will go up or down if you irrigate or not.
…We don’t have that one yet.

Current sensors

Direct: Measures the level of water stress in the plant **now**.
Indirect: Measures something about what the plant is doing **now**.

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2) FloraPulse
3) Saturas
4) ICT

(2–4): Automated

(1–4): All measure the same thing: **water potential**

"SWP"

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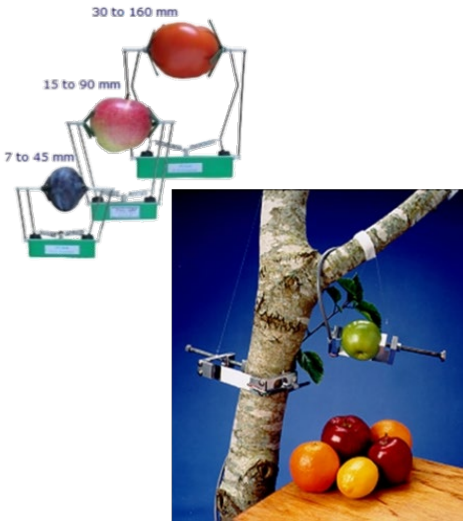
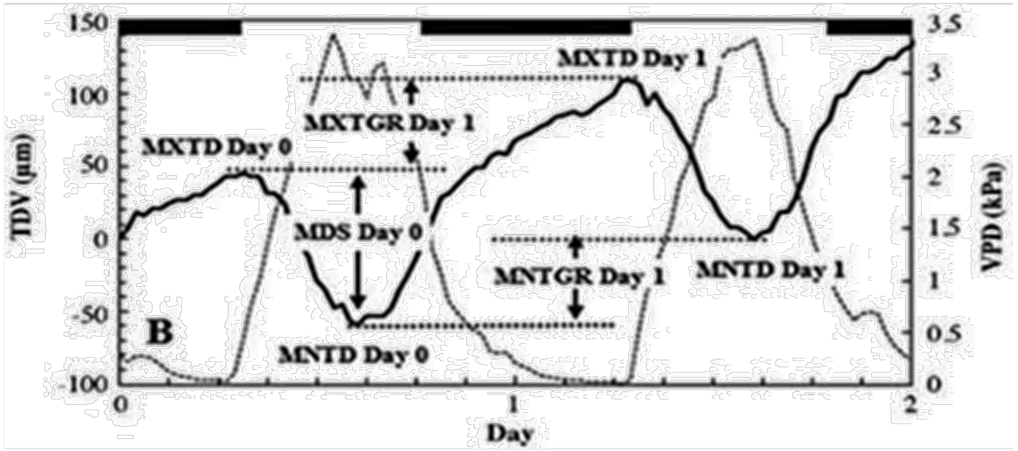
Trunk Dendrometer (Phytech)

(Fruit dendrometers)





Silva-Contreras C, Sellés-Von Schouwen G, Ferreyra-Espada R, Silva-Robledo H. 2012. Chilean Journal of Agricultural Research 72:

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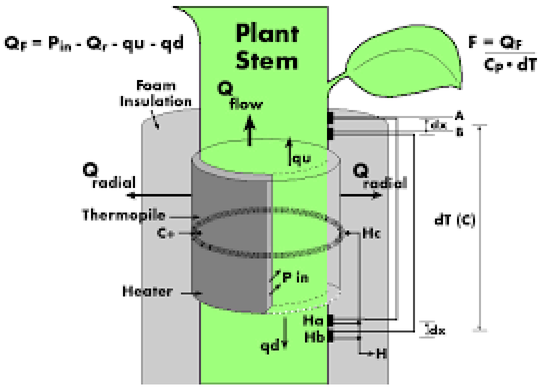

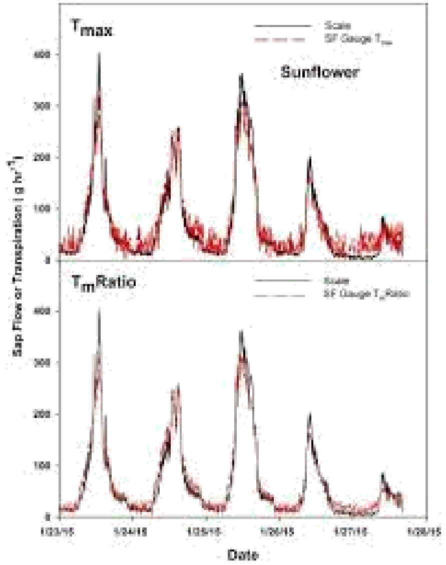

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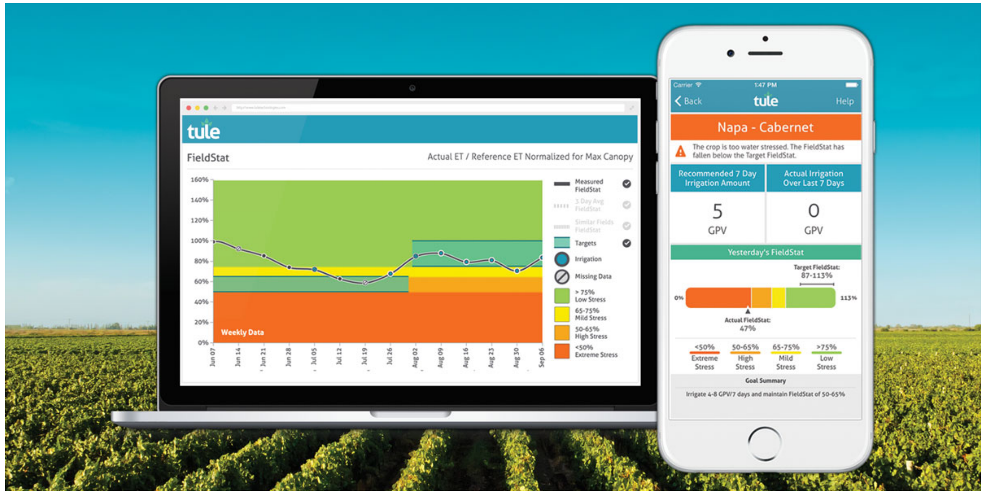
3) Canopy **ET** (e.g., Tule)



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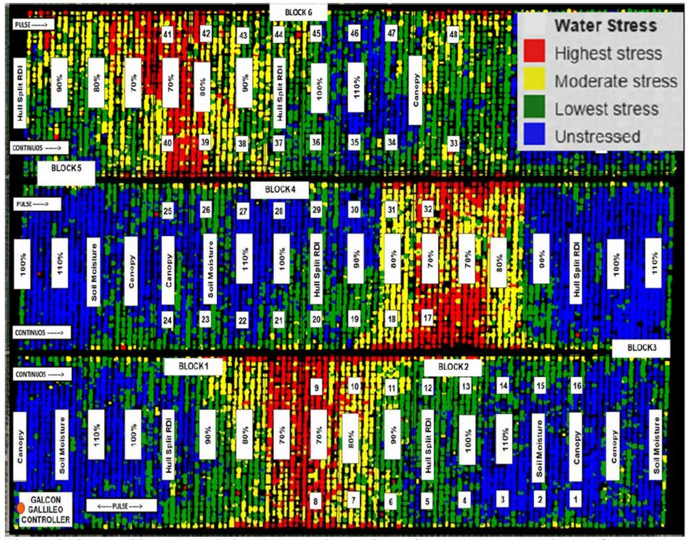

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3) Canopy **ET** (e.g., Tule)
4) Leaf or canopy **temperature** (evaporative cooling)/remote sensing (e.g., CERES)
5) Leaf, trunk, branch **water content** (too many to list)
6) Others……….

The main advantage of SWP is that we have some guidelines/recommendations:

- ‘Wet soil’ (baseline) conditions: 6-12 bars, depending on the weather (temperature, RH).
- Hull split: 14-18 bars.
- Significant stress (‘closed for business’): around 30 bars.
- Survival: 60 bars and ‘not dead yet,’ (but no yield next year).

Whether a sensor is direct or indirect, in order to be useful for irrigation management it needs to:

1) Measure specifically whether the trees need water or not.
2) In time to make an irrigation decision.
3) Hopefully have a close relation to overall tree health/productivity, or at least some processes that we think should be related to productivity (e.g., photosynthesis).

Whether you consider a sensor ‘cheap’ or ‘expensive’ depends on how valuable the information is to you!

So, how does your irrigation approach affect the tree?

A few (19) 'days in the life.'

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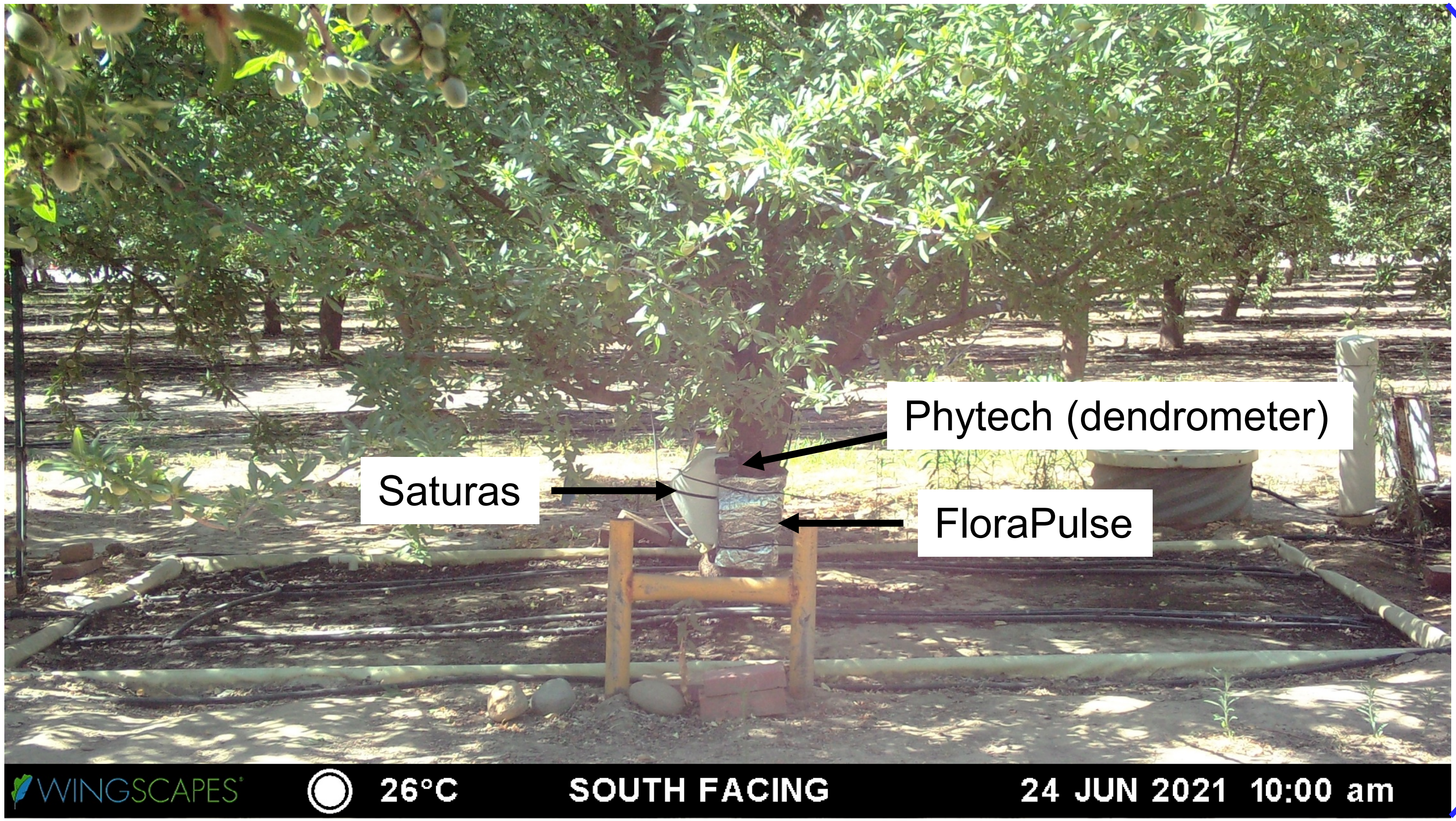
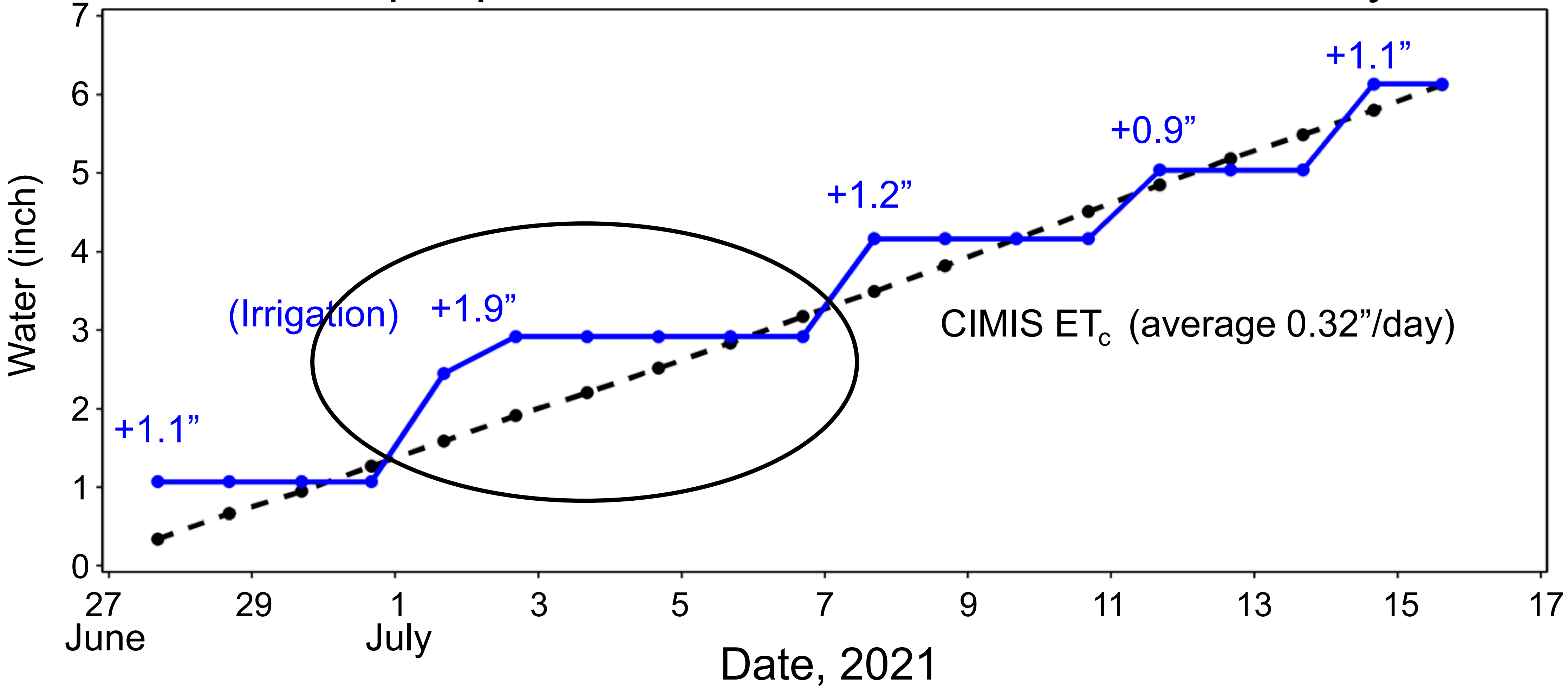
3 acre almond orchard in Parlier, CA

Tree in a lysimeter for <u>accurate</u> measurement of water use (ET_c), installed with commercial water stress sensors

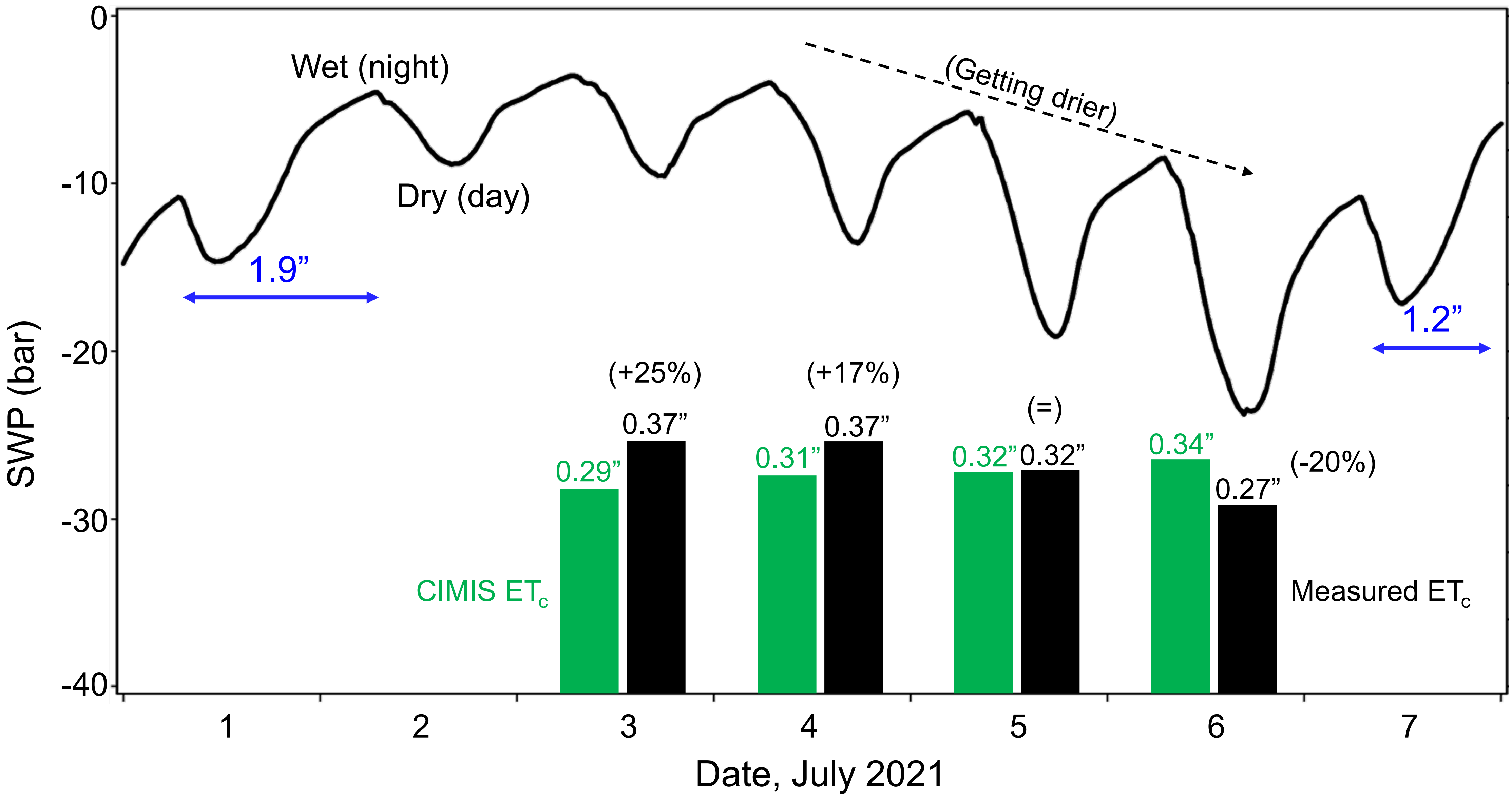


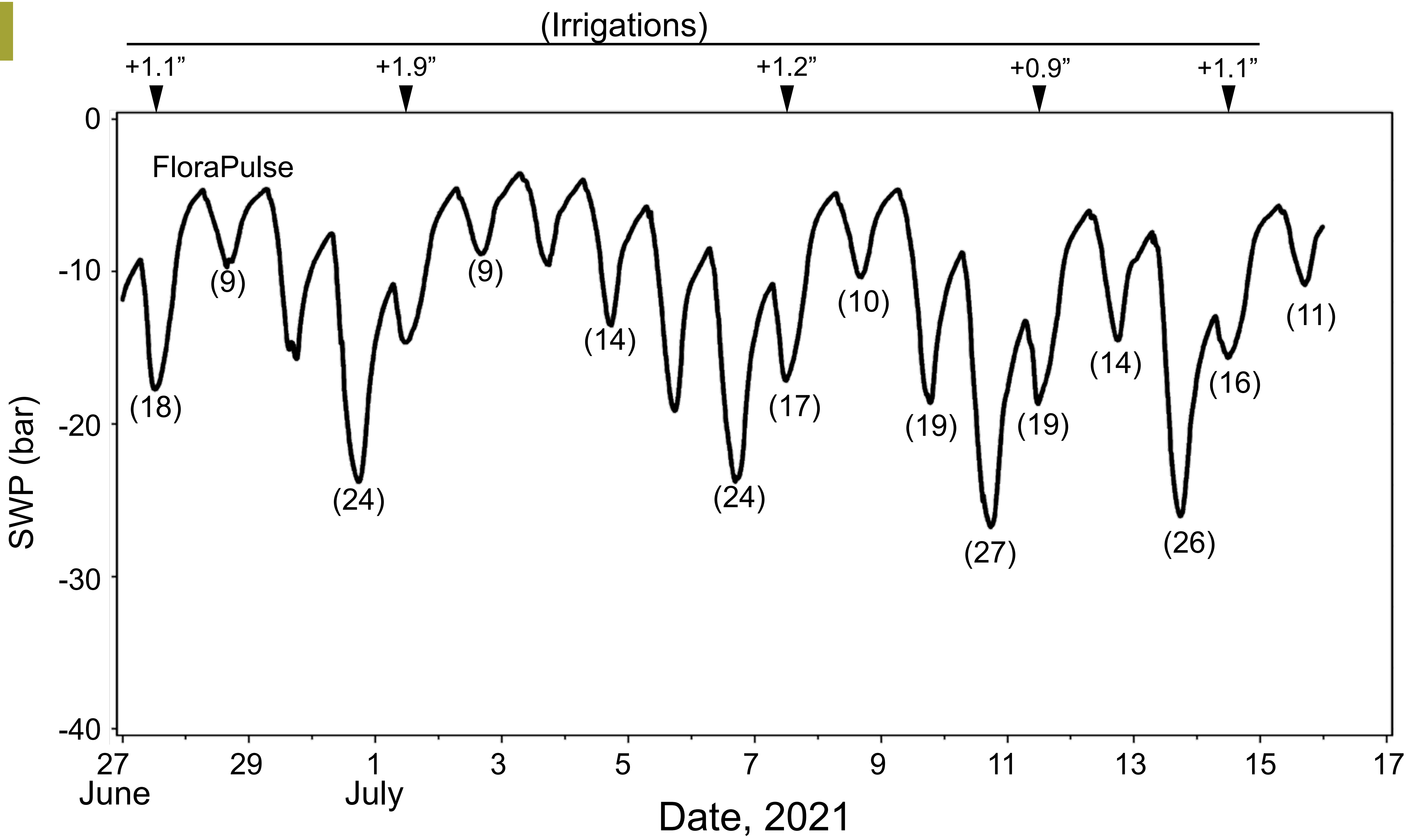
Almond ET and irrigation in Parlier, June 27 – July16, 2021. (double line drip on a deep and a very well drained Hanford sandy loam soil)

We ‘kept up’ with ET, but what did the sensors say?



24/7 SWP according to FloraPulse sensor: the 'heart beat' of the tree




(Irrigations)
+1.1”
+1.9”
+1.2”
+0.9”
+1.1”
FloraPulse
SWP (bar)
0
-10
-20
-30
-40
(18)
(9)
(24)
(9)
(14)
(24)
(17)
(10)
(19)
(27)
(19)
(14)
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29
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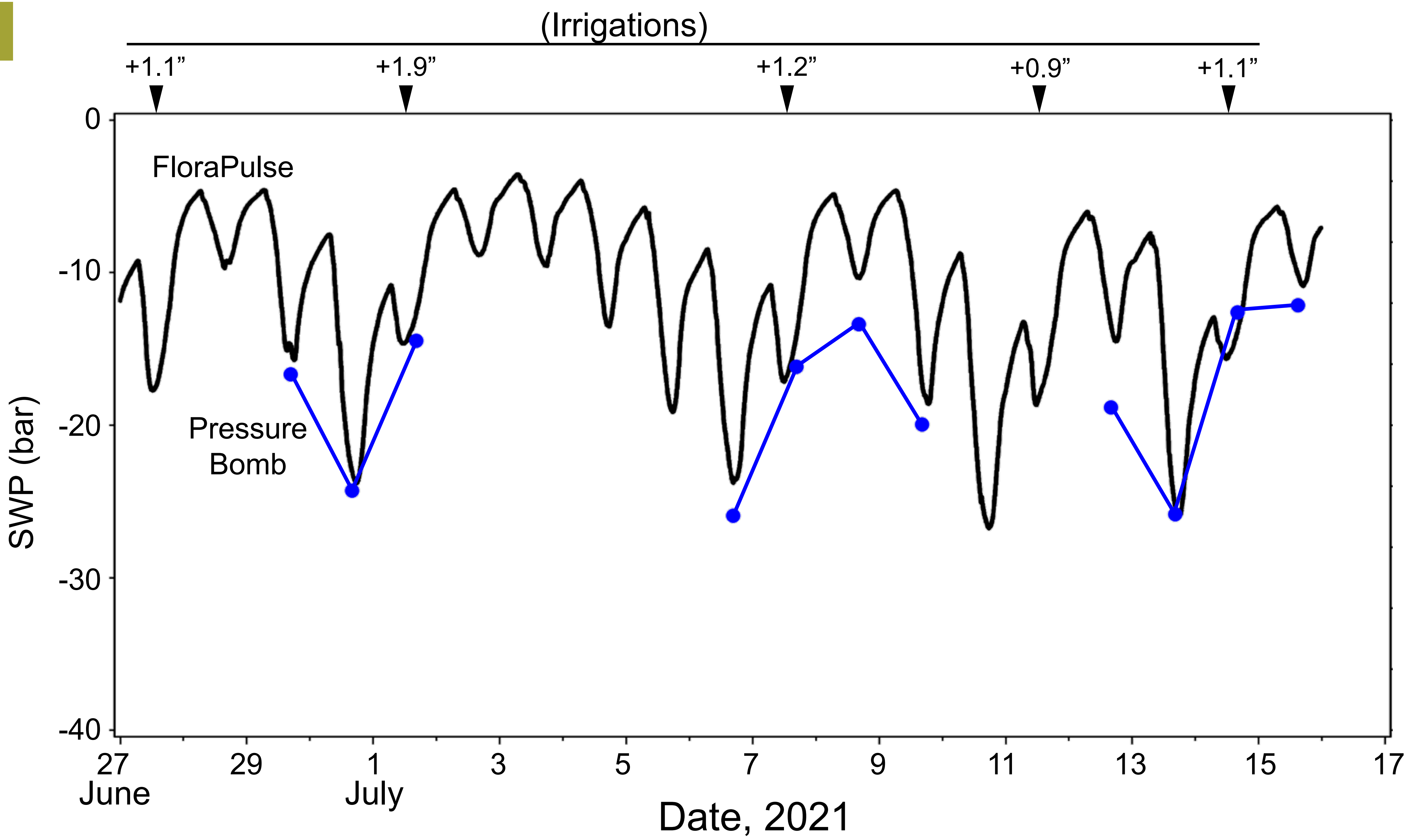
15
17
Date, 2021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29
1 July
3
5
7
9
11
13
15
17
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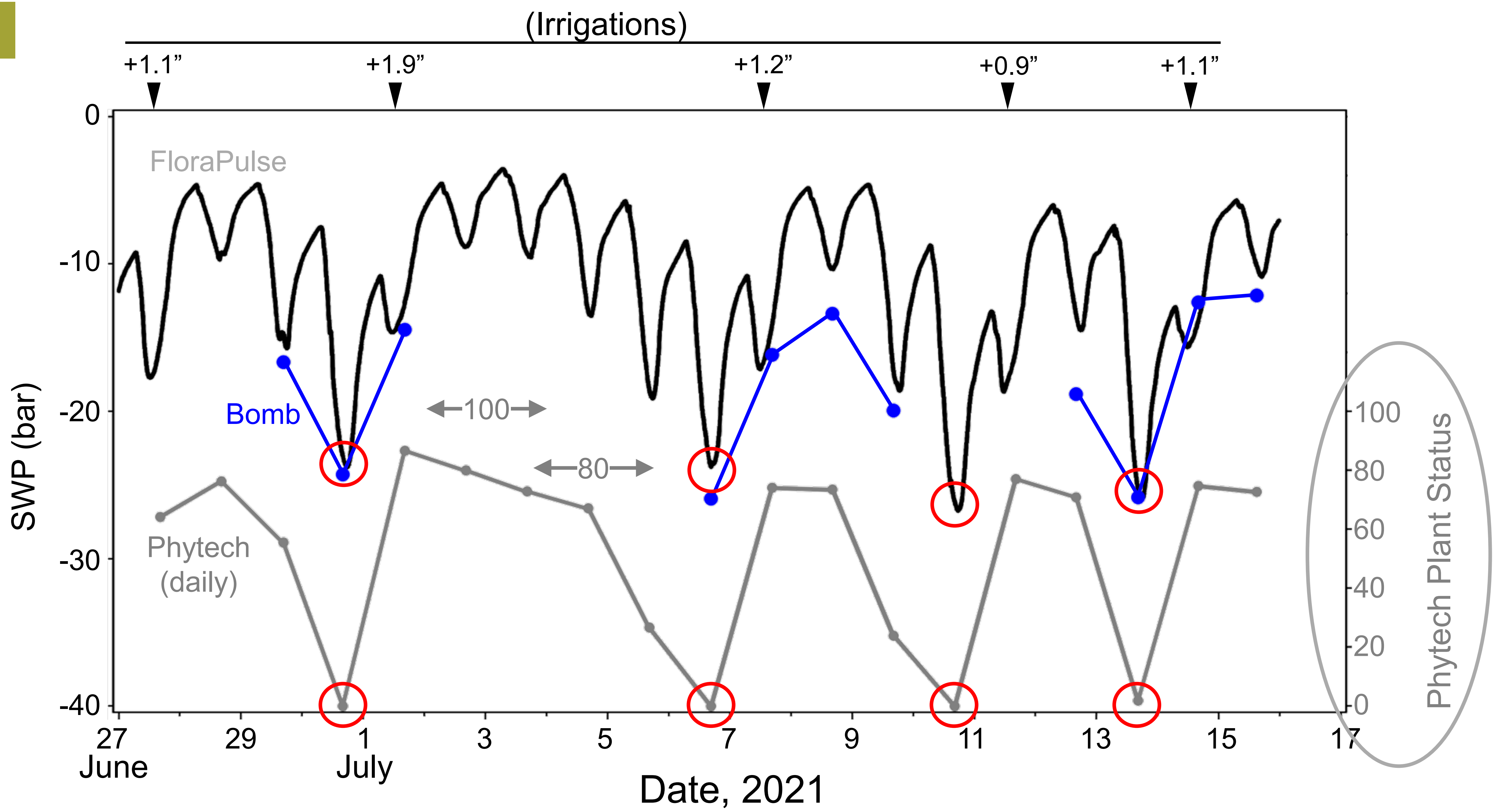
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FloraPulse
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←100→
←80→
Phytech
(daily)
100
80
60
40
20
0
Phytech Plant Status
27
June
29
1
July
3
5
7
9
11
13
15
17
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Summary:

1) Daily sensor (or pressure bomb) measurements on 1 or 2 'typical' trees per irrigation block can inform irrigation management decisions for the whole block.
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- On this deep, sandy-loam soil, daily SWP readings showed that trees go into significant stress within a few days after irrigation.
- Recommendation: measure SWP soon after irrigation to confirm recovery, and again just before the next irrigation to check for significant stress.
- More work will be needed to determine if this is less of a problem on heavier soils.

Thank You

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T-REX

Advancing towards Precision Irrigation

12 DEC 2021/ NICOLAS BAMBACH

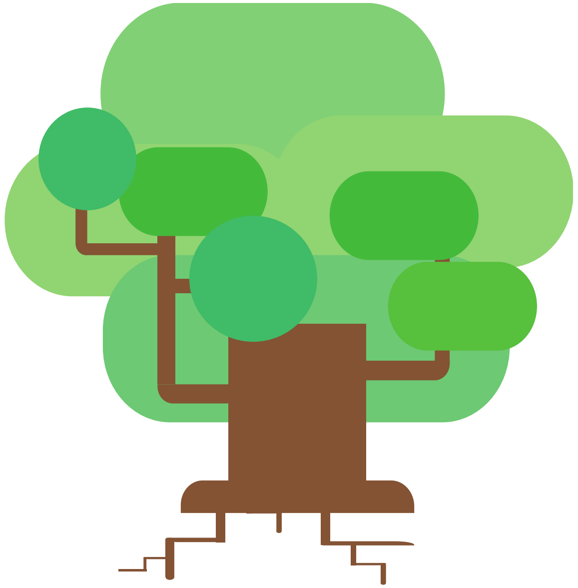
california almonds
Almond Board of California

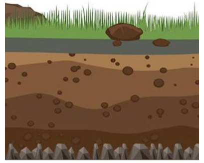
T-REX
Tree crop Remote sensing of Evapotranspiration eXperiment

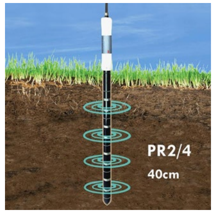
MOTIVATION

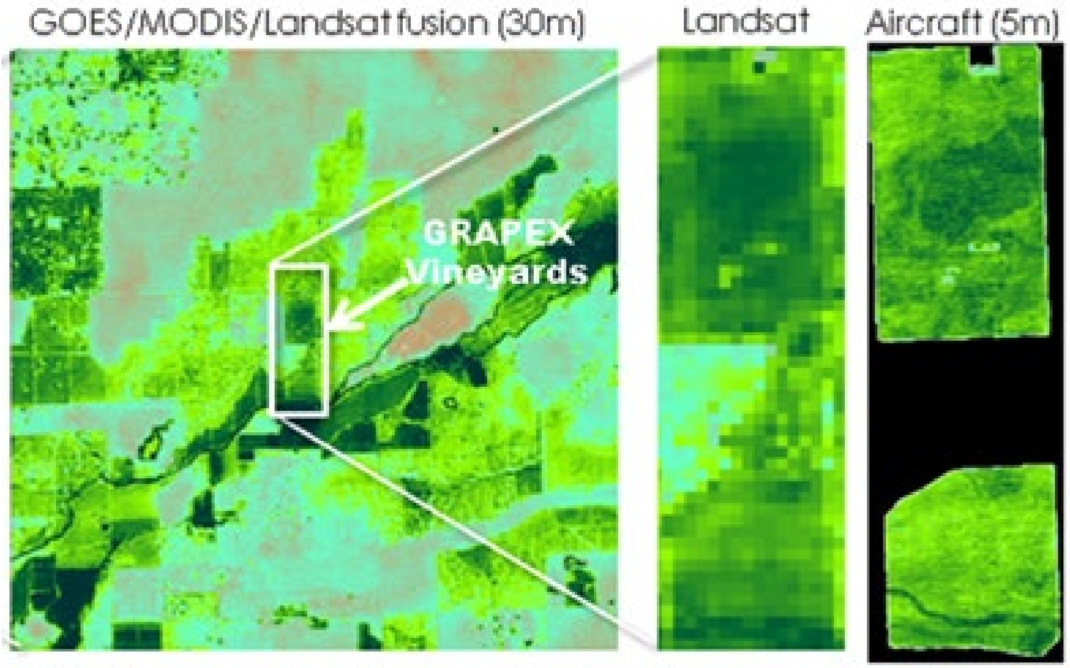
More almonds per drop…a journey to fine-tune irrigation

When, how much, and where to deliver water?





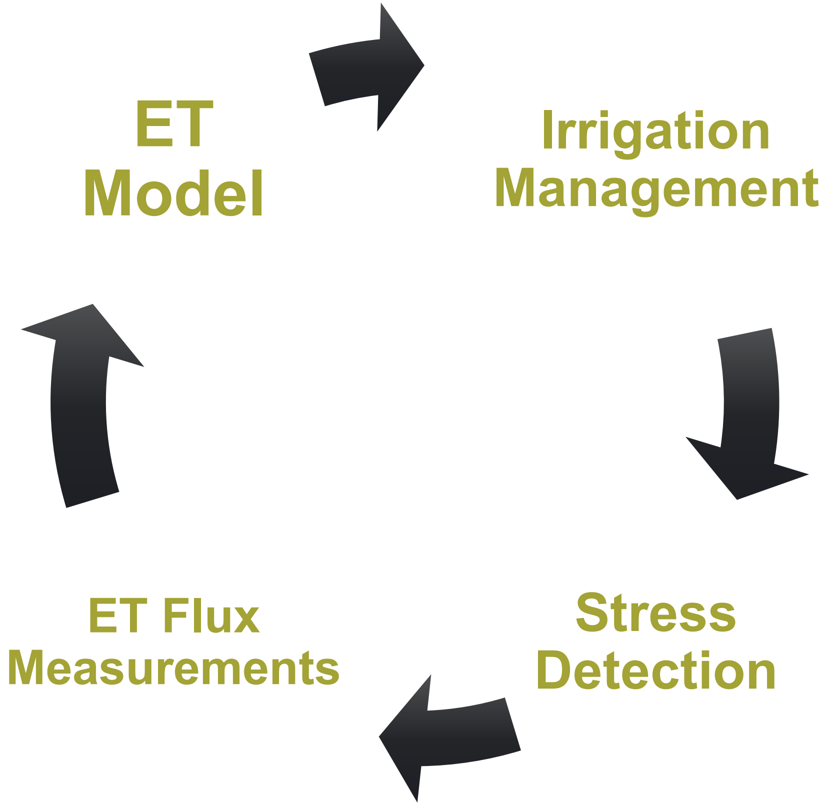




T-REX
Tree crop Remote sensing of Evapotranspiration eXperiment

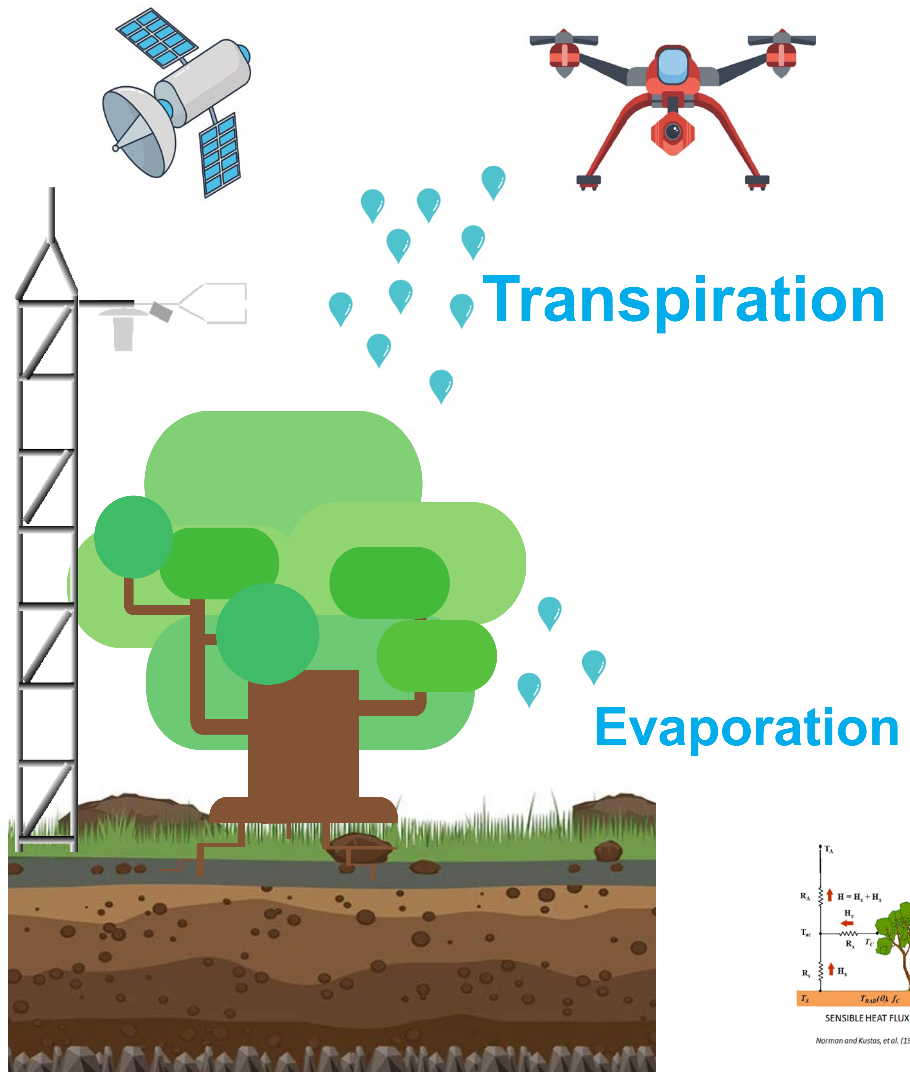
OUR PROJECT - *OBJECTIVE*

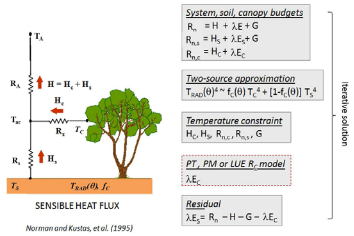
Test and refine ET models to support precision irrigation management decisions.



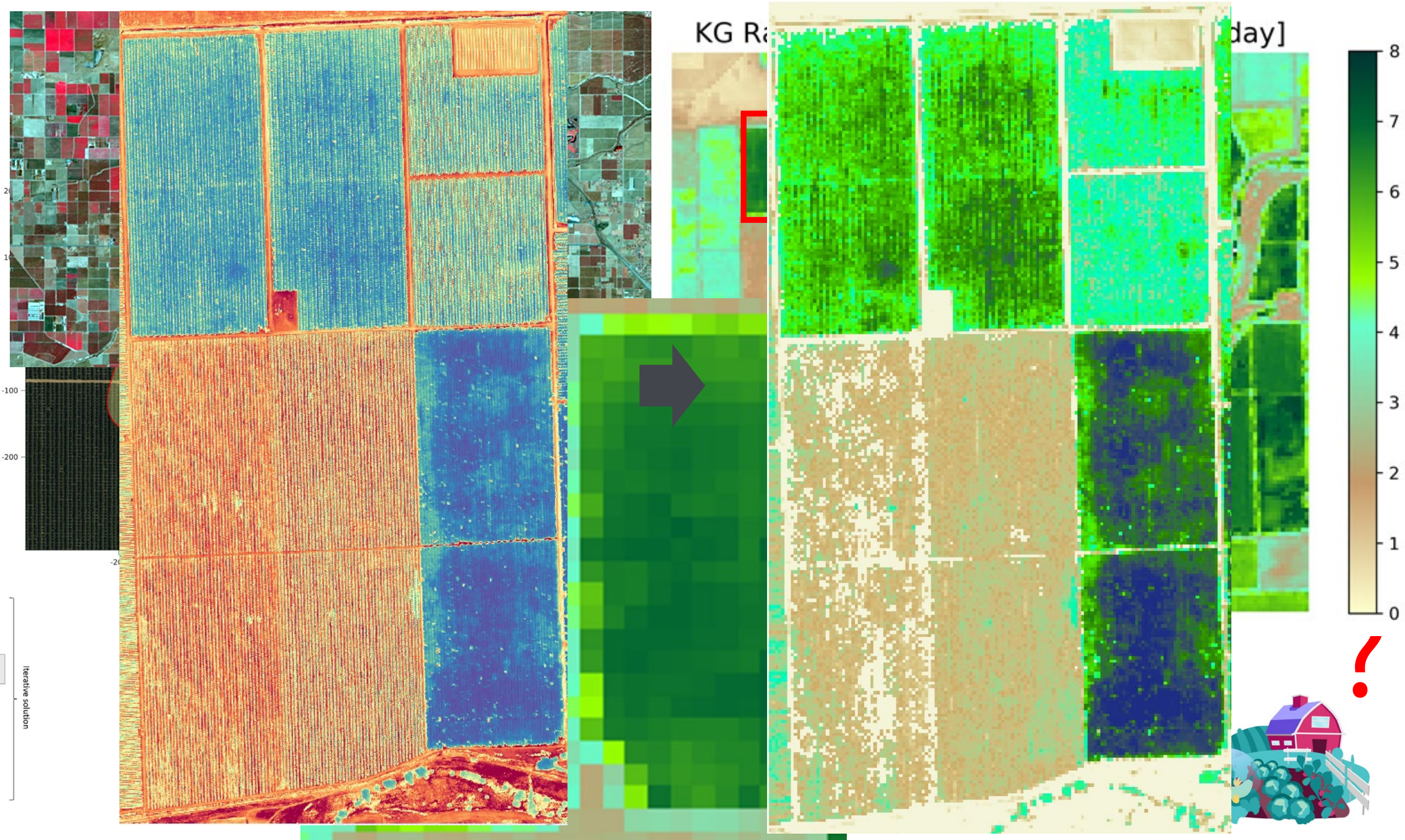
OUR PROJECT - *APPROACH*

T-REX
Tree crop Remote sensing of Evapotranspiration eXperiment





Direct ET measurements based on eddy covariance
Indirect ET estimates based on models



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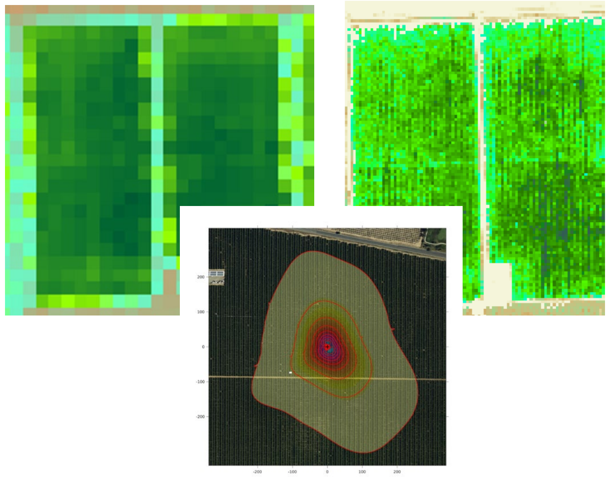
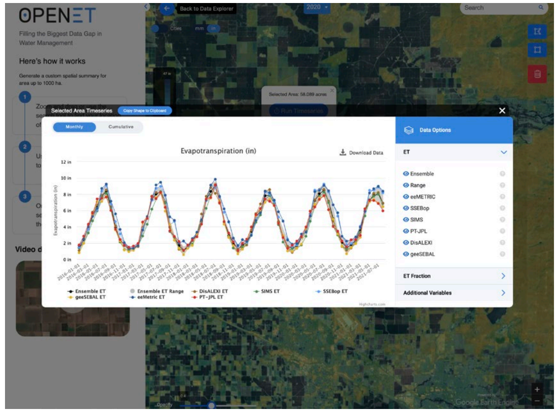
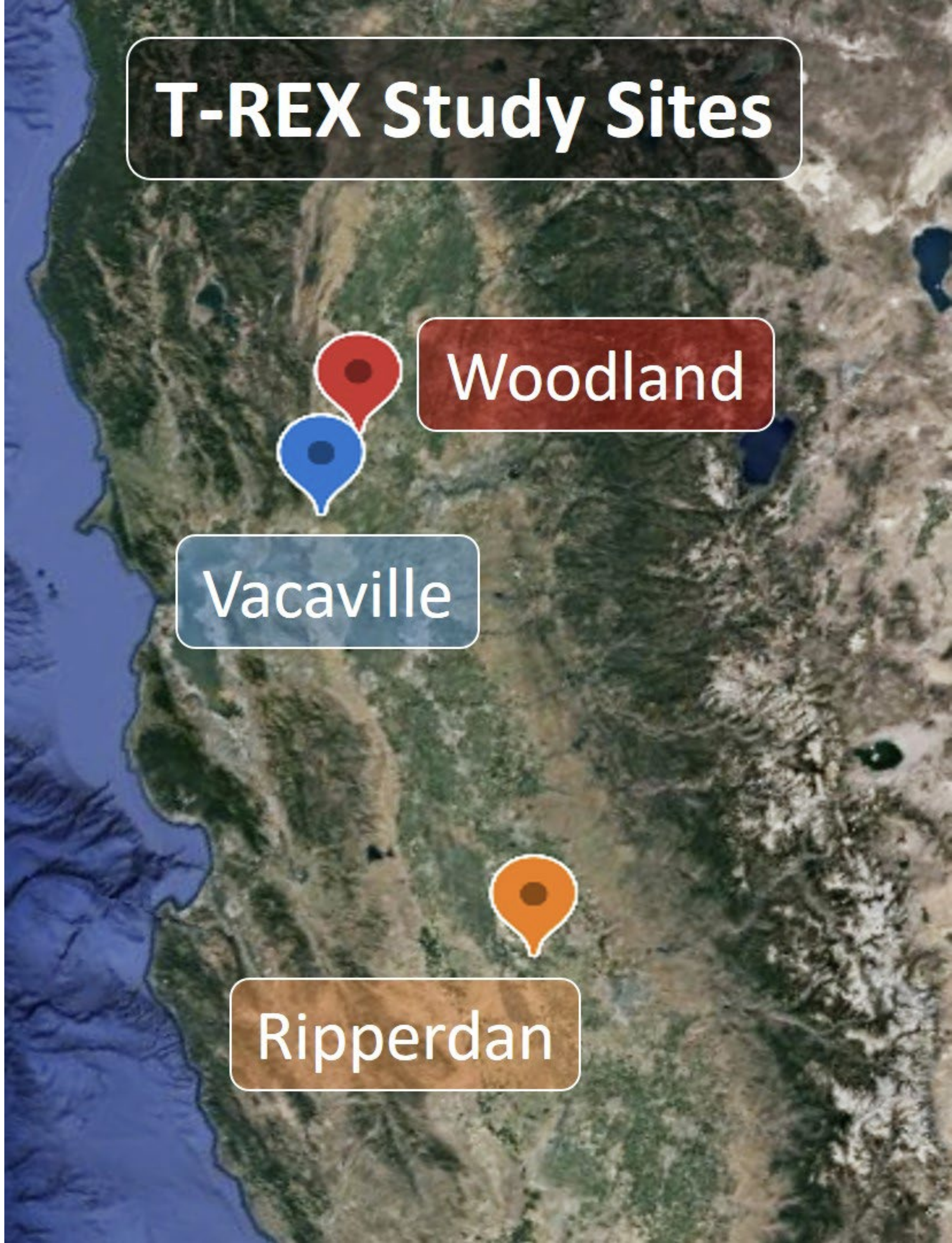
PLAN

Ground-Truth and Refine Models → Identify Stress → Data integration and decision support tools.





GROUND TRUTH EFFORTS



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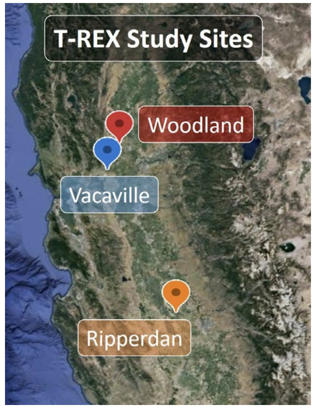


9th leaf
Non-pareil-50% | Monterey, Butte & Carmel-17%
Heavy clay vertisol

7th leaf
Independence -100%
Silty clay loam soil

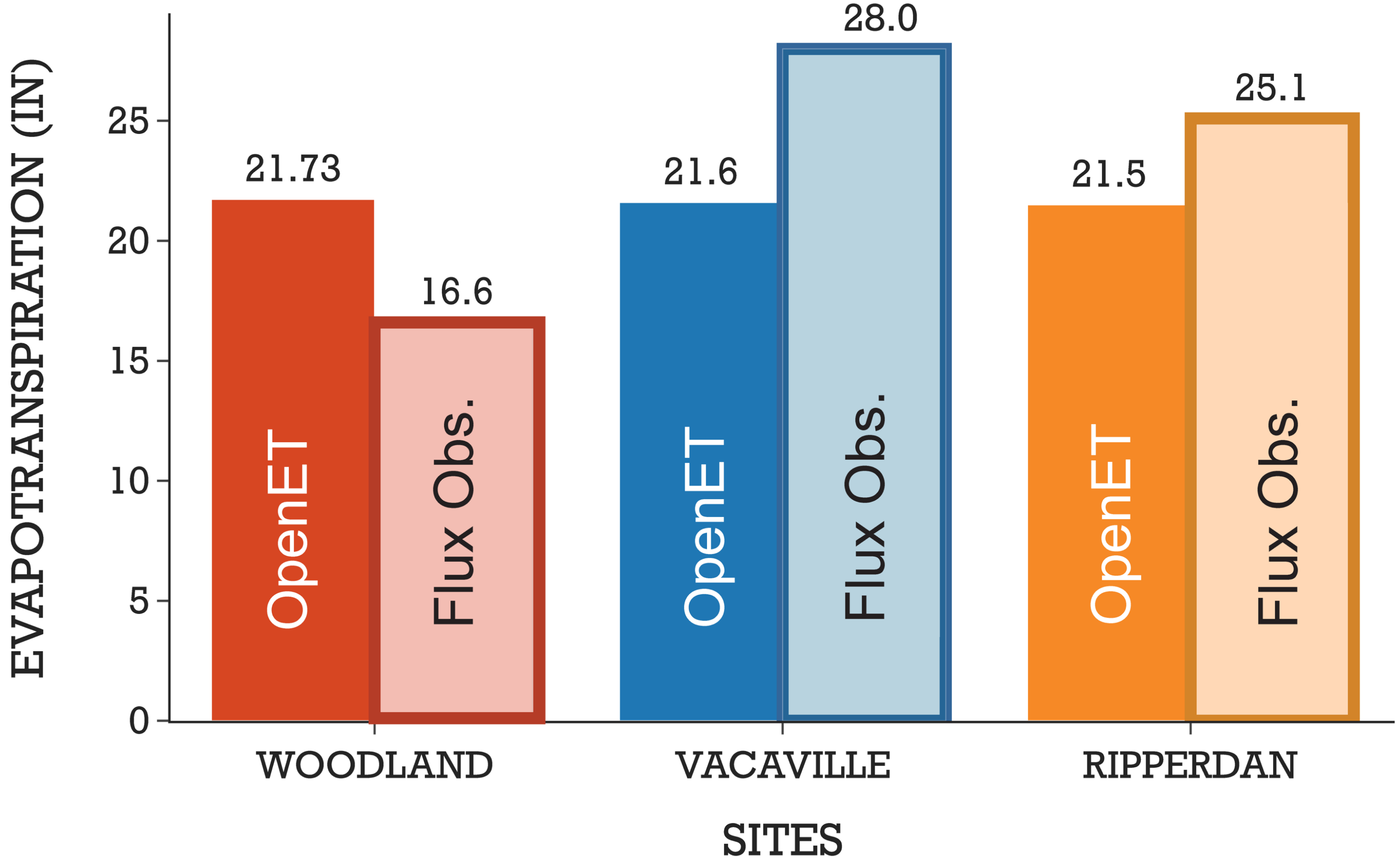
8th leaf
Non-pareil-50%,Wood Colony-37%, Supareil-13%
Sandy loam soil

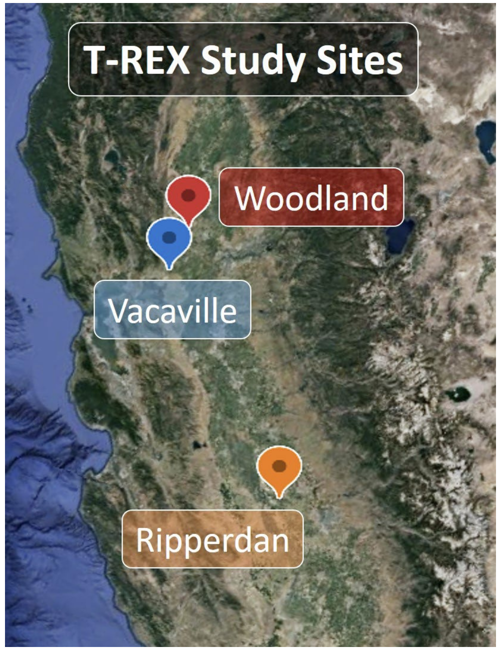
Actual ET - ET_a

Quantity of water that is actually removed from a surface due to the processes of evaporation and transpiration.

- Paired along atmospheric demands can help to understand water stress. (Actual ET/ Potential ET)
- Sensitive to local environmental conditions, soil characteristics and management.
- No need for crop coefficients.

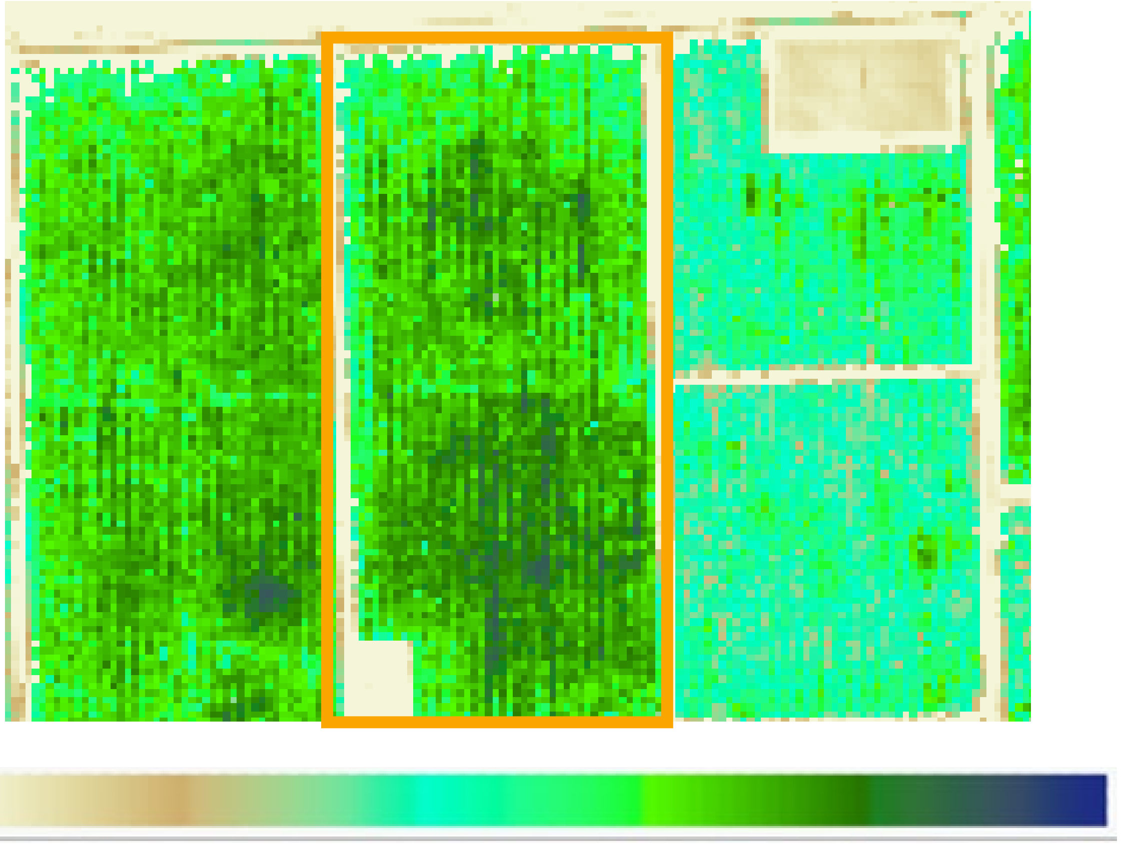
PRELIMINARY RESULTS





PRELIMINARY RESULTS

ET (mm/day)



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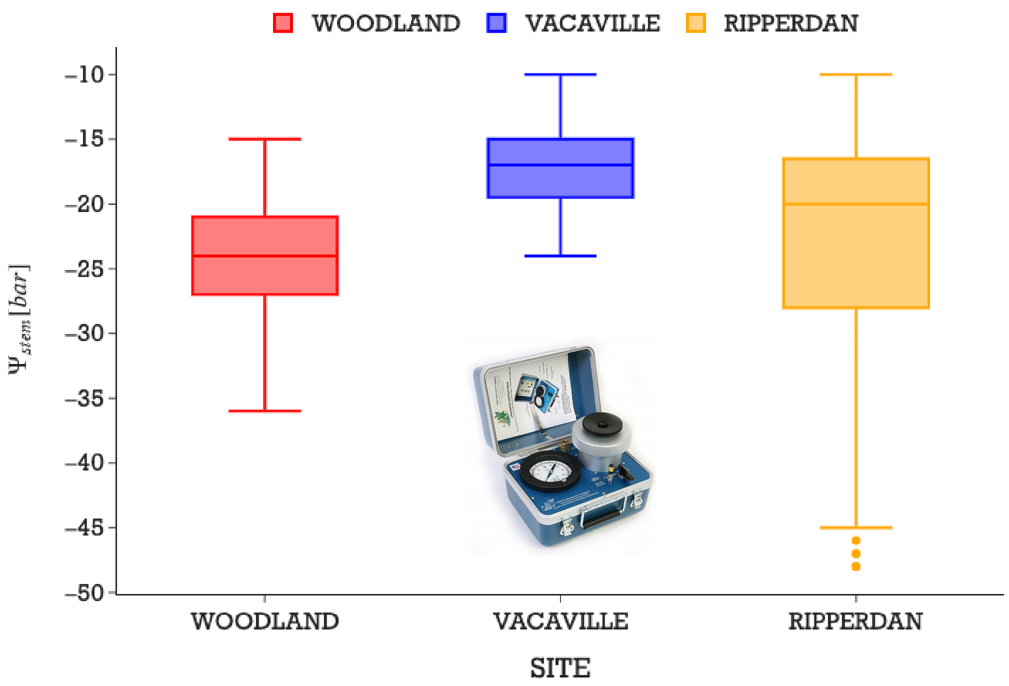
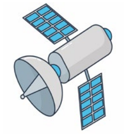
STEM WATER POTENTIALS (July – August)



T·REX
Tree crop Remote sensing of Evapotranspiration eXperiment

CORE TEAM



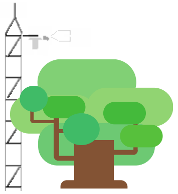
M.Anderson
USDA


B.Kustas
USDA


K.Knipper
USDA



A.Torres-Rua
USU



A.McElrone
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N.Bambach
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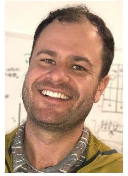
COLLABORATORS


F.Melton
NASA


M.Nocco
UCD


T.Magney
UCD


I. Kisekka
UCD


K.Shackel
UCD


A. Gaudin
UCD


K.Suvocarev
UCD

INSTITUTIONS

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California State University MONTEREY BAY
UtahState University

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WESTWIND FARMS
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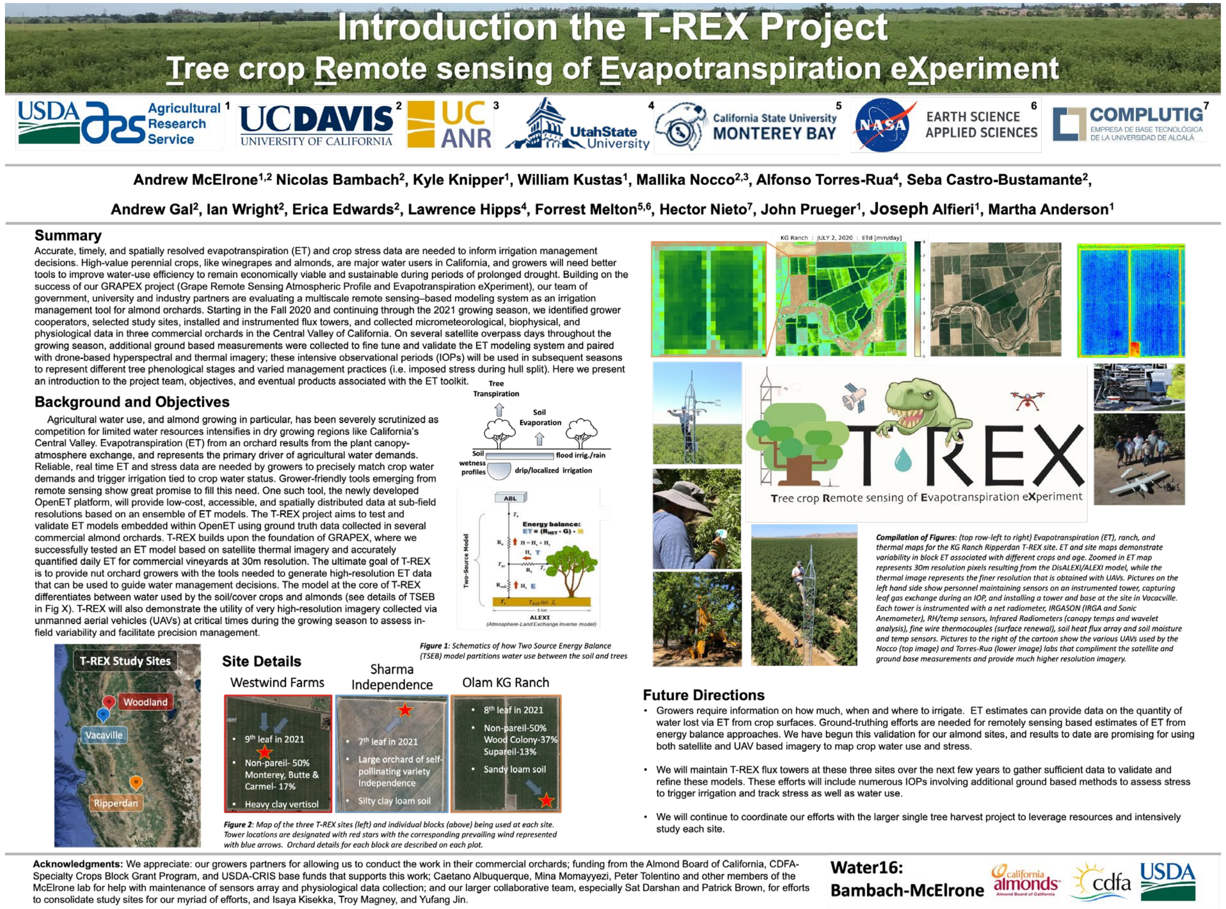
More…


Introduction the T-REX Project
Tree crop Remote sensing of Evapotranspiration eXperiment
Andrew McElrone, Nicolas Bambach, Kyle Knipper, William Kustas, Mallika Nocco, Alfonso Torres-Rua, Seba Castro-Bustamante, Andrew Gal, Ian Wright, Erica Edwards, Lawrence Hipps, Forrest Melton, Hector Nieto, John Prueger, Joseph Alfieri, Martha Anderson
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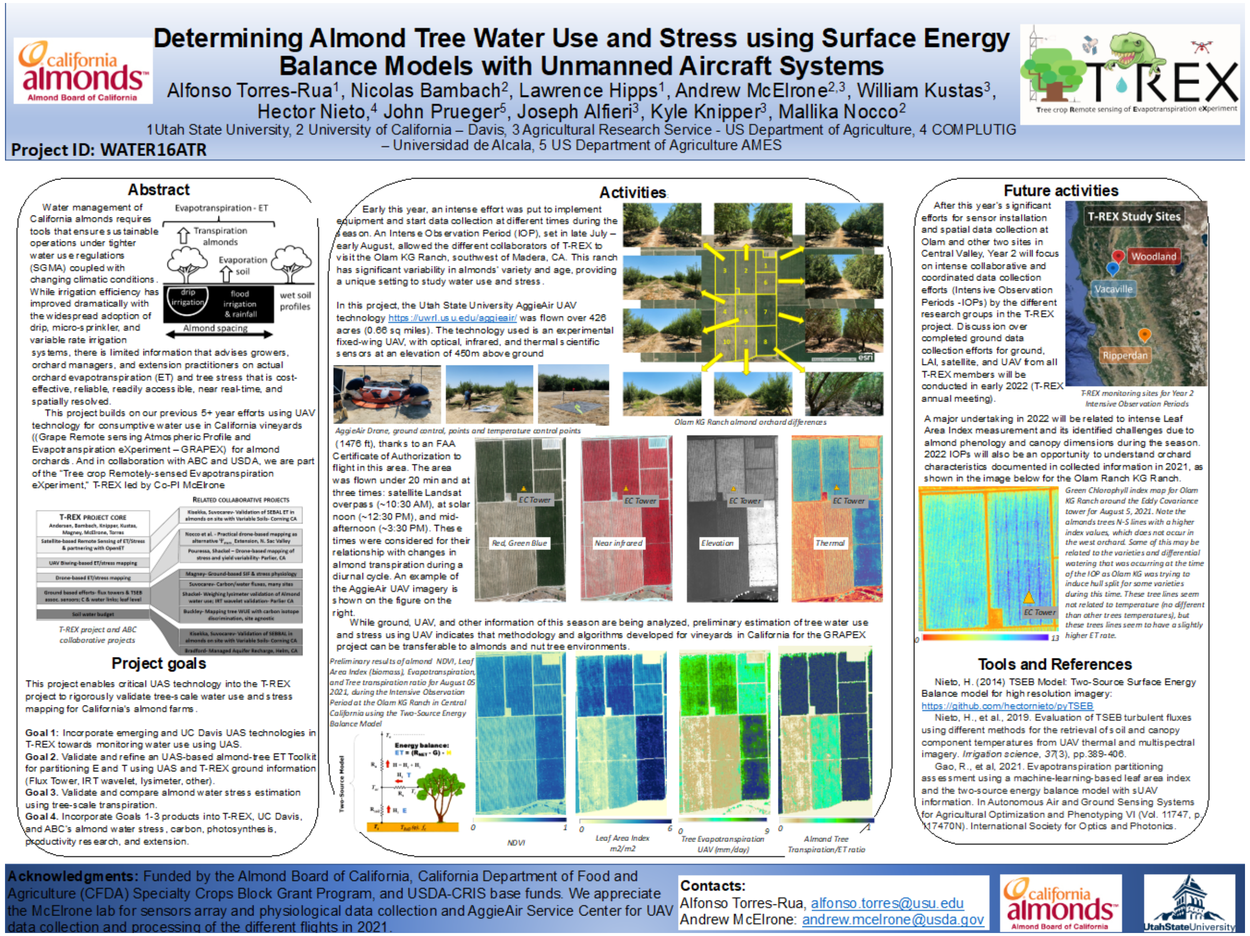
Bambach-McElrone


Determining Almond Tree Water Use and Stress using Surface Energy Balance Models with Unmanned Aircraft Systems
Alfonso Torres-Rua, Nicolas Bambach, Lawrence Hipps, Andrew McElrone, William Kustas, Hector Nieto, John Prueger, Joseph Alfieri, Kyle Knipper, Mallika Nocco
Project ID: WATER16ATR
Abstract
Activities
Future activities
Project goals
Tools and References
Contacts:
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Future Directions

- **Test model parameters and sensitivity** to improve ET estimates from satellite and UAV remote sensing.
- Expand ground-truthing efforts.
- **Identify key relationship** with known parameters used to support irrigation management (SWP).
- Work with industry partners and Ag. Tech. companies to translate our research into applications and **data integration**.


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Exploring Irrigation Technology

12/09/2021 Pat Biddy

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Exploring Irrigation Technology

01. INTRODUCTION

02. TYPES OF AG TECHNOLOGY

03. COMMUNICATION TYPES

04. GROWER CHEKLIST

EXPLORING IRRIGATION TECHNOLOGY

TYPES OF AG TECHNOLOGY

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Weather Stations

Weather stations have been some of the most common technology installed by growers. These allow you to monitor many field variables such as:

1. Frost conditions
2. Wind speed/direction for spray applications
3. Growing Degree Days (GDD)
4. IPM and disease models
5. Rain accumulation
6. ETo

Most common mistakes:

1. Installing in-field above canopy
2. Installing on concrete or dirt
3. Installing next to running pump equipment
4. Not level
5. Wind sensor pointed in the wrong direction

Plant Based Sensors

Manual pressure bomb readings have been around since the 1960's. These have been well researched, and guidelines have been documented by crop type. Automated plant-based sensors are becoming more common place some of these have well researched an have guidelines. Plant based sensors can help growers:

1. Identify stress
2. Measure fruit growth
3. Watch nutrient flow in sap
4. Localized NDVI
5. Stomatal conductance

Most common mistakes:

1. Installing in the wrong part of the plant
2. Fruit sensors not on an average fruit or fruit is damaged
3. Incorrect irrigation model
4. "Wounds" have healed
5. Sensors need to have regular maintenance or replaced annually

Soil Sensors

Manual methods of estimating soil moisture have been around since farming began. These have been well researched, and guidelines have been documented by soil type. Soil sensors can help growers:

1. Identify stress
2. Establish desired root zone
3. Monitor soil temperature
4. Monitor fertilizer movement through soil profile
5. Monitor soil moisture

Most common mistakes:

1. Installed out of root zone/wetted area
2. Installed in wrong soil type
3. Wrong technology for crop type
4. No infield verification
5. One sensor “covering” too many acres

Remote Data

Remote data can come from multiple sources. These sources include satellite, fixed wing, or drone. This data allows you to monitor many field variables such as:

1. Normalized Difference Vegetative Index (NDVI)
2. Soil water content
3. Soil variability
4. Compare different seasons
5. Consumptive water use (ETa)

Most common mistakes:

1. Not enough flights
2. Cloud or smoke coverage
3. Miss interpretation of data
4. Comparing two separate fields to one another
5. Cover crop skewing data

Automation and Control

Automation and control can be achieved through various ways like telemetry, pressure switch, or a manual timer. In some form, most growers have incorporated these into their day-to-day farming practices. Automation and control can help growers:

1. Reduce labor
2. Irrigate during off-peak
3. More accurately inject fertilizer or amendments
4. Increase irrigation efficiency
5. Utilize reservoirs more effectively

Most common mistakes:

1. Poor calibration
2. Little or no maintenance
3. No training provided to field staff
4. No infield verification
5. No feedback or lack of feedback sensors

EXPLORING IRRIGATION TECHNOLOGY

COMMUNICATION TYPES

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Cellular

Cellular data transmission is the most stable way to get your data out of the field.

Pros:

1. Can be upgraded as technology advances
2. Very reliable and California has great coverage
3. Signal can be boosted
4. Can be used in combination with other communication types
5. Majority of the telemetry providers have a cellular option
6. Can be installed below canopy

Cons:

1. May not be upgradable with some telemetry providers
2. Can be expensive
3. May not read in a metal pump house
4. You are at the mercy of big cellular companies

Radios

Radios have been utilized to cover more acreage at a lower cost. These are normally installed as a hub and spoke or mesh network.

Pros:

1. Lower hardware cost than cellular
2. Low to no annual subscription
3. Can be used with other communication types
4. Can be used where cellular signal is spotty
5. Low power consumption

Cons:

1. Must be installed above canopy
2. Must have a gateway or base station, these can be very expensive
3. Does not have a long range between stations
4. Interference can interrupt readings very easily
5. Can require lots of service
6. Be weary of using radios for automation or control

LoRaWAN

Newer technology that uses radios for long range communication.

Pros:

1. Lower hardware cost than cellular
2. Low to no annual subscription
3. Can be used with other communication types
4. Can be used where cellular signal is spotty
5. Low power consumption
6. Can be installed below canopy or underground

Cons:

1. Must have a gateway or base station, these can be very expensive
2. Base stations or gateways have a large footprint and 110v
3. Third party networks are not very common. You must create your own
4. Can require lots of service
5. Be weary of using for automation or control

Bluetooth

Bluetooth has been around for years and over 4 million BLE chips are made each year. BLE 5 provides “long range” integration for Ag applications.

Pros:

1. Lower hardware cost than all other options
2. Low to no annual subscription
3. Can be used with other communication types
4. Can be used where cellular signal is spotty
5. Low power consumption
6. Can be installed below canopy
7. Can cover large acers at a very low cost

Cons:

1. Must have a gateway or base station, these can be very expensive
2. Does not have a long range between stations (+/- 500’)
3. Interference can interrupt readings very easily
4. Can require lots of service
5. Be weary of using Bluetooth for automation or control

Wi-Fi

Wi-Fi networks have become more common place in field. These can be easily expanded and connect field crews to valuable apps.

Pros:

1. Lower hardware cost than cellular
2. Low to no annual subscription
3. Can be used with other communication types
4. Low power consumption
5. Can cover large acers at a very low cost

Cons:

1. Must be installed above canopy
2. Not very stable
3. Does not have a long range between stations
4. Interference can interrupt readings very easily
5. Can require lots of service
6. Be weary of using Wi-Fi for automation or control
7. Very little to no savings in annual fees

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EXPLORING IRRIGATION TECHNOLOGY

GROWER CHECKLIST

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EXPLORING IRRIGATION TECHNOLOGY

Grower checklist

1. Where are you today and where do you want to be in 5 years?
2. Are they backwards compatible?
3. Can their hardware expand and adapt to the fast pace of technological advancement?
4. What is their expertise?
5. Are they a one trick pony?
6. Does the company have **local** support?
7. Are they financially stable enough to stand on their own?
8. Who has access to YOUR data?
9. Are you solving a problem or just buying hardware?
10. Are you a Guinea pig?
11. Do they give you action an item or charts and squiggly lines? Are these action items being directed by more than just one type of sensor?


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Novel Technology for Weed Control

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Cornell AgriTech New York State Agricultural Experiment Station

Weeds are direct competitors with crops that result in yield loss

But wait! There's more!

Reductions in harvest efficiency

e.g. Palmer amaranth

Parasitism of crops

e.g. dodder, mistletoe, broomrape

Host for pests and pathogens of crops

e.g. tree of heaven and spotted lanternfly

Dangerous, noxious, poisonous, toxic, harzardous

e.g. poison ivy, giant hogweed

Ecosystem disruption and aesthetics

e.g. medusahead and fire cycles, kudzu


Herbicides are heavily relied upon for weed control

Herbicide Use May Not Always Be Effective or Desirable in a System

- Herbicide resistance
  - *508 cases globally*
  - *266 species*
  - *164 herbicides*
- Injury potential
- Environmental concerns
- Consumer perceptions
- Regulatory mandates

Accidental herbicide application to apple canopy

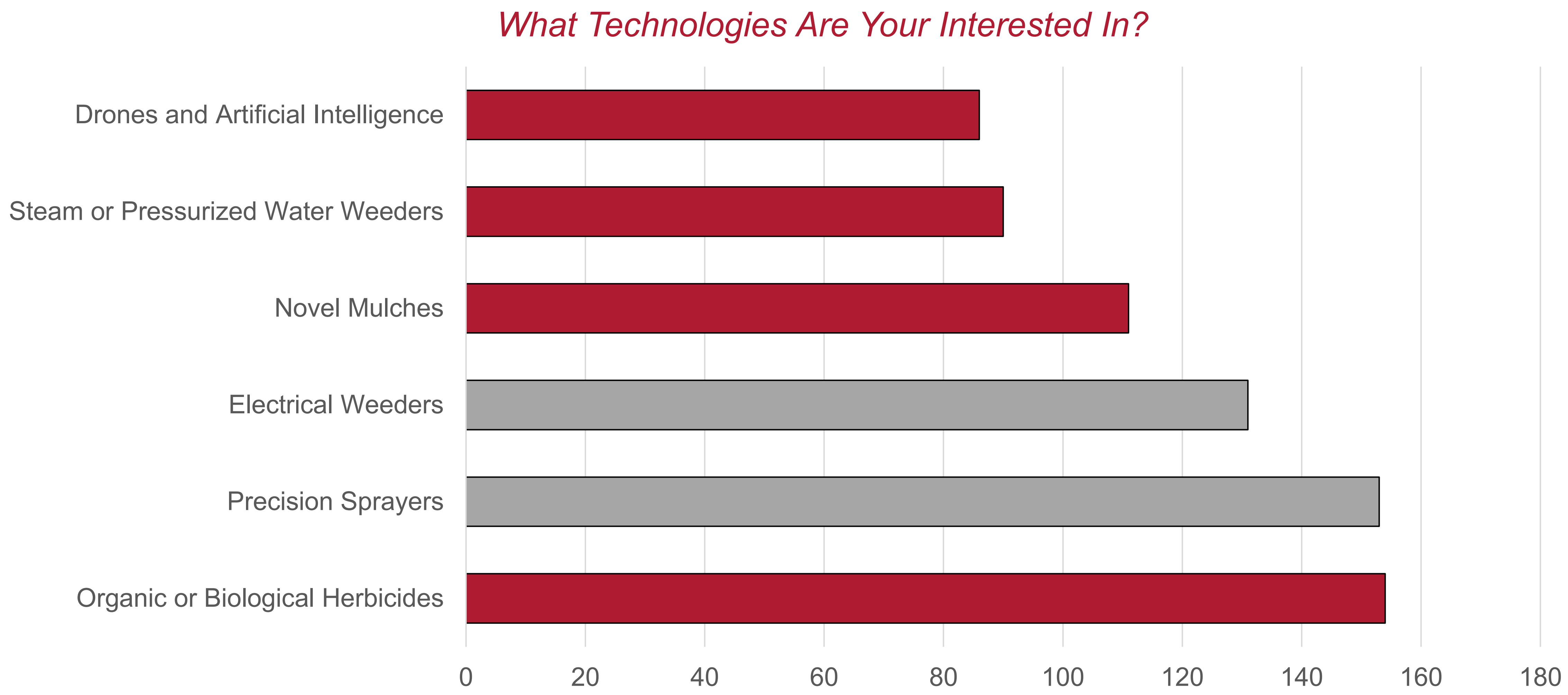
WEED MANAGEMENT IN 2050
WESTWOOD ET AL. 2018. WEED SCIENCE 66:275-285

Field bindweed in grapes

- Why 2050? That is when the planet's population is estimated to hit 9 billion and the global capacity to provide enough energy, water and food could be strained
- Meeting these needs will require improved weed control; "integrating old and new technologies into more diverse weed management systems"

- New herbicide chemistries and targets (*Note: herbicides won't go away*)
- Biological control of weeds
- Enhancing crop competitiveness
- Strategies and equipment to reduce seed inputs/deplete seedbanks
- Novel technology for weed control, including precision agricultural tools

Nut and Fruit Grower Interest in Novel Technology (2019)



300 responses from across the US

Automated Weeders are in Development and on the Market

Farmwise

Naio

Weed IT

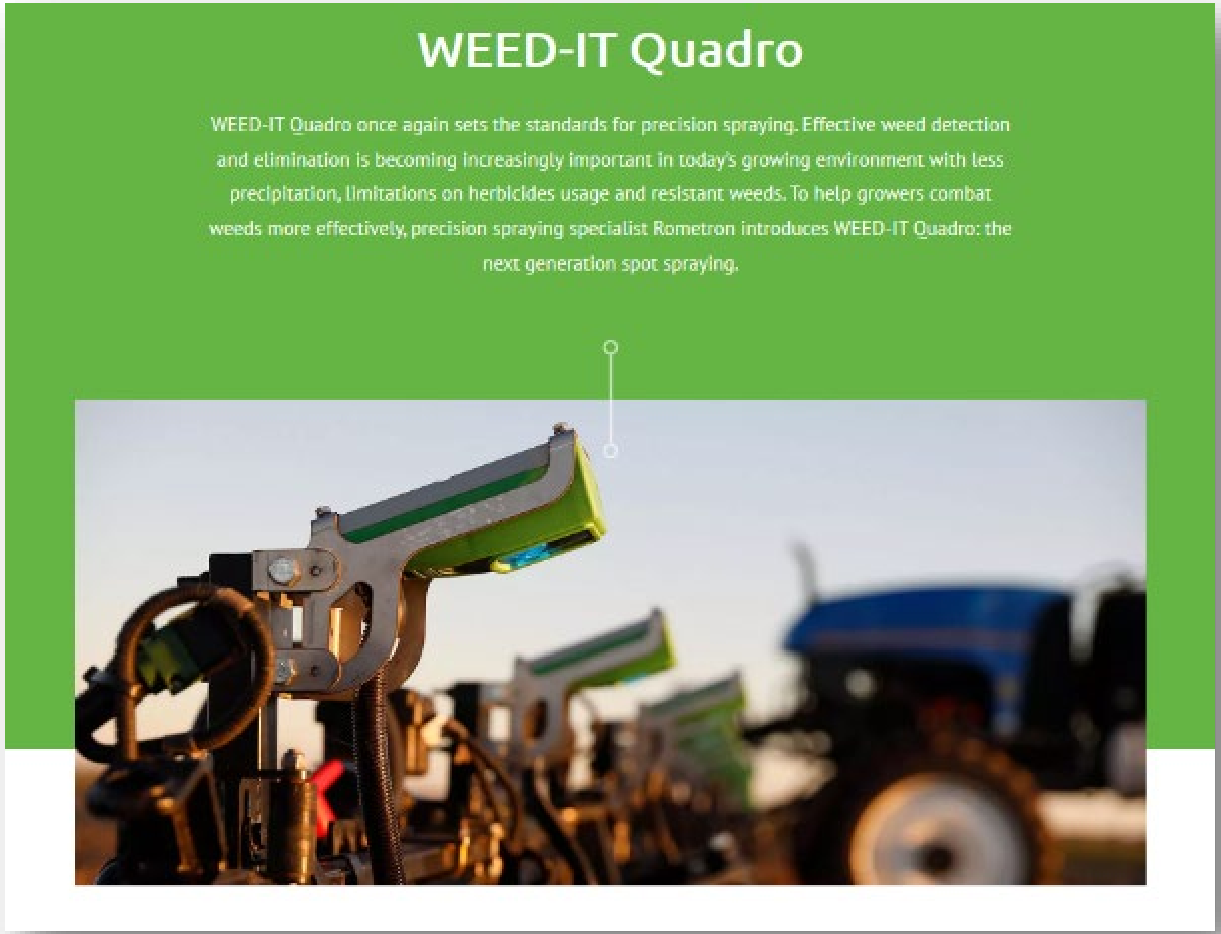
Not all weeders are appropriate for all systems (i.e. annual vs perennial crops)

AUTOMATION FOR WEED CONTROL OFTEN REQUIRES DETECTION AND ACTUATION

- *Detection*
  - Differentiate the unwanted plant from the background soil
  - Differentiate the crop from the weeds (or weeds from the crop) by size differences, crop row pattern and/or machine learning
- *Actuation*
  - Spray weeds with herbicides
  - Physically remove or damage weed tissue

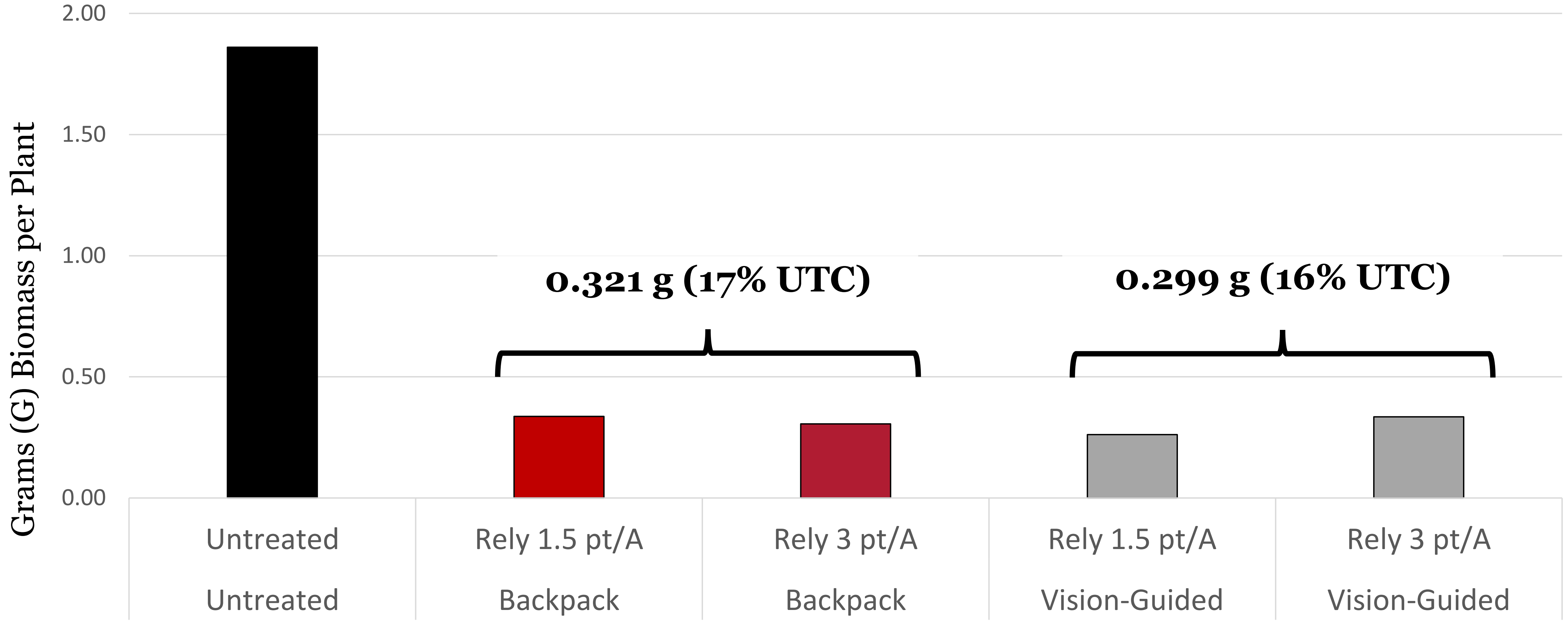
- *No detection and differentiation, GPS alignment to crop rows and passive removal*

CORNELL'S 2021 (AND 2022) AUTOMATED SPRAYER TRIALS



- Weed-It Quadro
- Newer iteration of "green-seeker" technology
- Green on brown by detecting chlorophyll fluorescence (no image processing)
- Detection information is relayed to solenoids that operate nozzles
- Not selective, can spray crop plants that are detected by the sensor
- Commercially available now and being used in fallow dryland production systems, examining in row crops and fruit systems

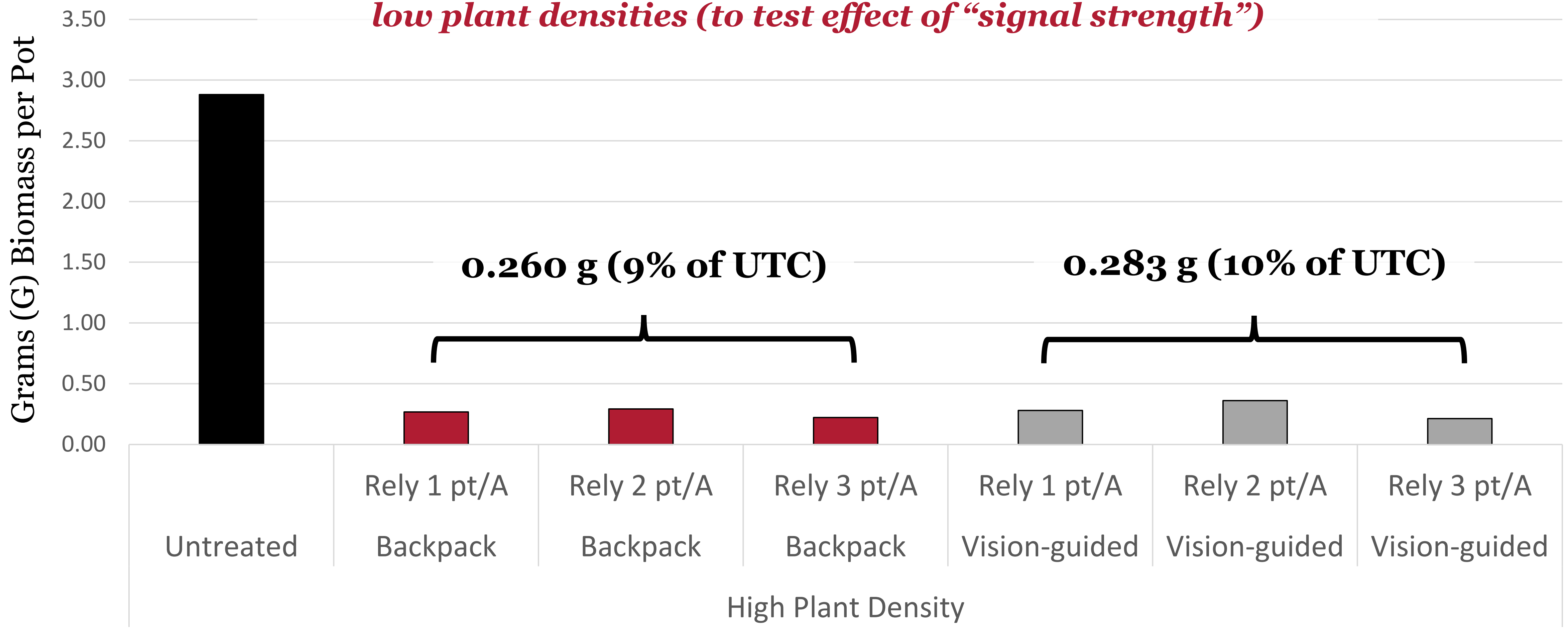
Comparison of Backpack vs Vision-Guided Sprayer Applications on Palmer Amaranth Control with Glufosinate (14 DAT)



1 plant per plot, plants were treated at the 2 to 4 leaf stage
Total of 36 replicate pots per treatment (3 reps of 12 pots)

Comparison of Backpack vs Vision-Guided Sprayer Applications on Horseweed Control with Glufosinate (14 DAT)

All treatments were applied to pots with high plant densities and low plant densities (to test effect of "signal strength")



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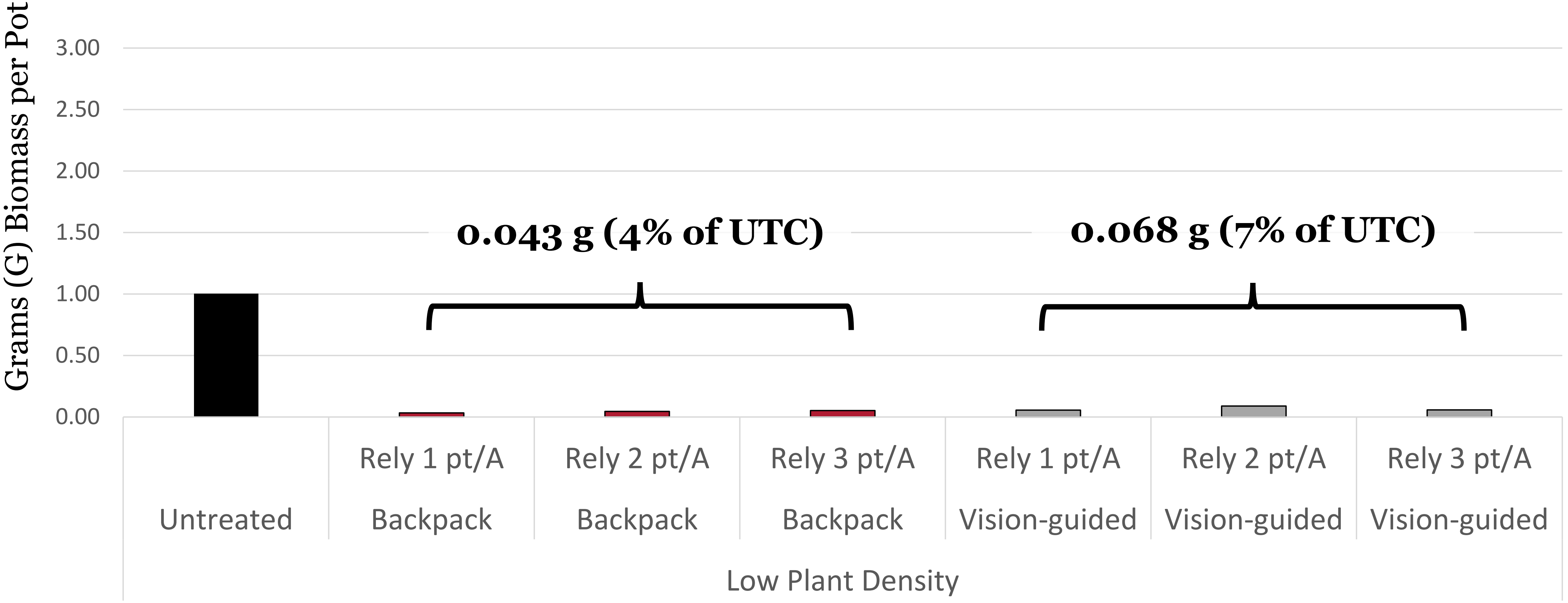
10 plants per plot each 2 to 2.5 cm in diameter
Total of 36 replicate pots per treatment (3 reps of 12 pots)

Comparison of Backpack vs Vision-Guided Sprayer Applications on Horseweed Control with Glufosinate (14 DAT)

All treatments were applied to pots with high plant densities and low plant densities (to test effect of "signal strength")



1 to 2 plants per plot each 2 to 2.5 cm in diameter
Total of 36 replicate pots per treatment (3 reps of 12 pots)

IT S ELECTRIFYING!

Sosnoskie, Kikkert, Hanchar, and Brown (2020) *Managing Herbicide-Resistant and Other Difficult-to-Control Weeds in Field and Vegetable Crops Using Electrical Discharge Systems* – NYFVI ($81,324)

Moretti, Hanson, Sosnoskie, Formiga, Brewer, and Goodrich (2021) *Performance and Economics of Electric Weed Control in Organic Perennial Crops: A Multiregional Approach* – USDA OREI ($2,044,595)

ELECTRICAL WEED CONTROL (EWC)

Controls weeds by applying an electric current directly to unwanted vegetation

The flow of electricity through the plant generates heat, which causes water in cells to vaporize and tissues to burst and die

Touted benefits include no disturbance of the soil surface, no chemical application

First patents for electrical weed control devices were issued in the 1890's and explored in sugar beets in 1980's

Lots of recent, renewed interest because of herbicide resistant weeds and rising labor costs

WEED ZAPPER™ IS A TRACTOR-TOWED, PTO-DRIVEN GENERATOR THAT PRODUCES 100,000+ WATTS OF ELECTRICITY THAT CHARGES A FRONT-MOUNTED METAL BAR

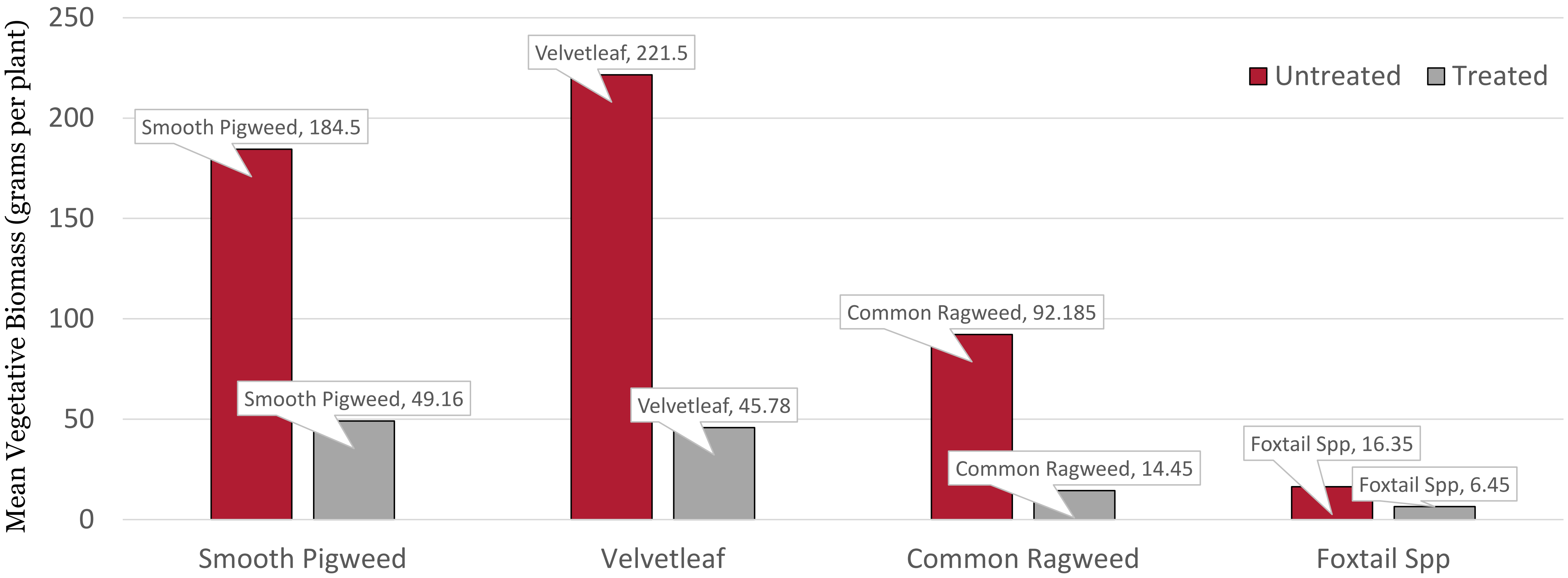
WEEDS ABOVE THE CANOPY THAT CONTACT THE BAR ARE ELECTROCUTED

IN 2020 AND 2021, PARTNERED WITH THREE GROWER-COOPERATORS IN NEW YORK WHO OWN/OPERATE OR RENT/OPERATE WEED ZAPPER™ UNITS TO EVALUATE WEED RESPONSES TO EWC

Weed Biomass (g) 7DAT with Weed Zapper Annihilator (in Soybean 2020)

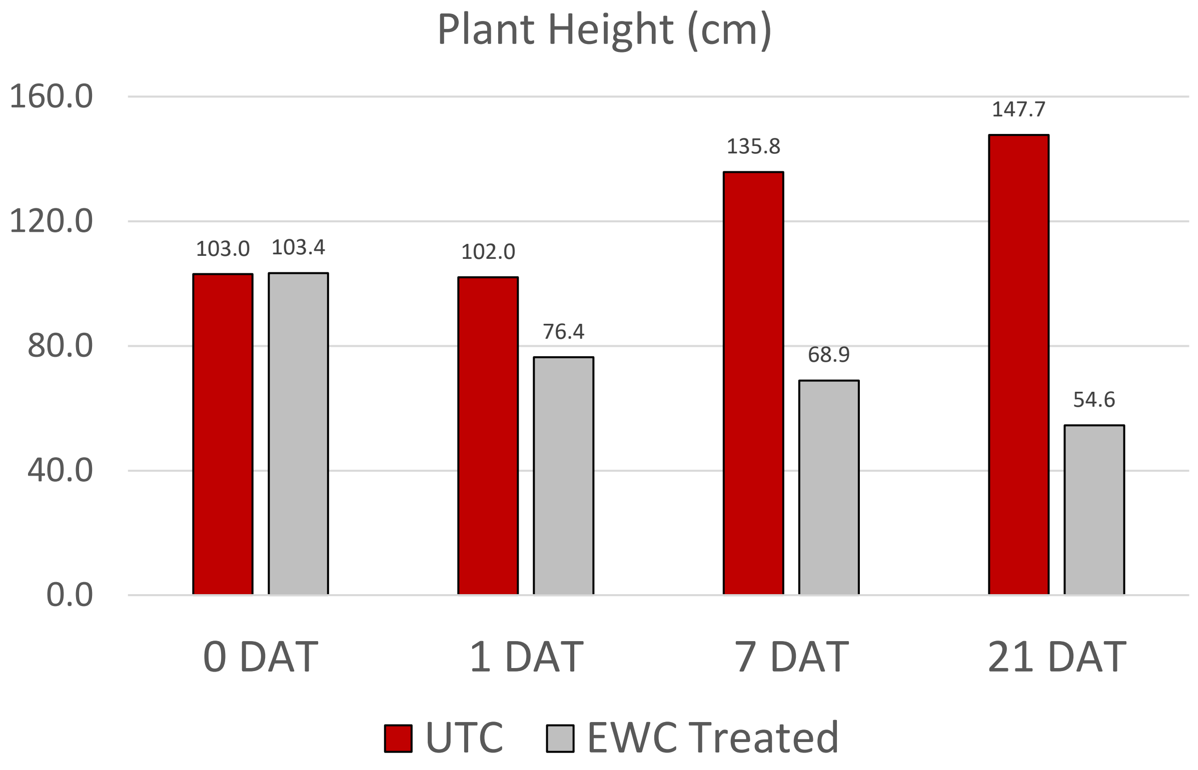
61 to 84% Reduction in leaf and stem tissue biomass per plant

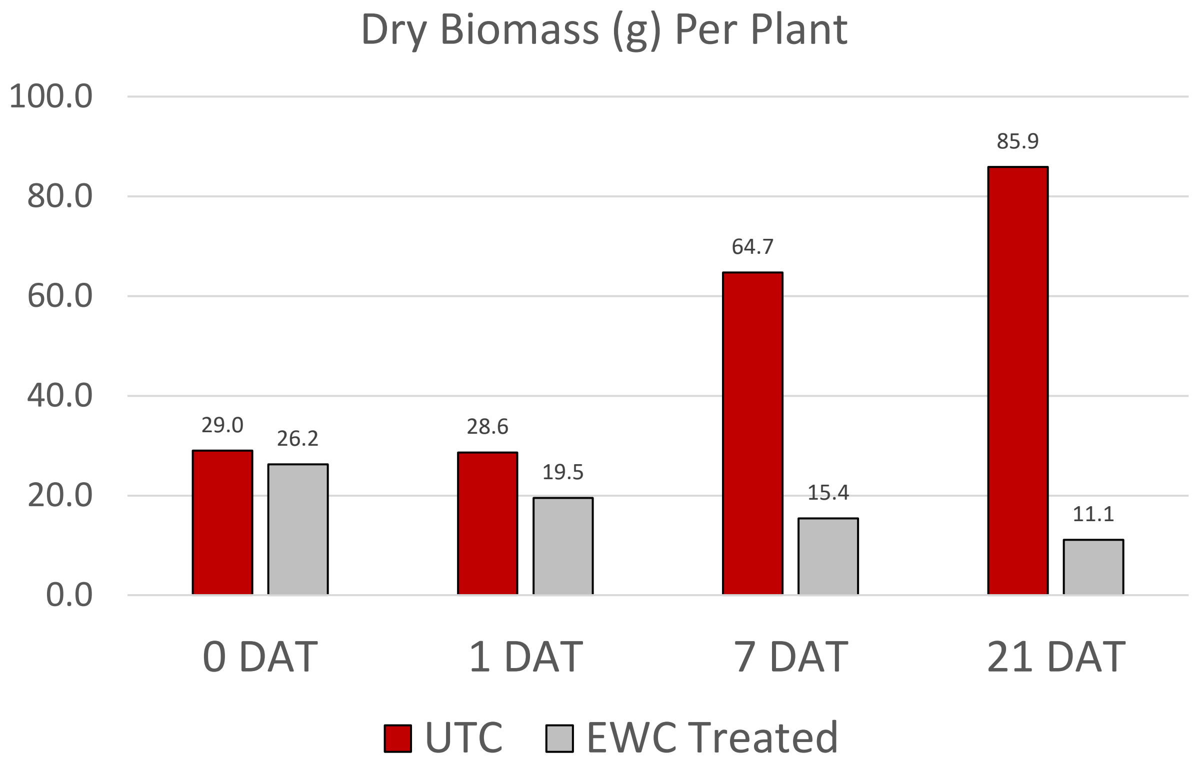
67 to 88% in reproductive output (data not shown)



Changes in Mean Lambsquarters Height (cm) and Biomass (g) over time in response to EWC (in Beets 2021)

Lambsquarters were succulent and just beginning to flower when EWC was applied





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EWC 28 July 2021, Biomass 1, 7, 21 DAT

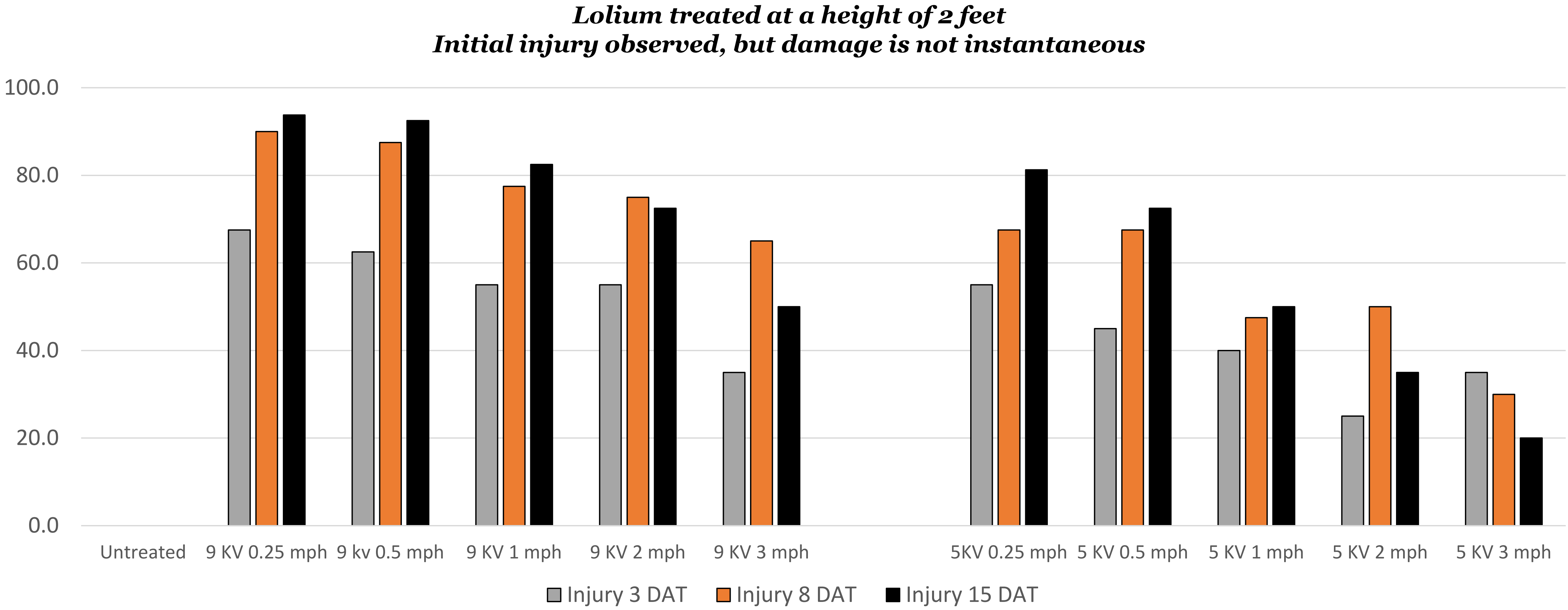
Equipment (Zasso Electroherb) at Oregon State University (Lab of Dr. Marcelo Moretti)

Mechanical power is generated by the tractor and a rear-mounted box containing a PTO-driven generator transfers it to high-frequency, high-voltage transformers

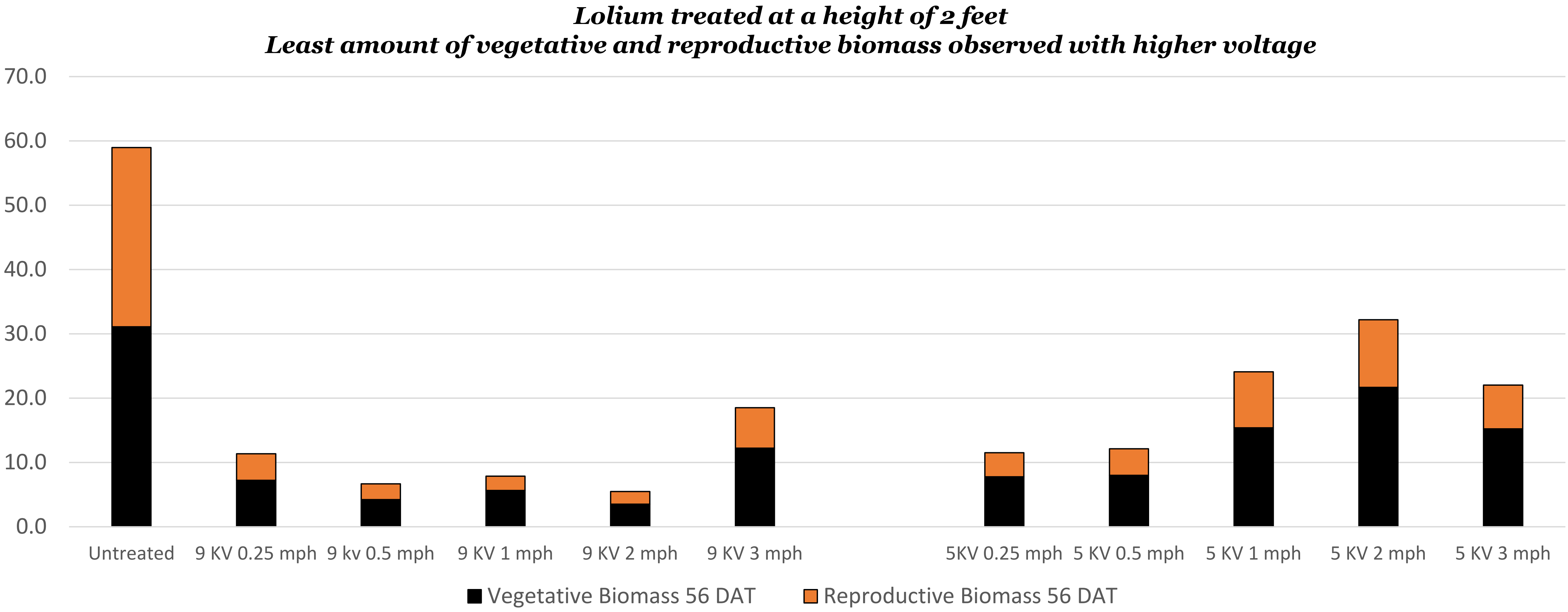
High-voltage cables and connectors

Electrical current passes through plants on the surface and down into their roots before completing the electrical circuit

Italian Ryegrass (*Lolium multiflorum*) Injury in Response to Voltage and Travel Speed (in Hazelnuts 2021)



Italian Ryegrass (*Lolium multiflorum*) Biomass in Response to Voltage and Travel Speed (in Hazelnuts 2021)



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Data Courtesy of Dr. Marcelo Moretti

Research Projects In 2022 (And Beyond)

Precision Spraying

Evaluate the impacts of the following factors on weed control success

Species identity

Plant size

Plant density and arrangement

Herbicide type

Herbicide rate

Travel speed

Interference (leaves, pruning clippings)

Electric Weed Control

WEED CHARACTERISTICS: Weed type (broadleaf vs grass), life cycle (annual vs perennial), root system (fibrous vs tap), weed size, weed density and arrangement (solitary vs clustered)

EDAPHIC CONDITIONS: Soil type and moisture content on weed control efficacy and crop safety

SELECTIVE FORCES: Who survives (and why) and how does this affect drive changes in weed community composition

SYSTEM IMPACTS: Soil microbiome communities, pollinator/pest/predator interactions

Final Thoughts

Herbicides won’t go away, but they won’t be released as frequently as they have in the past

The nature of the products may change (i.e. plant- or microbial- based products, biopesticides)

Weed and crop biology will need to be better understood and exploited (especially under climate change conditions) to maximize weed suppression

Weed seed reduction/return to the seedbank and seedbank reductions will be crucial for weed management going forward

Technological and infrastructure advances (e.g. battery storage, processing power speed, improved cellular and broadband services)

Labor pools are getting older, more expensive, and difficult to source, but the labor needs will change (e.g. designing, building, servicing, operating novel technology, data management and analysis)

Thank You!

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Local Growers and Cornell AgriTech
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