Pistachio Irrigation: Determining Water Needs and Managing Drought

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9th Advances in PISTACHIO PRODUCTION
November 16, 2020

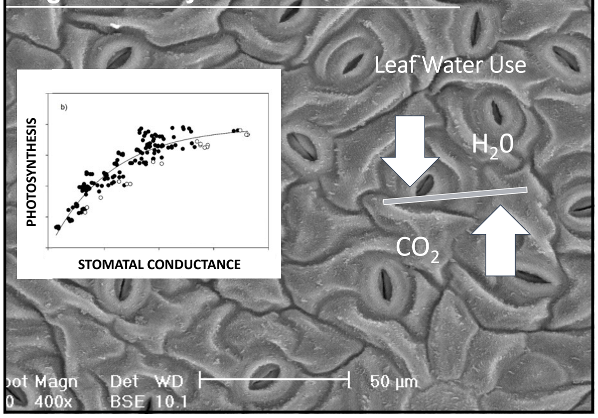
- Irrigation system
- Soil
- Water quantity and quality
- Cultivar, spacing, rootstock
- Environment

Irrigation to achieve our productive objectives

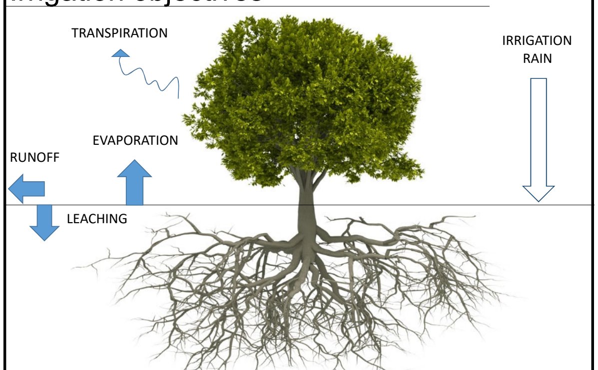
Outline

- Irrigation and yield
- Crop evapotranspiration (how much?)
- Soil and plant monitoring (when?)
- Deficit irrigation

Irrigation and yield

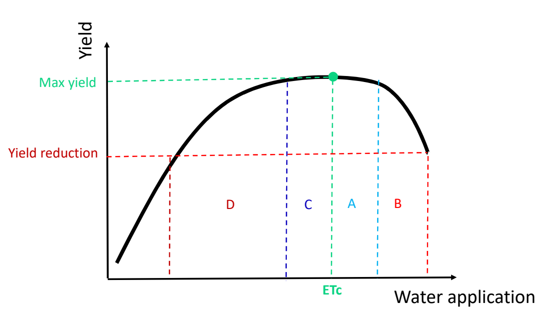


Irrigation objectives



ET= EVAPORATION + TRANSPIRATION

Irrigation objectives

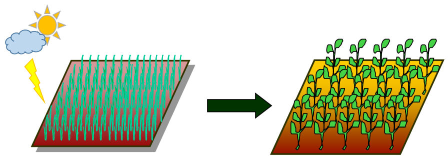


A = Over irrigation without impacting yield
B = Over irrigation impacting yield
C = Deficit irrigation without impacting yield
D = Deficit irrigation impacting yield

Crop Evapotranspiration (ETc)

$$ET_c = ET_o \times K_c$$

- ET_o accounts for weather factors
- K_c accounts for crop differences



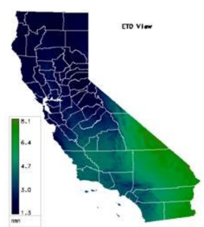
ETo = Reference ET

Kc = Crop coefficient

Reference Evapotranspiration (ETo)

CIMIS

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SYSTEM
CALIFORNIA DEPARTMENT OF WATER RESOURCES



https://cimis.water.ca.gov/

Weather Station for ET_o

ET_o = a measure of evaporative demand
$ET_o \approx ET$ of 0.12 m tall, cool -season grass

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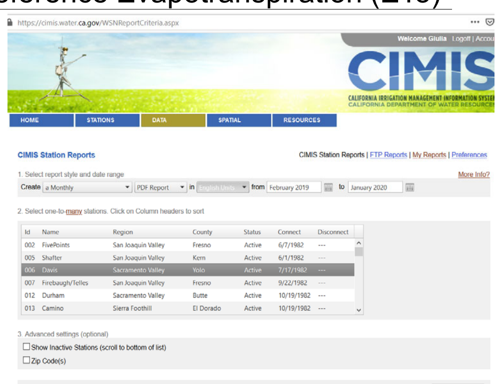
Reference Evapotranspiration (ETo)



Reference Evapotranspiration (ETo)

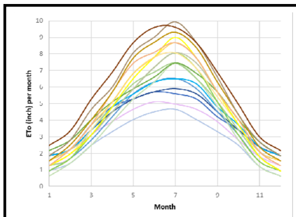
California Irrigation Management Information System (CIMIS)

CIMIS Monthly Report

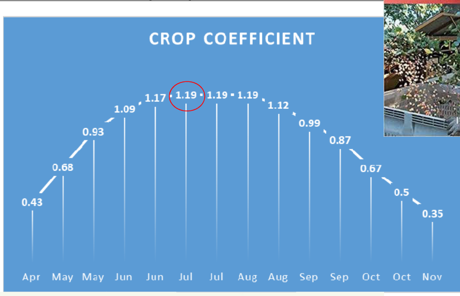
Rendered in ENGLISH Units.
January 2019 - December 2019
Printed on Friday, November 6, 2020

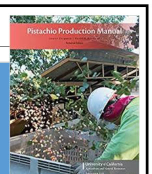
Merced - San Joaquin Valley - Station 148

Month Year	Total ETo (in)	Total Precip (in)	Avg Sol Rad (Ly/day)	Avg Vap Pres (mBars)	Avg Max Air Temp (°F)	Avg Min Air Temp (°F)	Avg Air Temp (°F)	Avg Max Rel Hum (%)	Avg Min Rel Hum (%)	Avg Rel Hum (%)	Avg Dew Point (°F)	Avg Wind Speed (mph)	Avg Soil Temp (°F)
Jan 2019	1.42 K	2.31 K	201 L	9.2	60.3	36.9 K	46.9 K	96	58	83 K	41.8 K	3.4 K	52.3
Feb 2019	1.84	4.16 K	255	7.9 K	57.3 K	35.4 K	45.4 K	94	49	75 K	37.9 K	4.9 K	50.2
Mar 2019	3.51	2.43 K	409 K	9.6 K	66.5	39.4 K	52.1	96	43	72 K	43.1 K	3.9 K	54.0
Apr 2019	5.17	0.05	530	11.5 K	76.8	44.6	60.7 K	94	35	63 K	48.0 K	3.7	59.3
May 2019	5.76 K	2.25	569	12.1	76.3 K	47.5 K	61.6 K	93	40	65 K	49.4 K	3.6	62.9
Jun 2019	7.69	0.00	696	14.5 K	92.0 K	53.0 K	73.1 K	92	27	51 L	53.7 L	3.0	69.6
Jul 2019	8.09	0.00	685	14.4	96.8	53.5 K	76.0	92	23	47	54.2	2.7 K	73.8
Aug 2019	7.45 K	0.00	620	15.0 L	95.7 L	55.1 L	74.2 L	80 L	31 L	50 L	55.3 L	3.0 K	75.0
Sep 2019	5.40 K	0.07	515 K	13.9 K	88.8 L	51.5 L	69.2 L	93 K	31 K	57 L	53.2 L	2.9	68.9 K
Oct 2019	3.87	0.00	388	9.4	80.8	38.6 K	57.5 K	99	24	57 K	42.4 K	2.5	59.0 K
Nov 2019	2.21 K	0.89	250	8.6	71.9	34.7 K	50.3	99	36	69	40.3	2.4	52.6 K
Dec 2019	1.13	4.06	152	10.0 K	60.2 K	38.5 K	48.5 K	99	63	85 K	44.1 K	3.2 K	51.1
Tots/Avgs	53.54	16.2	439	11.3	77.0	44.1	59.6	94	38	65	46.9	3.3	60.7



Crop coefficient(Kc)





Crop Evapotranspiration (ETc)

ETc = ETo x Kc

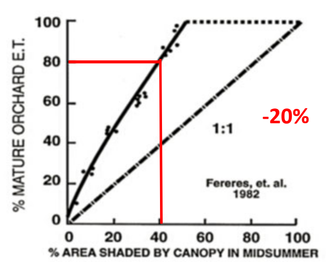
	Historical			Actual			
Month	ETo	Kc	ETc	ETo	Kc	ETc	Difference
jan	1.2	0	0	1.4	0	0	0
feb	2.2	0	0	1.8	0	0	0
mar	3.7	0	0	3.5	0	0	0
apr	5.7	0.25	1.4	5.2	0.25	1.3	0.1
may	7.4	0.81	6.0	5.8	0.81	4.6	1.4
jun	8.1	1.13	9.2	7.7	1.13	8.7	0.5
jul	8.7	1.19	10.3	8.1	1.19	9.6	0.7
aug	7.8	1.16	9.0	7.5	1.16	8.6	0.3
sep	5.7	0.93	5.3	5.4	0.93	5.0	0.3
oct	4.0	0.59	2.4	3.9	0.59	2.3	0.1
nov	2.1	0	0	2.2	0	0.0	0
dec	1.2	0	0	1.1	0	0.0	0
TOT	57.9		43.5	53.5		40.1	4.4

Calculations

Case Scenario	Formula	Calculation per week
Merced in July	ETc = ETo * Kc	2.1*1.19=2.5 in

Adjustment for site specific conditions

1 – Canopy cover



Adjustment for site specific conditions

1 – Young Trees

% of ET for Developing Pistachios

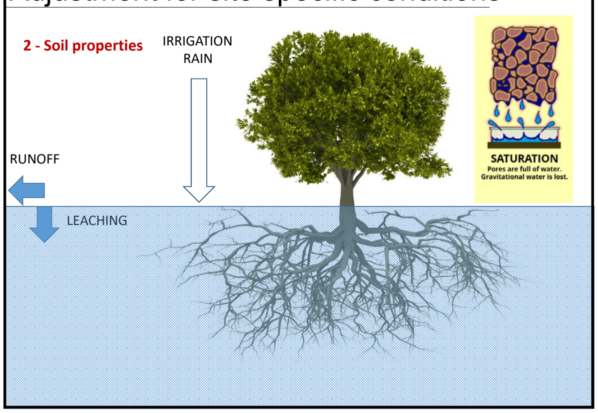
Age of Orchard	Drip	Fan Jet
Year 1	0.10	0.40
Year 2	0.20	0.45
Year 3	0.30	0.52
Year 4	0.40	0.59
Year 5	0.52	0.65
Year 6	0.65	0.70
Year 7	0.78	0.78
Year 8	0.90	0.90
Year 9 (>65% cover)	1.00	1.00

Calculations

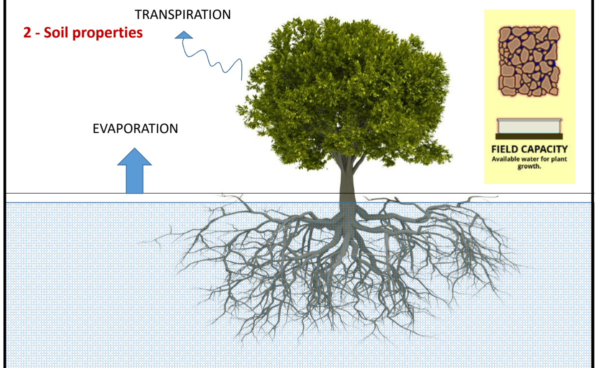
Case Scenario	Formula	Calculation per week
Merced in July	ETc = ETo * Kc	2.1*1.19=2.5 in
Orchards with 40% CC	ETc * 0.80	2.5 in * 0.80 = 2 in

Adjustment for site specific conditions

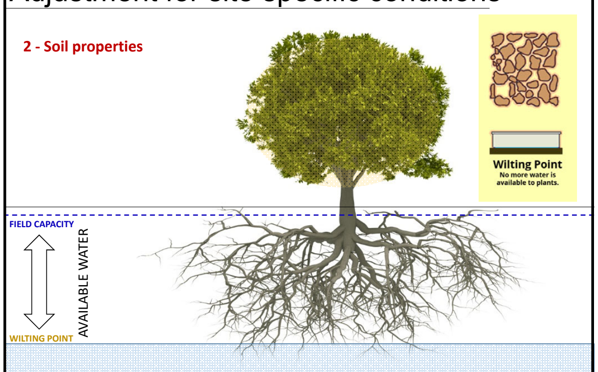
2 - Soil properties



Adjustment for site specific conditions



Adjustment for site specific conditions



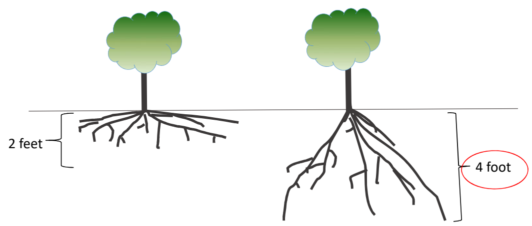
Adjustment for site specific conditions

2 - Soil properties

Soil texture	Field Capacity		Wilting point		Available water	
	In/ft	%	In/ft	%	In/ft	%
Sand	1.2	10	0.5	4	0.7	6
Loam	3.2	27	1.4	12	1.8	15
Silt Loam	3.6	30	1.8	15	1.8	15
Sandy clay	3.4	28	1.8	15	1.6	13
Clay loam	3.8	32	2.2	18	1.6	13
Silty clay	4.8	40	2.4	20	2.4	20
clay	4.8	40	2.6	22	2.2	18

Adjustment for site specific conditions

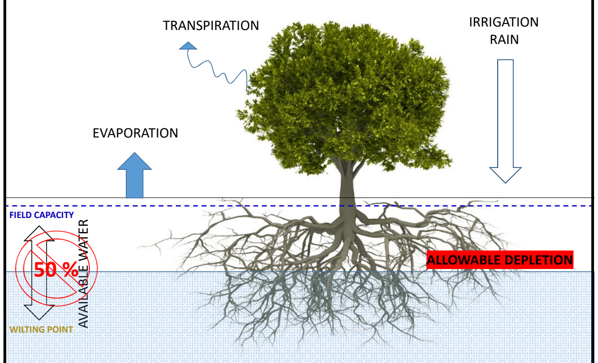
3 – Root zone



Available Water for trees = AW per feet of soil depth * Root Depth

AW = 4 ft of root depth = 1.8 in/feet x 4 feet = 9 inches of water

Adjustment for site specific conditions



Allowable depletion = AW / 2 = 9 in /2 = 4.5 in

Calculations

Case Scenario	Formula	Calculation per week
Merced in July	ETc = ETo * Kc	2.1*1.19=2.5 in
Young orchards (40% CC)	ETc * 0.80	2.5 in * 0.80 = 2 in
Silt-loam soil, 4 m root depth	AD = (AW * RD)/2	(1.8 * 4)/ 2 =4.5 in

Adjustment for site specific conditions

4 – Effective rain

Assume only 50% is effective

Merced - San Joaquin Valley - Station 148

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Effective rain(Re): Rain (in) / 2

Net irrigation requirement (NIR): ETc- Re

Calculations

Case Scenario	Formula	Calculation per week
Merced in July	ETc = ETo * Kc	2.1*1.19=2.5 in
Young orchards (40% CC)	ETc * 0.80	2.5 in * 0.80 = 2 in
No rains	NIR=ETc-Re	2 – 0 = 2 in
Silt-loam soil, 4 m root depth	AD = (AW * RD)/2	(1.8 * 4)/ 2 =4.5 in

Adjustment for site specific conditions

4 – Irrigation system

APPLICATION EFFICIENCY

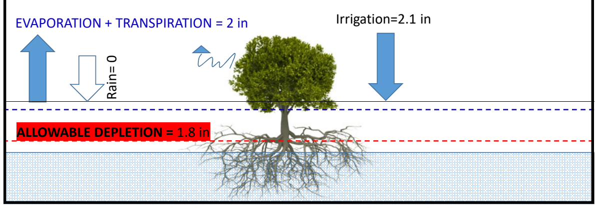
Irrigation System	AE (%)
Flood	65-80
Micro-sprinkler	85-90
Drip	90-95

WETTED AREA

Irrigation System	WA (%)
Single line drip	20-30
Double line drip	20-50
Microsprinkler	30-60

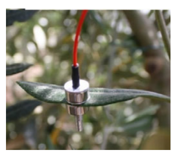
Calculations

Case Scenario	Formula	Calculation per week
Merced in July	ETc = ETo * Kc	2.1*1.19=2.5 in
Young orchards (40% CC)	ETc * 0.80	2.5 in * 0.80 = 2 in
No rains	**NIR=ETc-Re**	**2 – 0 = 2 in**
Micro drip irrigation (95% AE)	**GIR=IR/AE**	**2/0.95 = 2.1 in**
Silt-loam soil, 4 m root depth	AD = (AW * RD)/2	(1.8 * 4)/ 2 =4.5 in
Micro drip irrigation (40% WA)	**AD*WA**	**4.5*0.40= 1.8 in**



Soil and plant monitoring

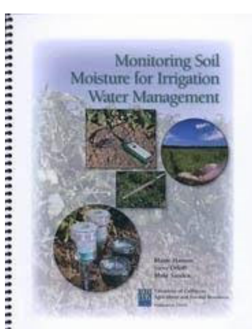
ETc



Soil ⟷ Plant

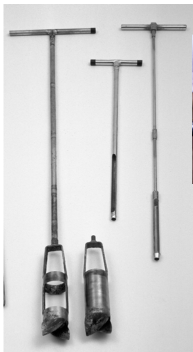
Soil Monitoring

In micro irrigated orchard it is very important selecting the monitoring point



Soil Monitoring: direct soil moisture by feel

1) Direct soil moisture by feel



- Simple

- Time consuming
- Subjectivity

Wet medium-textured soil

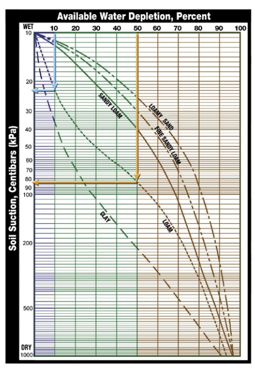
Dry medium-textured soil

https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_051845.pdf

Soil Monitoring: soil tension

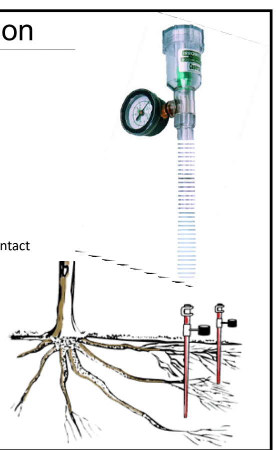
Soil tension

- Measures the surface tension that the water is held to the soil
- The tension increases as soils dry, plants spend more energy
- Measurement unit centibars (cb)
- Types
  - Tensiometer
  - Resistance blocks



Soil Monitoring: soil tension

- **Tensiometer**
  - Pros:
    - no power needed
    - Not affected by salinity
    - Easy to install
    - Not expensive
  - Cons:
    - Requires maintenance
    - Not good for dry soil- can lose soil contact
    - Manually read and keep records



Soil Monitoring: soil tension

- **Modified electrical resistance**
  - Pros-
    - No maintenance
    - Least cost
    - Can have many sensors going different depths and areas
    - Possible to use data loggers or remotely
    - Easy hand held meter option
    - Easy to install
  - Cons-
    - Can have problems contacting soil in course textures
    - Can be affected by salinity
    - Need to periodically replace them (3-4 years)

Soil Monitoring: soil tension

- **Reading Soil Tension**

Use the following readings as a general guideline:

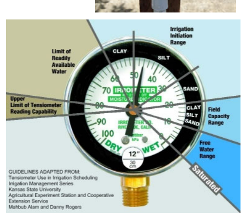
0-10 Centibars = Saturated soil

10-30 Centibars = Soil is adequately wet (except coarse sands, which are beginning to lose water)

<u>**30-60 Centibars** = Usual range for irrigation (most soils)</u>

60-100 Centibars = Usual range for irrigation in heavy clay

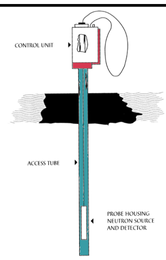
100-200 Centibars = Soil is becoming dangerously dry for maximum production. Proceed with caution!



http://www.irrometer.com

Soil Monitoring: neutron probe

- **Neutron probe**



- Pros:
  - Adapts to many soil types
  - Reads actual water content
  - Only need to install access tubes
  - Reads multiple depths in one tube
  - Largest sample "volume" to estimate moisture
- Cons:
  - Need radiation license to use
  - Needs to be calibrated to soil type
  - Reading includes water that is not free for plant use
  - Not possible to automate
  - Dependent on consultant

Soil Monitoring: soil moisture

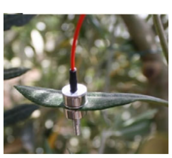
Dielectric sensors: Measure the ability of a material to establish an electrical field

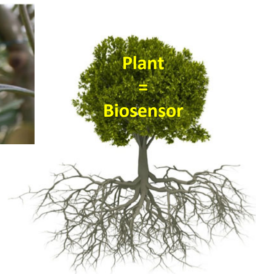
- Air dielectric constant of 1
- Dry soil dielectric constant of 3 to 5
- Water dielectric constant of about 80
- More moisture increases the dielectric constant

Pros:
- Increased accuracy with calibration to soil type
- Reads actual water content
- Able to automate readings

Cons:
- Complicated electronics
- Requires power
- Some may be effected by salts or heavy soils
- Errors can occur with loss of soil contact with sensor

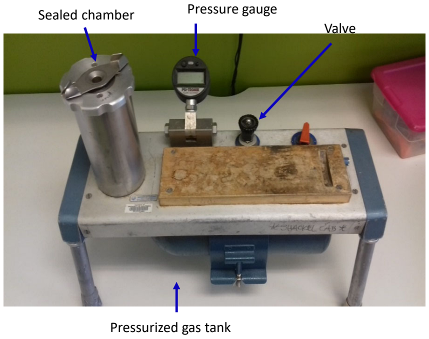
Plant monitoring



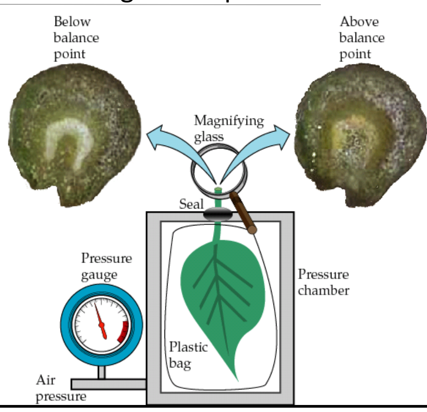


Integrates soil and atmosphere

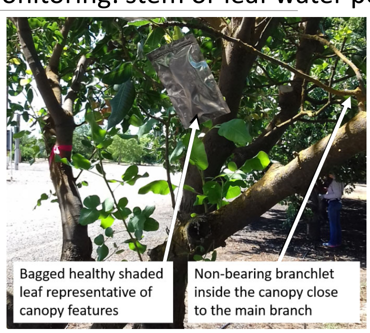
Plant monitoring: pressure chamber



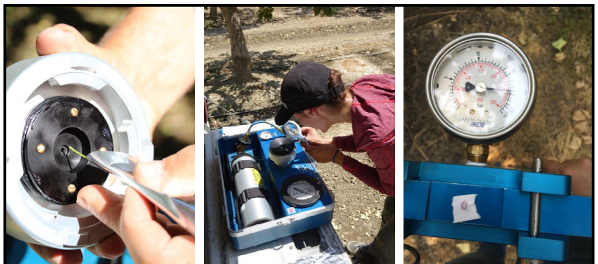
Plant monitoring: water potential



Plant monitoring: stem or leaf water potential

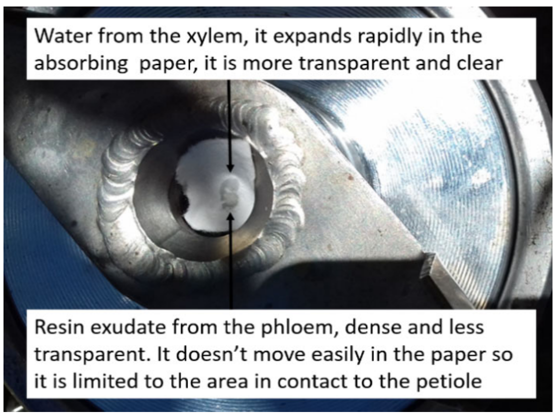


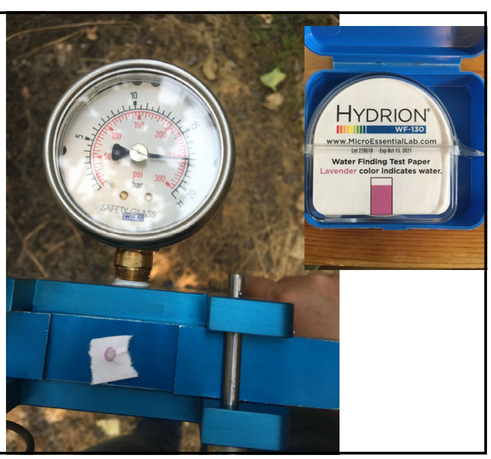
Enclose the leaf in light and moisture impervious bags to stop leaf transpiration and wait at least 15 minutes, to allow the leaf to equilibrate with the branch underneath



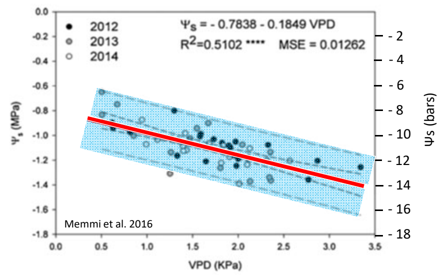
Plant water potential

- Measurement made at midday
- The highest the values the higher the stress
- Resins (or latex) from resinous channels can make the reading difficult



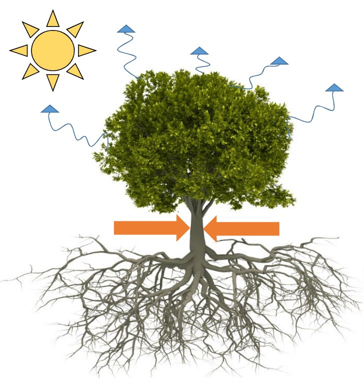


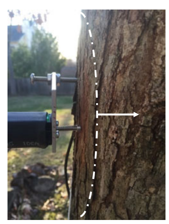
Plant monitoring: water potential baseline

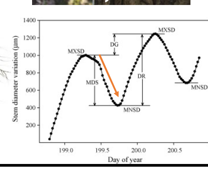


- Baseline is about 1/10th of temperature
- SWP 2 bars below baseline before irrigating
- Mature trees also 4 bars
- -14/16 bars is considered stress (stomatal closure)

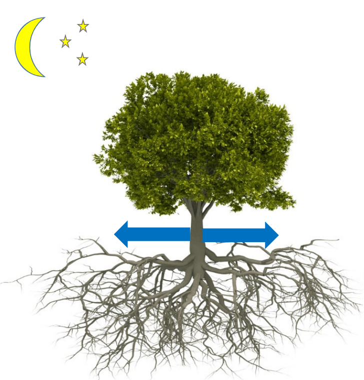
Plant monitoring: dendrometers

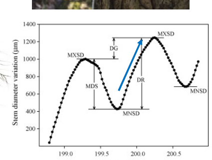




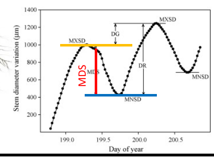


Plant monitoring: dendrometers

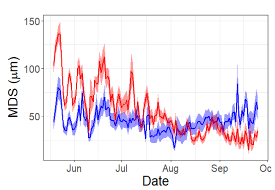


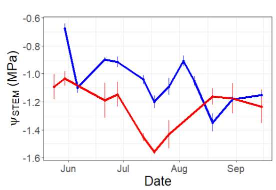


Plant monitoring: Maximum Daily Shrinkage



Plant monitoring: Maximum Daily Shrinkage





Higher MDS and lower stem water potential in a stressed pistachio orchard (red lines) versus a non stressed one (blue lines)

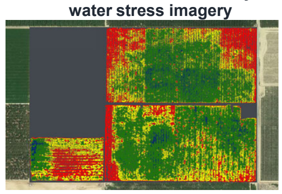
NOTE: All plant-based indicators of tree water status are affected by environmental conditions, so baseline need to be developed and used for a correct interpretation of the results

Marino et al. in press

Plant monitoring: Aerial Imaging

What the eye sees – 180 acre almond orchard

Inefficiencies identified by water stress imagery



Courtesy of CERES Imaging

Stem water potential *(negative bars)*

- Red: 20-24
- Yellow: 16-20
- Green: 12-16
- Blue: 8-12

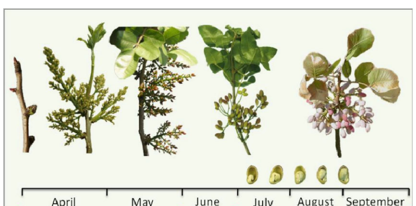
Putting the tools to work

1. Track ET
2. Monitor soil
3. Monitor plant
4. Irrigate
5. Check results

University of California
Agriculture and Natural Resources

Deficit irrigation

Planned water deficits at specific crop developmental stages that control vegetative growth or improve quality without negatively affecting production



Nut growth
Leaf expansion
STAGE 1

Shell hardening
Trunk growth
STAGE 2

Embryo filling
STAGE 3

Senescence

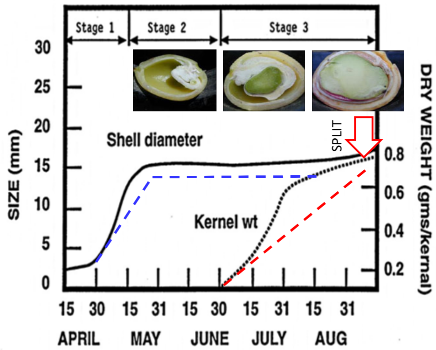
Deficit irrigation

Regulated Deficit Irrigation Impacts on Yield
(Goldhamer et al., Kettleman City 1988-92)

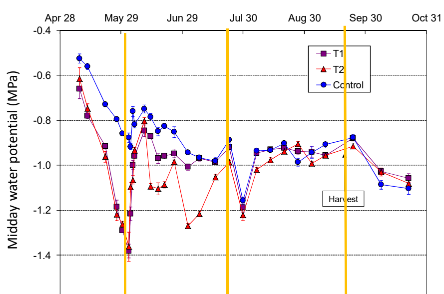
Irrigation Treatment	Split Nuts (%)	Dry Split Yield (lb/ac)	Water Use Efficiency (lb splits/inch irrigation)
0% Stage 1	87.8 d	2828 d	91.7 bc
0% Stage 2	73.6 b	2239 bc	91.7 bc
0% Stage 3	43.6 a	1014 a	64.8 a
0% Postharvest	78.8 bc	2451 bcd	77.6 ab
50% Stage 2; 25% PH	81.7 cd	2744 cd	106.1 c
Control	79.5 bc	2714 cd	81.5 ab

* Values followed by the same letter are not statistically different at p=0.05.

Deficit irrigation



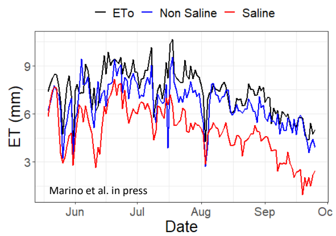
Deficit irrigation (Goldhamer et al.)



Treatment	STAGE 1	STAGE 2	STAGE 3	PH
T1	-1.6 MPa	Full ETc	Full ETc	Full ETc
T2	-1.6 MPa	50% ETc	Full ETc	Full ETc
CONTROL	Full ETc	Full ETc	Full ETc	Full ETc

Irrigation under saline conditions

- Salinity reduces water use
- Apply canopy cover reduction
- Check soil moisture, since water uptake may be lower
- Stem water potential may be misleading
- Progressive reduction of ET from stage 2 due to ion accumulation in leaves



Pistachio is resistant to drought and salinity but very sensitive to overirrigation and saturated soil conditions

Take-home Messages

- Pistachio is a drought tolerant crop but it can use large amount of water (40 inches over the entire season)
- Calculate the ETc to quantify the water need of your orchard (you just need ETo from CIMIS website and Kc)
- ETc alone is not enough to manage irrigation properly
- Integrate ET estimates with soil and plant water status monitoring to decide when to irrigate
- If you have water shortage, Stage II (shell hardening) is the preferred window to irrigate in deficit

Thank you

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