Effective irrigation tools and strategies in the era of water constraints: an overview of the recent studies in the desert southwest

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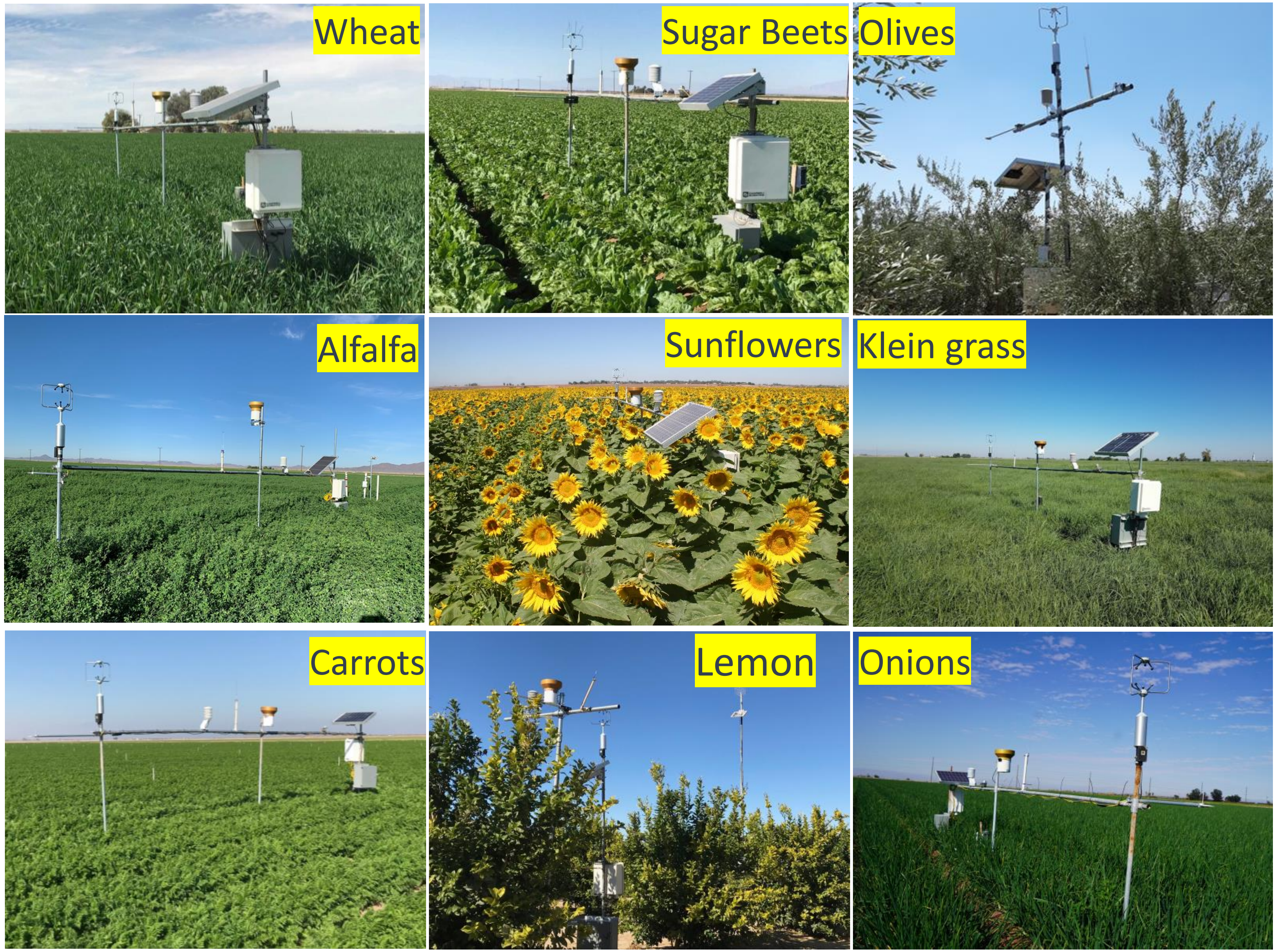
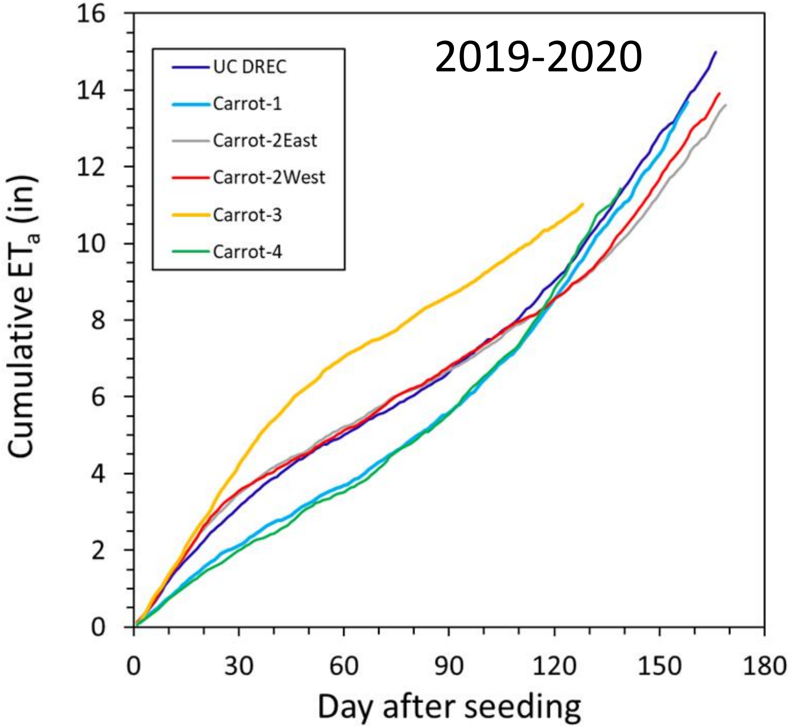
Adapted Water Conservation Practices in Imperial Valley (survey's results, 2020)

Water conservation practice	% of growers who adapted the practice
Surface Irrigation Optimization	87 (rank 1)
Sprinkler Irrigation	73 (rank 2)
Irrigation Scheduling Technology	65 (rank 3)
Drip/Micro Irrigation	43 (rank 4)
Portable Tailwater Recovery System	43 (rank 4)
Deficit Irrigation	43 (rank 4)
On-Farm Reservoir	34 (rank 5)
Permanent Tailwater Recovery System	26 (rank 6)
Other practices	26 (rank 6)
Automated Surface Irrigation	8 (rank 7)

How much water does my crop need?

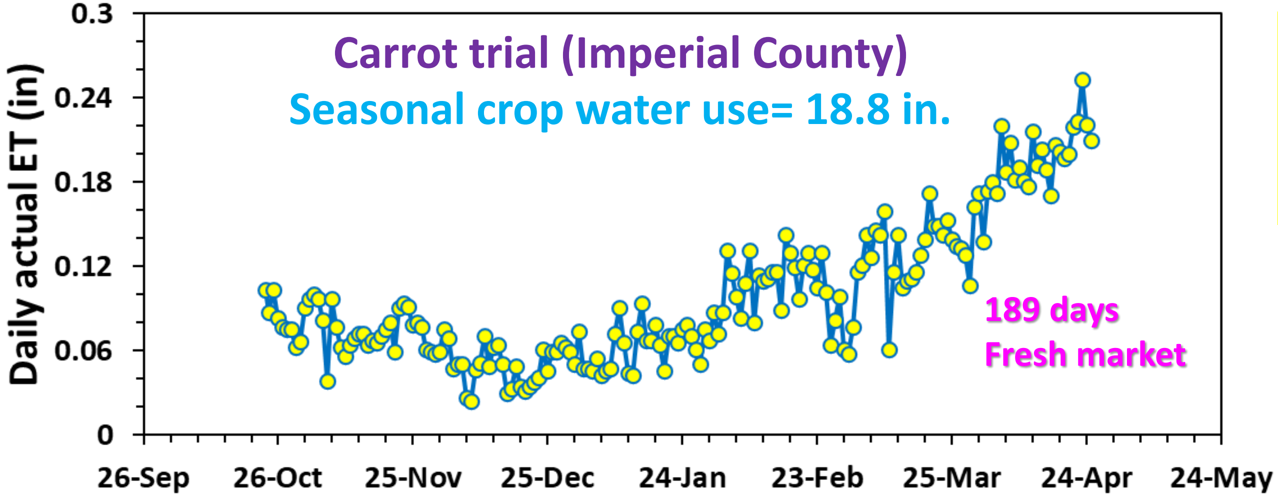


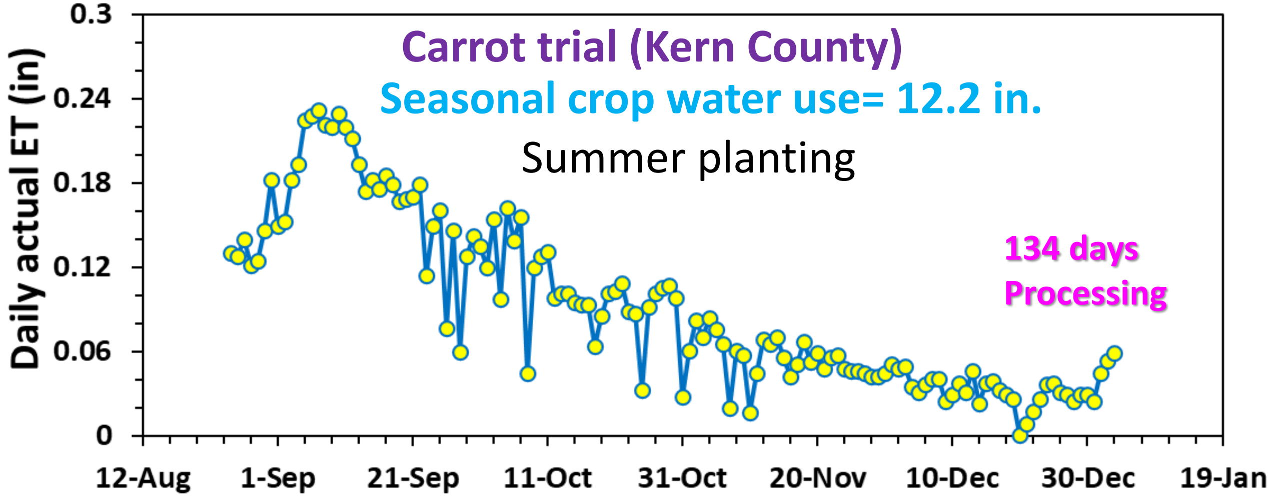
Seasonal ET in Carrots in the Low Desert



"Variable seasonal crop water use (12-19 inches) depending on early/late planting, length of season, variety, soil type, and irrigation practice.

Carrot crop water use (actual ET)





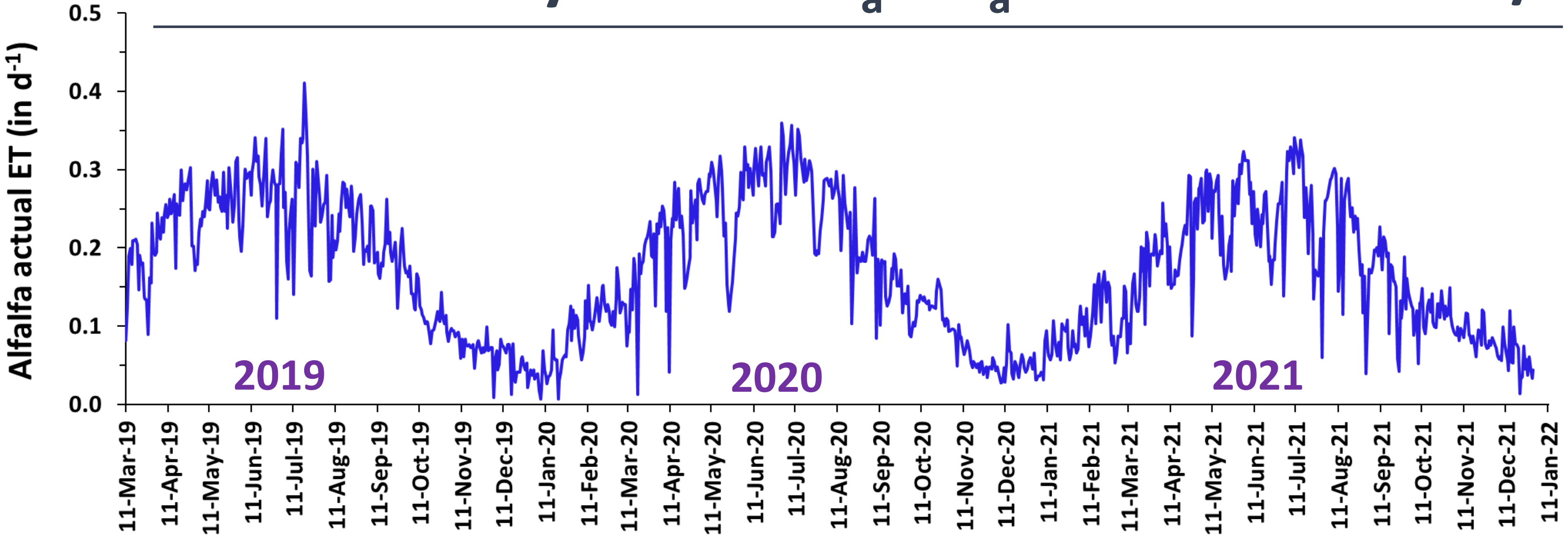
IC: Crop water use varied from **11.7 to 18.8 in.** across the trial fields.

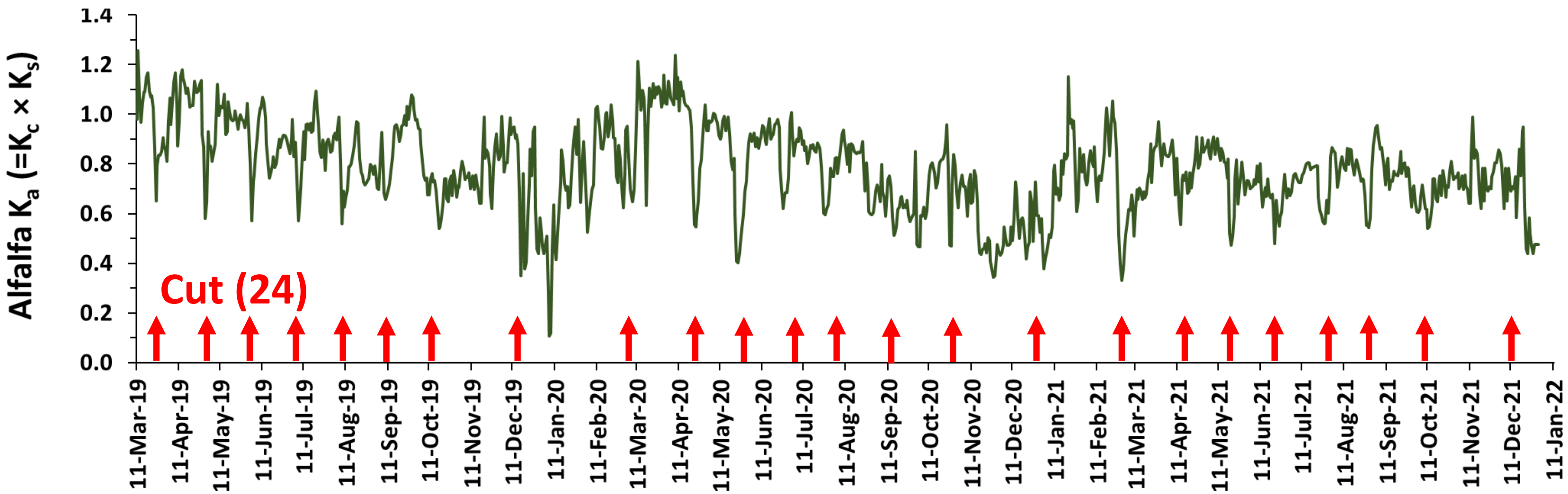
KC. Crop water use varied from **10.4 to 12.9 in.** (summer planting) & from **20.5 to 22.7 in.** (winter planting) across the trial fields.

Water use categories

1. Low water use (summer planting-Kern)
2. Medium water use (fall planting-Imperial)
3. High water use (winter planting-Kern)

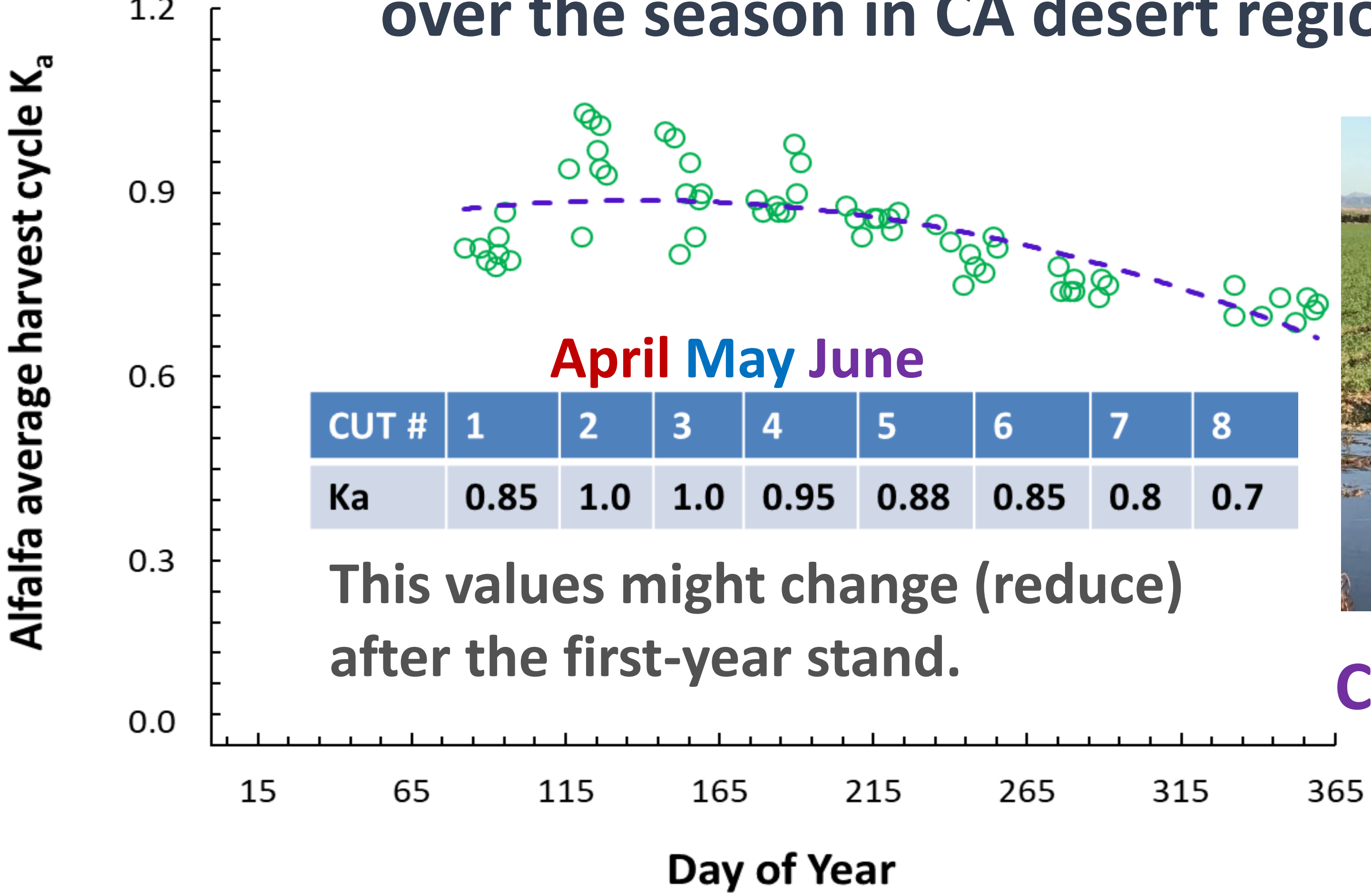
Variable Daily Alfalfa ET_a & K_a Over the Season/s





- Daily
- Harvest cycle
- Yearly

Average harvest cycle crop coefficients over the season in CA desert region



April May June

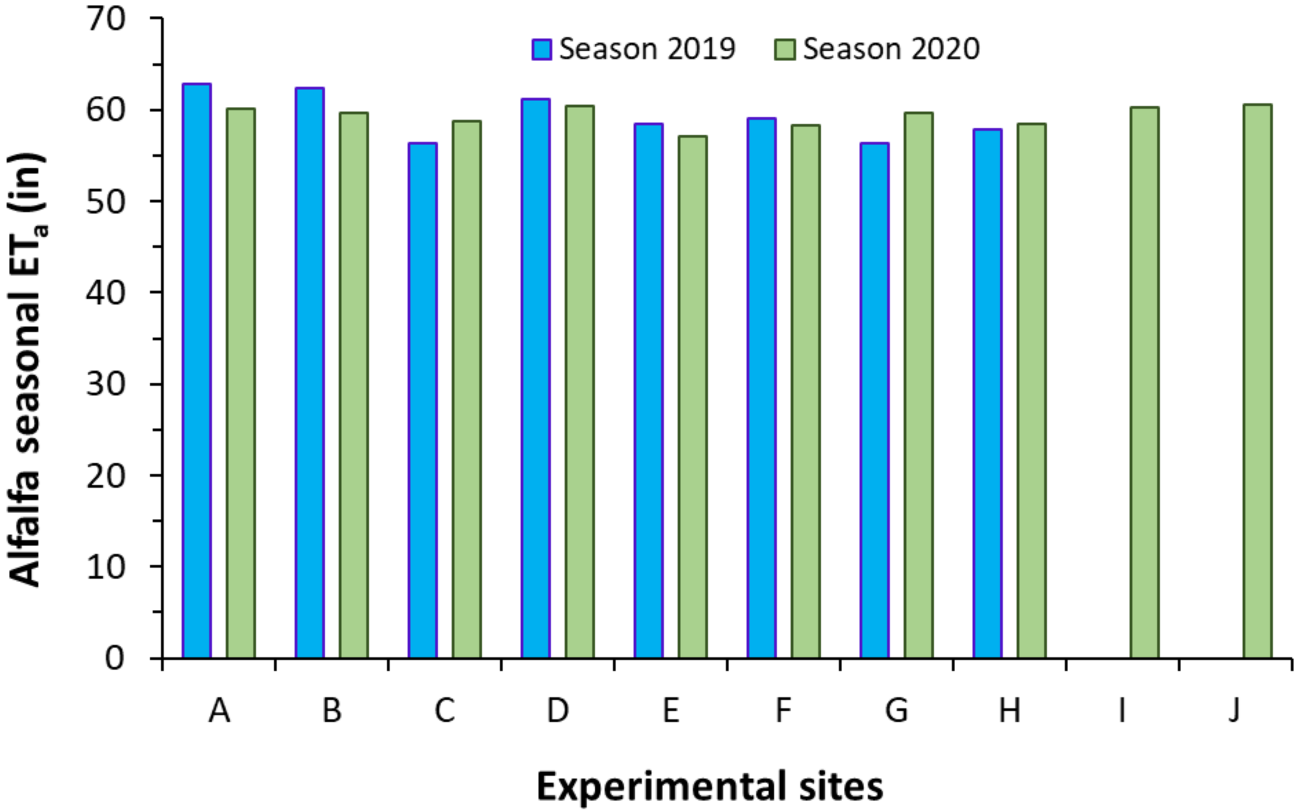
CUT #	1	2	3	4	5	6	7	8
Ka	0.85	1.0	1.0	0.95	0.88	0.85	0.8	0.7

This values might change (reduce) after the first-year stand.

Crop ET= Crop coefficient × ET_o

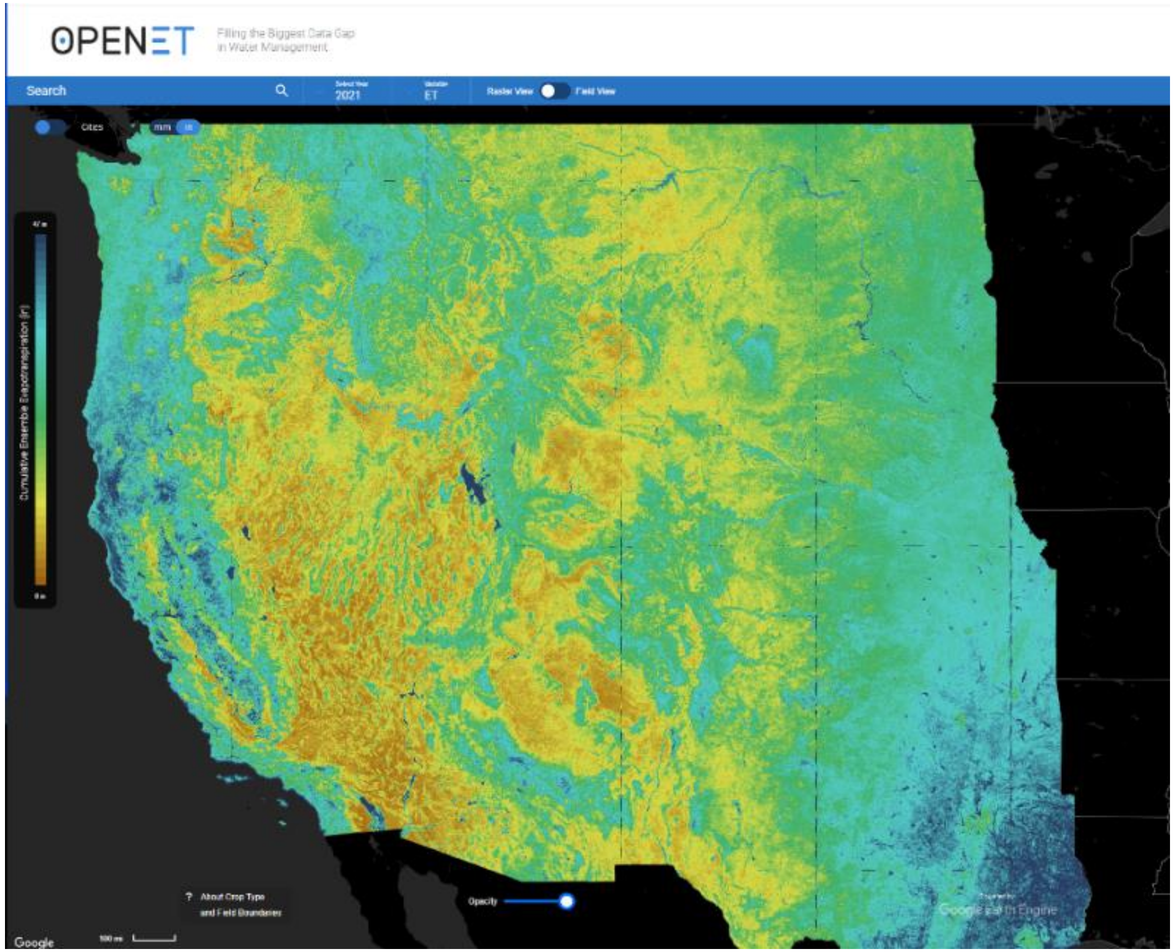
Well-watered Grass ET (CIMIS stations)

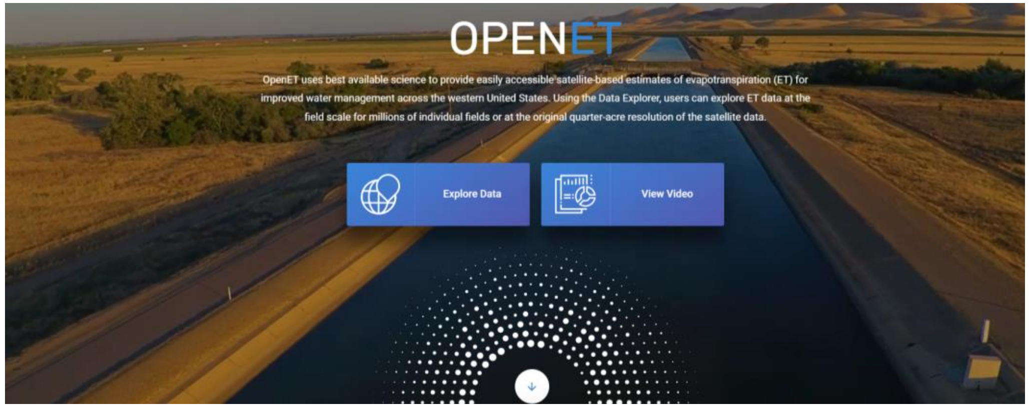
Alfalfa seasonal ET in the low desert



Field	Dominate soil type	Irrigation practice
A	Loam	Surface (furrow)
B	Loam	Surface (furrow)
C	Clay	Surface (flat)
D	Sandy loam	Surface (flat)
E	Silty clay loam	SDI
F	Sandy loam	SDI
G	Silty clay loam	Automated surface irrigation (flat)
H	Silty clay	SDI
I	Silty clay	Linear move sprinkler
J	Silty loam	Linear move sprinkler

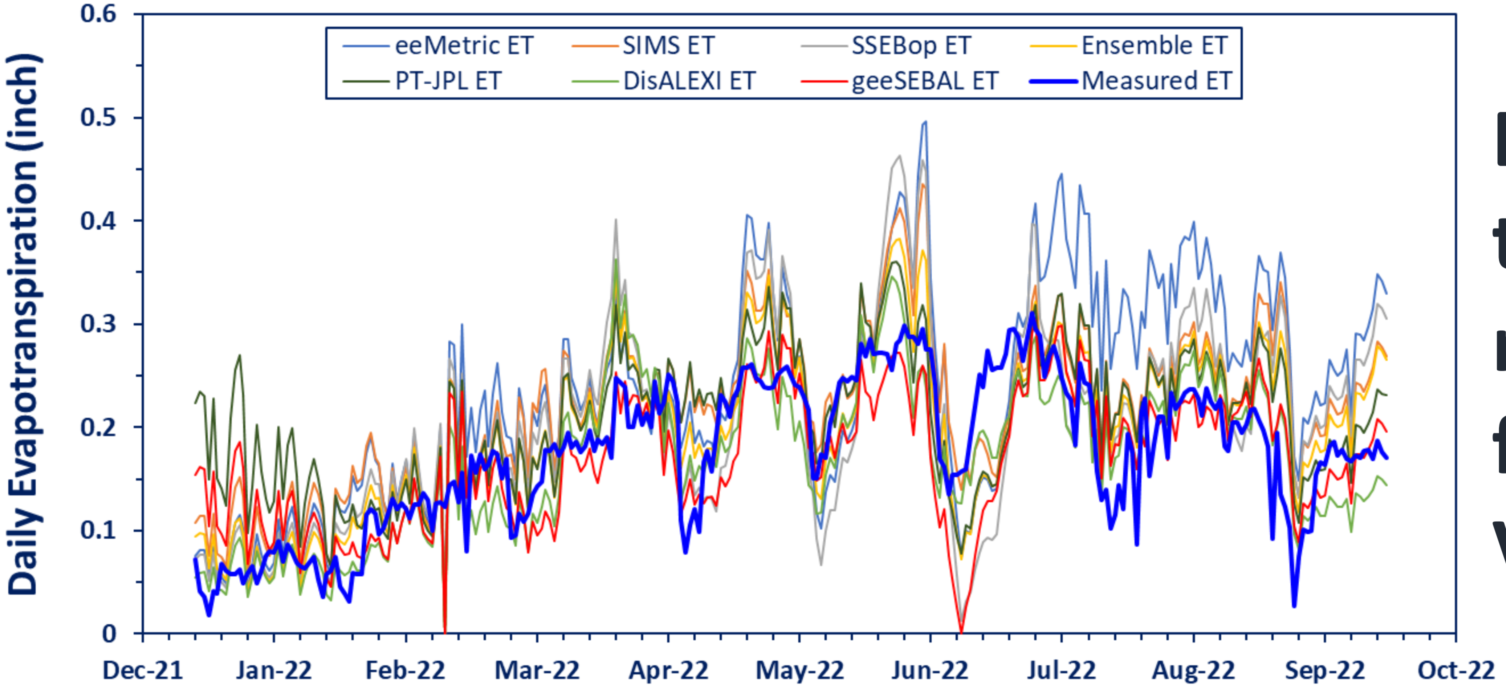
The seasonal crop water consumption varied from 56.3-in to 62.8-in.





OpenET is a new online platform that uses satellites for mapping evapotranspiration (actual ET) at the scale of individual fields.

https://openetdata.org



Evaluation of OpenET to estimate crop water requirements of alfalfa fields in the Imperial Valley

	Ensemble	eeMetric	SIMS	SSEBop	PT-JPL	DisALEXI	geeSEBAL	Measured
Cumulative ET	54.25	65.51	60.36	55.98	57.31	46.22	46.31	47.71
Max. Daily ET	0.38	0.50	0.44	0.46	0.36	0.36	0.30	0.31
Average Daily ET	0.20	0.24	0.22	0.21	0.21	0.17	0.17	0.17

Soil moisture sensors as useful tool may answer <u>critical questions</u>:

- How is water status of the soil early in the season?
- When is the right time for the first and subsequent irrigation events?
- Is the soil profile full after each irrigation event?
- What is the length of irrigation time?
- Should irrigation practice need to change?

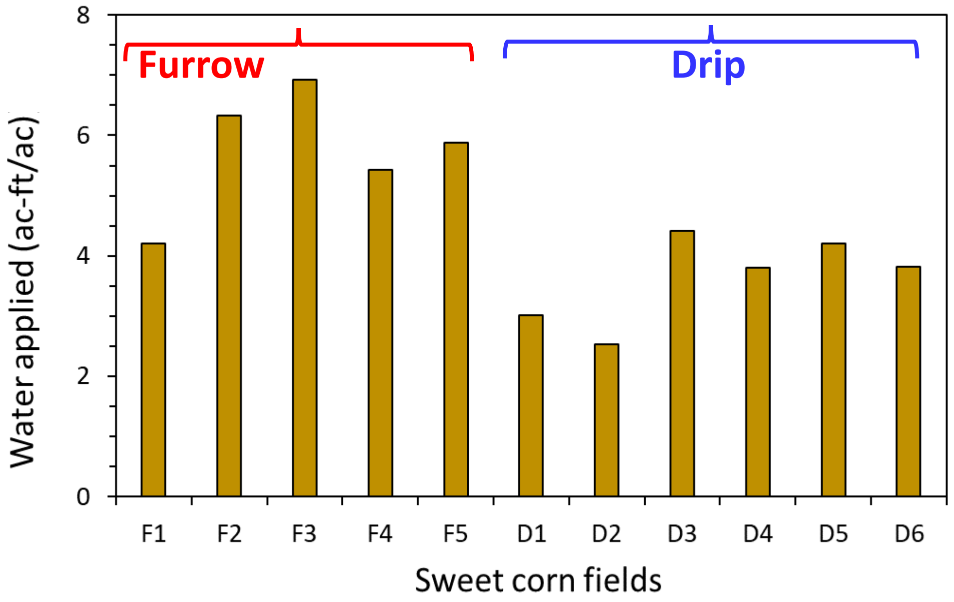
"<u>Vegetable Grower:</u> Soil moisture sensor is the most cost-effective irrigation tool that I have ever used."

Drip irrigation in sweet corn

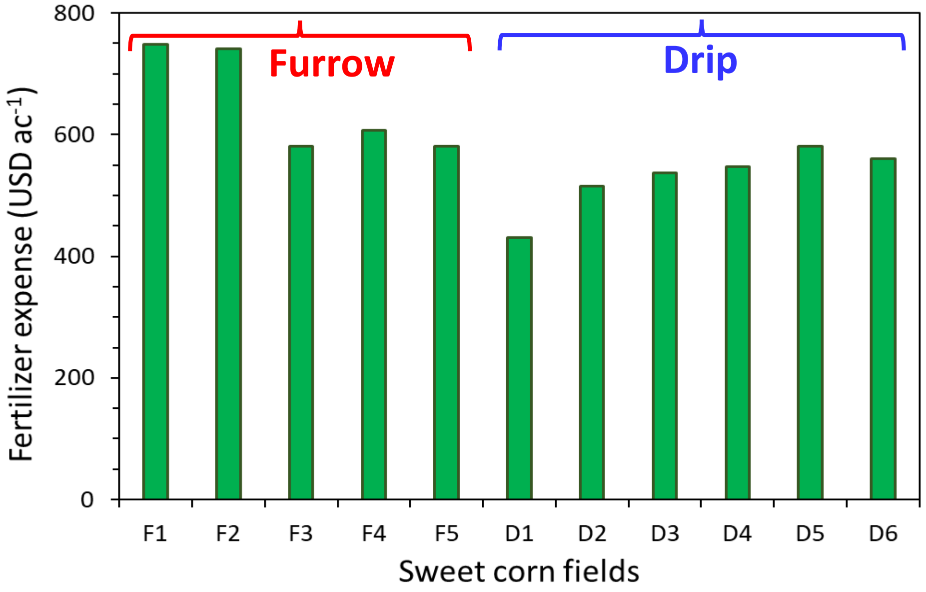
- 15 trial fields in the 2020 and 2021 seasons
- 7 furrow vs. 8 drip irrigated fields

Nearly 450 acres furrow vs. 450 acres drip

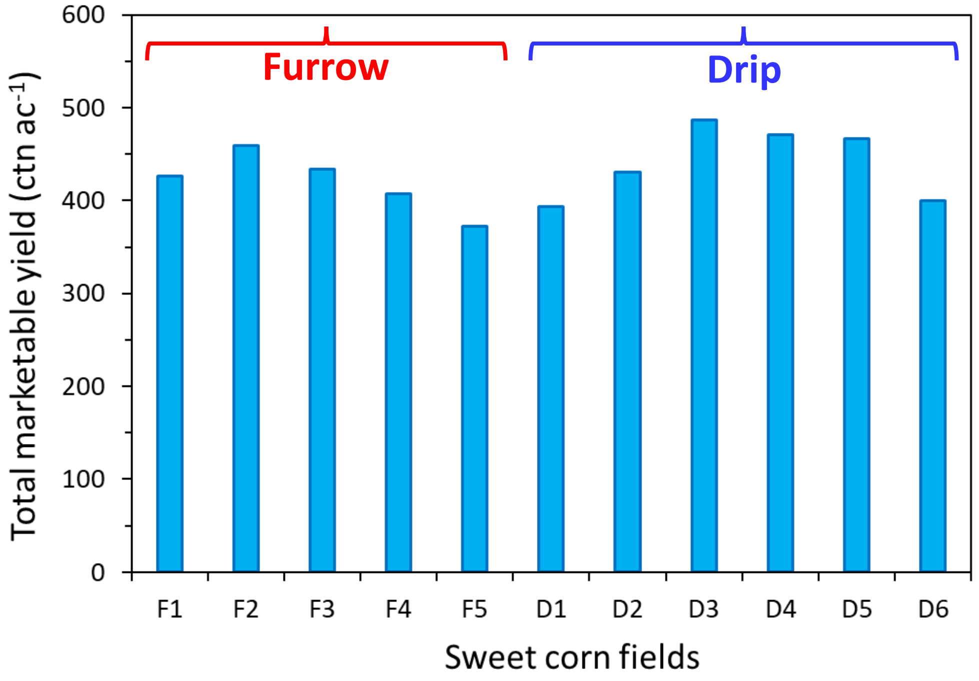
Dominant soil: Sandy loam - Loamy fine sand



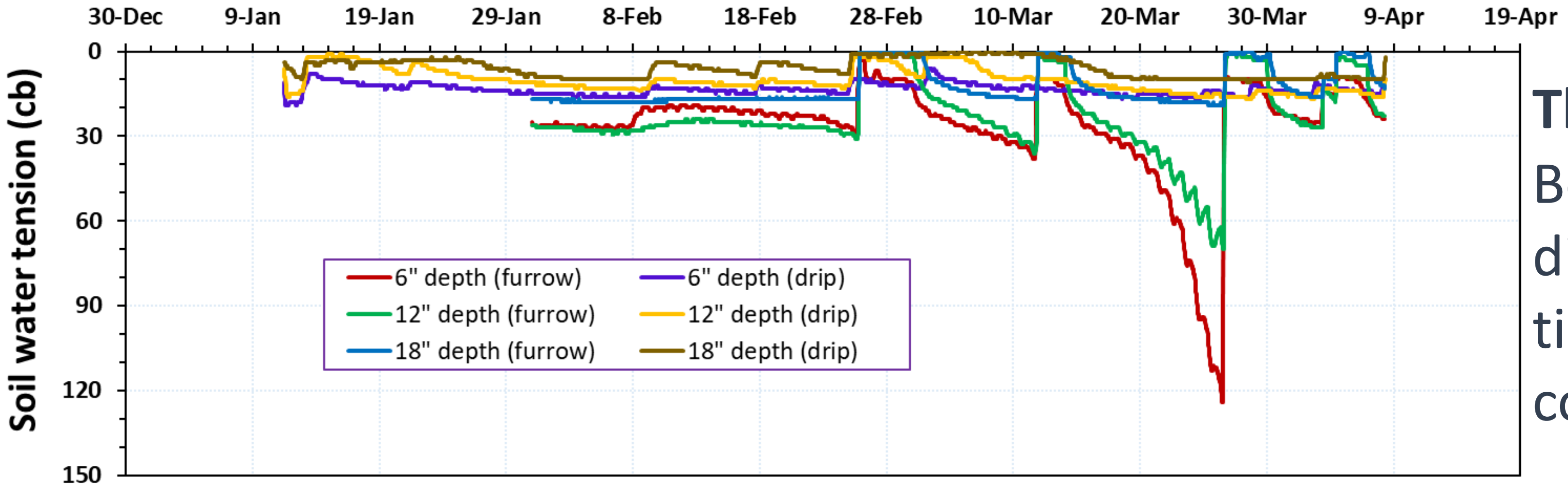
37% water conserved (2.2 ac-ft/ac)



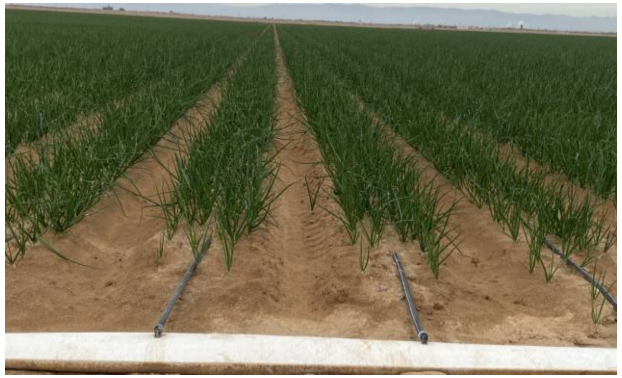
26% fertilizer conserved (146.0 $/ac)



5% marketable yield increase in drip (21.0 ctn/ac)



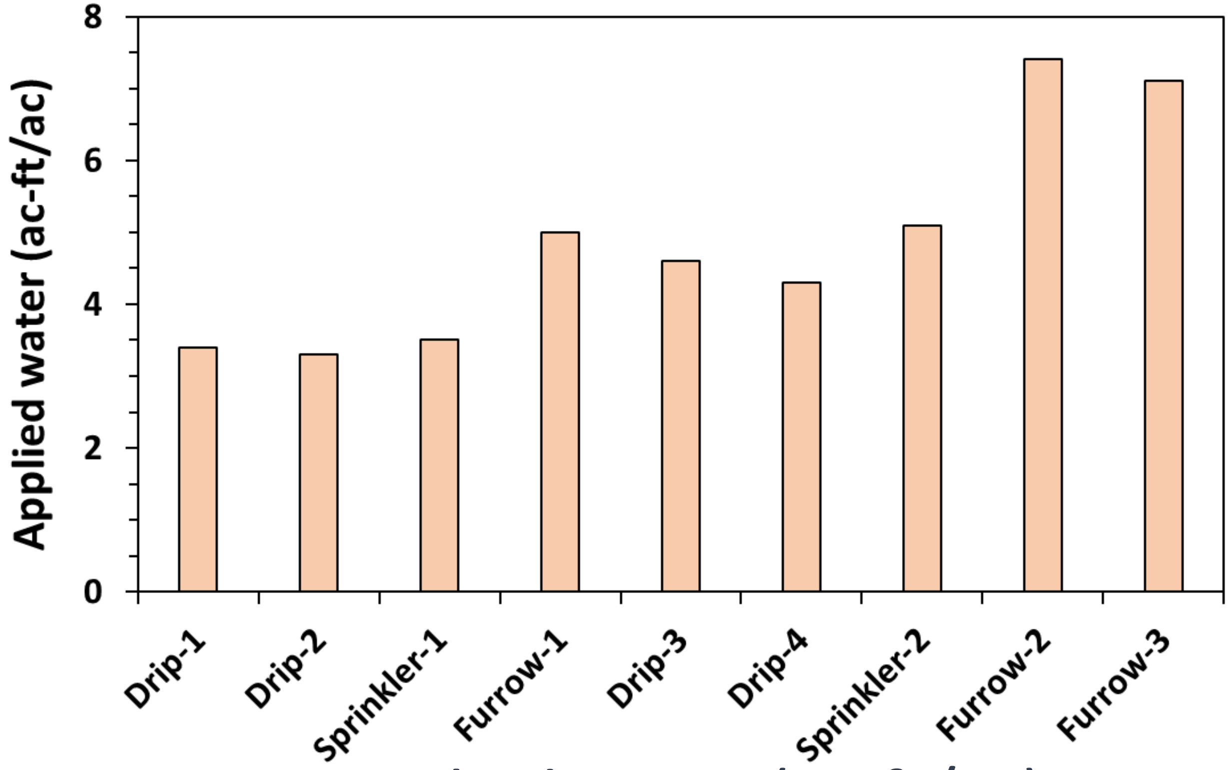
The key advantage of drip:
Better soil moisture distribution uniformity over time and space in sweet corn fields



Irrigation practices adopted in the desert onions

The current % of irrigation methods in the desert:

Furrow: ≈ 60-62%; Sprinkler: ≈ 35-37%; Drip: ≈ 3%

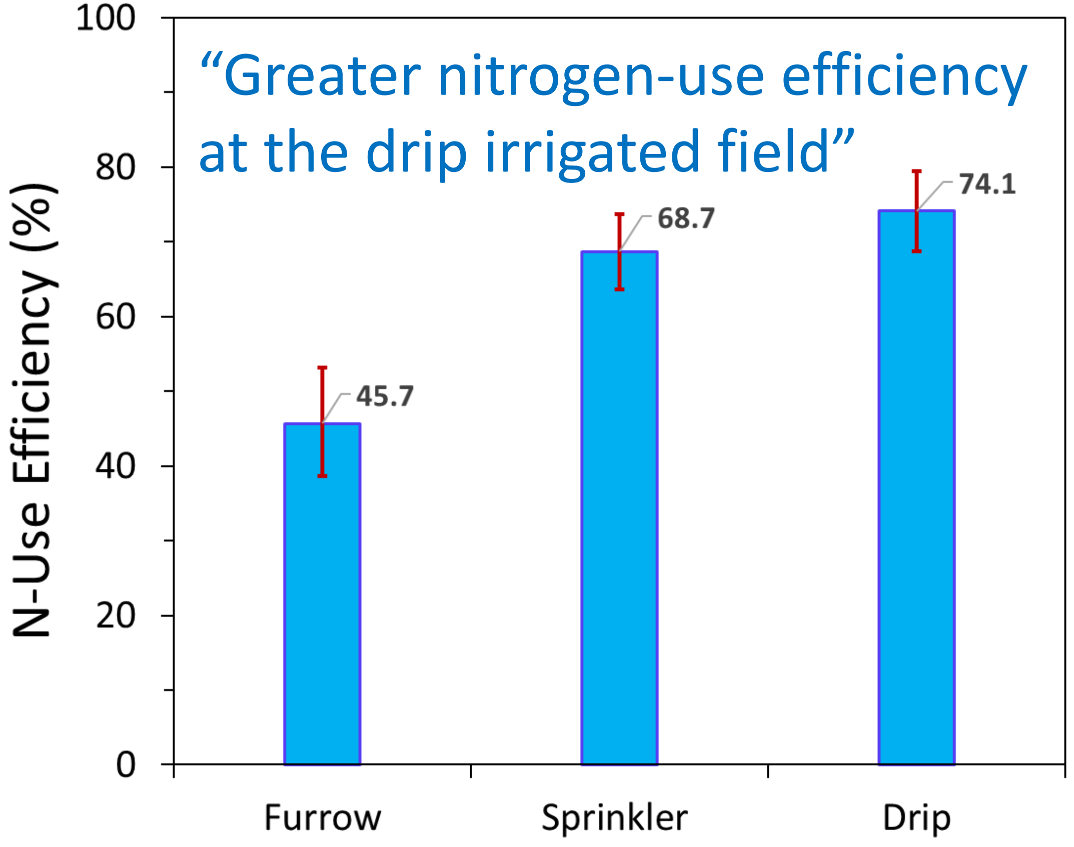


<u>Average applied water (ac-ft/ac)</u>

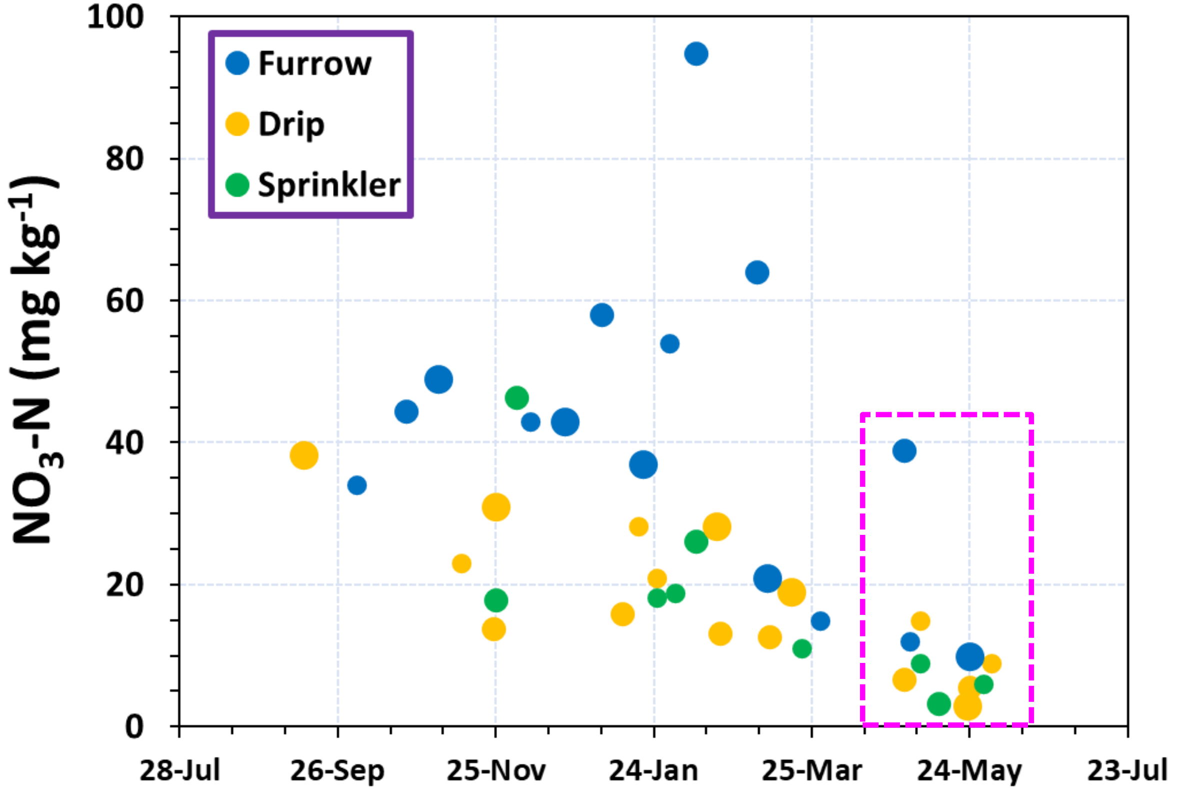
Drip: 3.9   Sprinkler: 4.3   Furrow: 6.5

Processed onions

N-use efficiency =
(N in plant/N applied) ×100



Soil nitrate-N concentrations (top 1 foot)



Higher level of nitrate-N in furrow (over the season and at harvest) field than sprinkler and drip.

Downy Mildew and Irrigation Methods

Spinach: An overall effect of irrigation treatment on Downy Mildew incidence: It was lower (2-5 times) in the plots irrigated by drip.

Onions: Downy mildew disease was not observed in any of the onion trial fields.

Fungicides application expense per acre as a measure to evaluate the impact irrigation methods on DM:

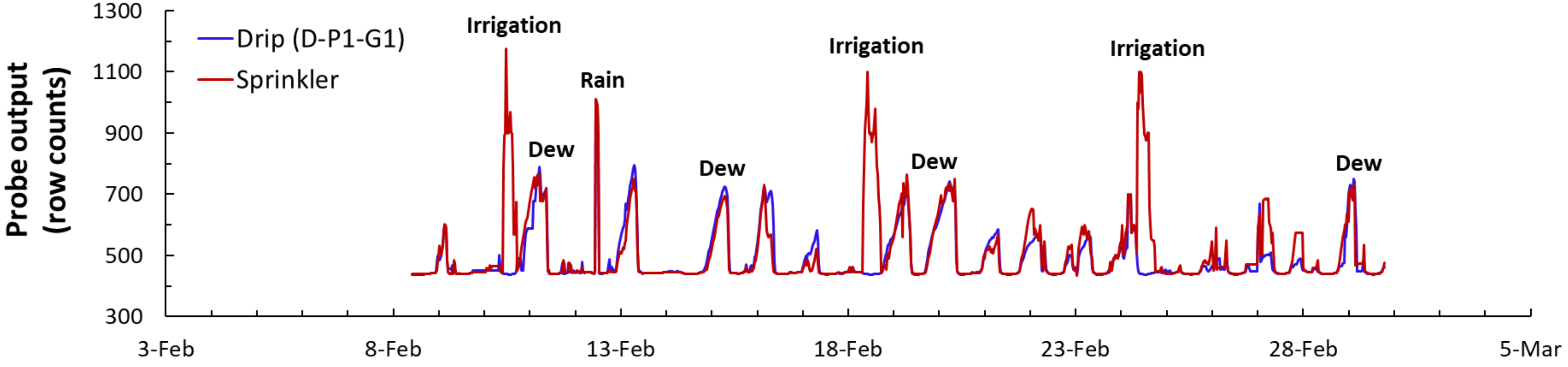
- **45% higher in sprinkler than furrow**
- **87% higher in sprinkler than drip**

Grower perspective on the DM pressure:

Sprinkler > Furrow > Drip

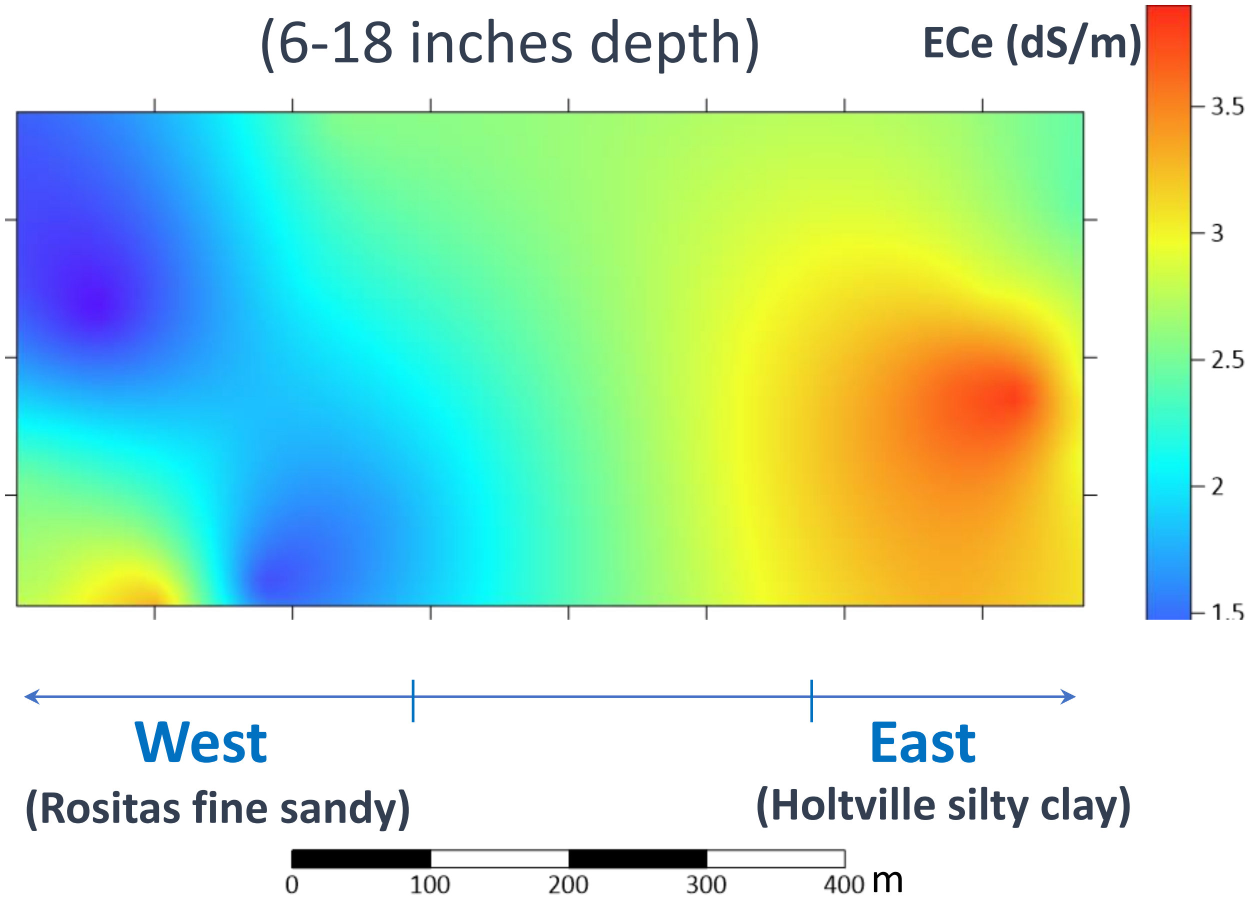
Leaf Wetness (Drip vs. Sprinkler)

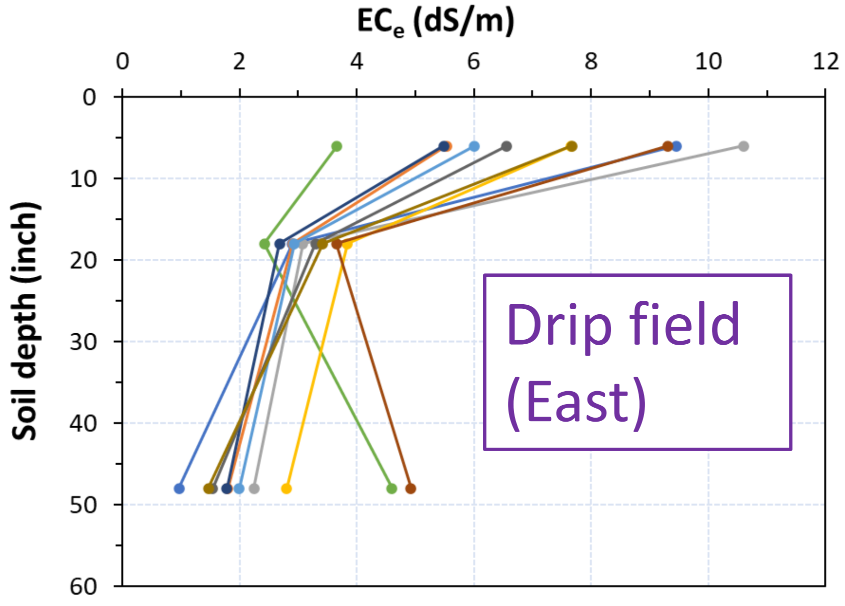
Winter 2021 Trial (20-day period)

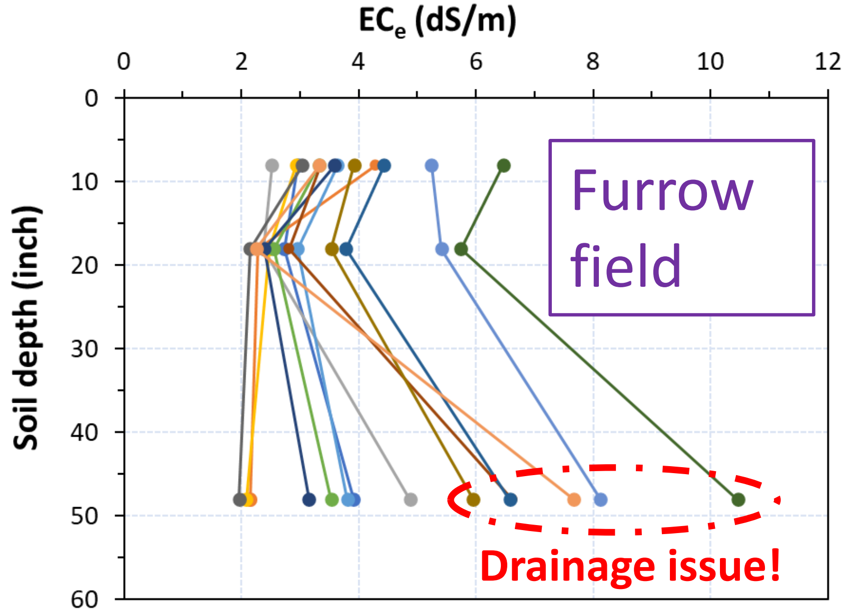


"Sprinkler irrigated crop canopies remained wet for 22% more time than crop canopies under the drip irrigated plots at the period."

Salinity map
(Onion drip irrigated field – June 2021)





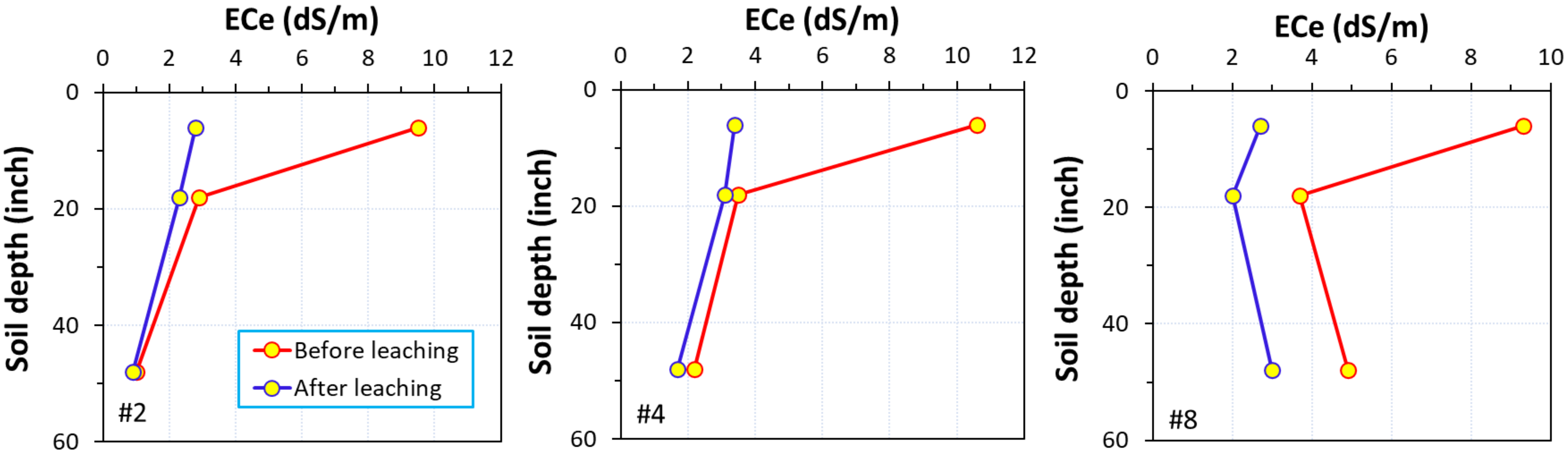


Soil salinity may be a key limitation for using SDI in alfalfa as well:

Average of soil salinity (EC_e, dS/m)

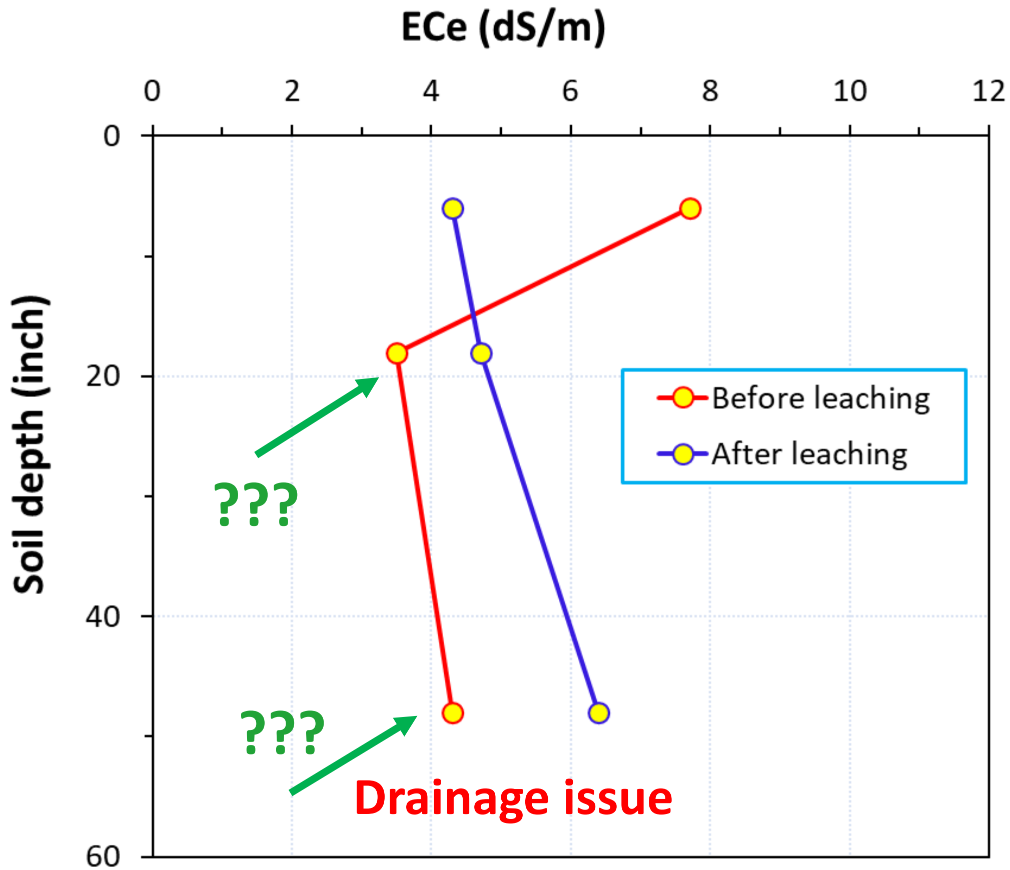
Soil depth	Field under flood irrigation	Field under SDI (10" away from driplines- 40" lateral spacing)	Field under SDI (20" away from driplines- 40" lateral spacing)
6"	+ 1.21	2.14	2.35
12"	1.09	1.72	2.03
18"	- 0.78	1.15	1.35 +

Soil salinity before and after leaching (onion field under drip)



- This field was leached using flood irrigation on early-September.
- Leaching was effective and the salts were drained from the soil profile.

Drip irrigated field with drainage issue



Drian tiles at 4-5 ft depth

Leaching (flood) won't be effective to sustain land productivity if drainage system doesn't work properly.

Objects found inside tile drains in commercial fields in the Imperial Valley

Importance of maintaining drainage system!

- **L**eaching is the most effective tool to maintain salinity

  (the optimal strategy depends on irrigation practice, soil types)

- **E**ffective drainage system is a <u>MUST</u> to sustain land

  productivity over time (Drainage issues!)

- **M**ore salinity hazard than sodium hazard in the desert

  (high levels of Calcium, Sodium, Magnesium, Chloride)

- **G**ypsum is appropriate amendment for fields with sodium hazards <u>NOT</u> necessarily for salt-affected fields

  (**S**ulfur-based amendments???)

On-farm practices

- Conserve water
- Improve quality of drainage water

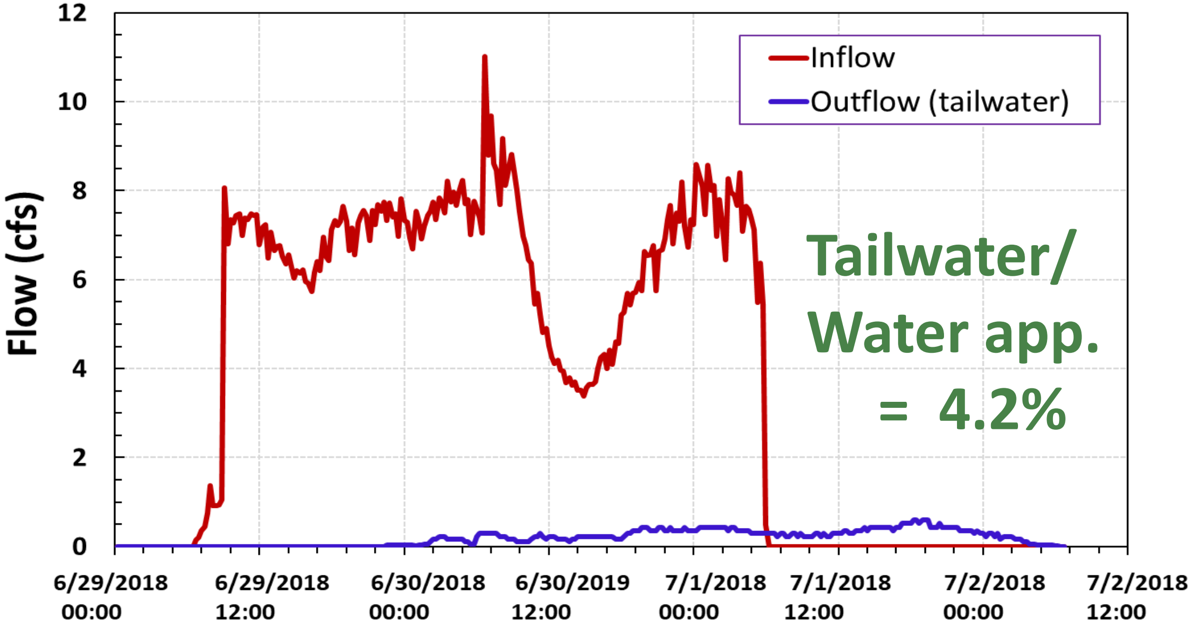
Automation of Surface Irrigation

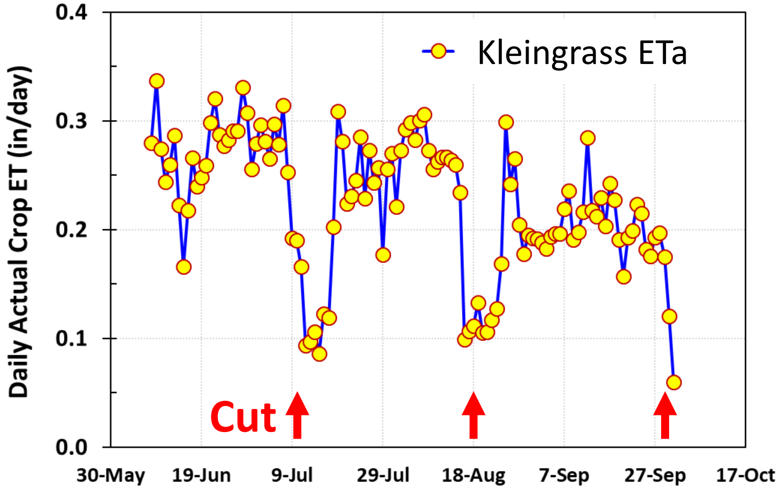
Runoff Measurement Station

Tailwater Recovery Systems

EC of water
3 dS/m

Case study for Kleingrass (automated surface irrigation)





6 irrigation events

Irr. =2.1 ac-ft/ac

ET_a =1.6 ac-ft/ac (76%)

Tailwater=0.15 ac-ft/ac (7%)

Deep percolation= 0.35 ac-ft/ac (17%)

???Leaching salt (10%)

Irrigation efficiency = 86%

Sacramento Valley

Summer Deficit Irrigation

Deficit irrigation in alfalfa

Moderate partial-season irrigation in alfalfa:
Skip 2-3 irrigation events during the summer period.

Imperial Valley

Key drivers to optimize deficit irrigation strategy:

- **Yield loss**
- **Plant stands**
- **Soil water depletion**
- **Salt accumulation**
- **Hay quality**

Deficit irrigation in alfalfa could be a drought strategy & water conservation tool.

Deficit irrigation strategies

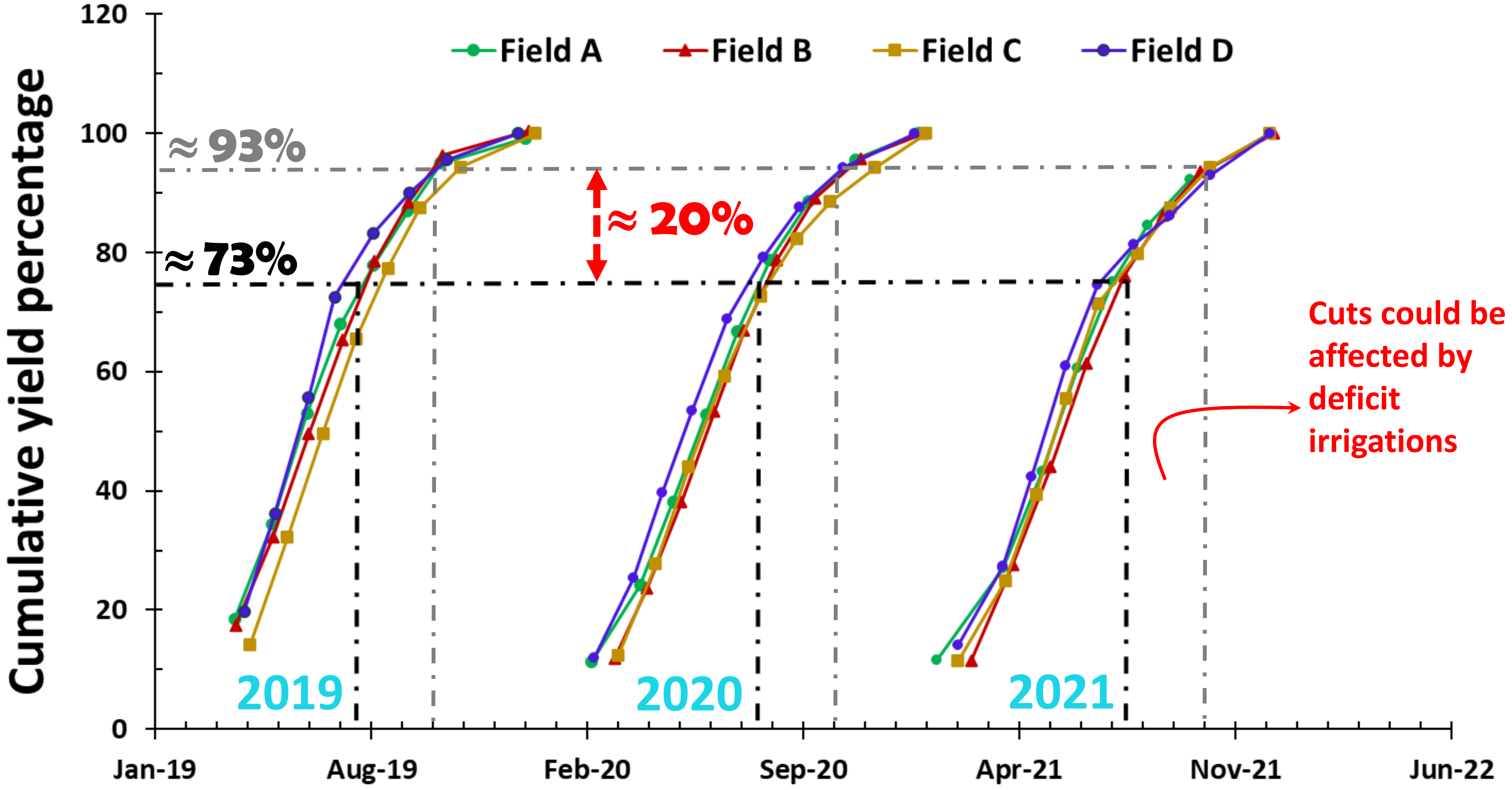
Triage: Reduce the irrigated acreage of alfalfa (cease irrigating some fields while fully irrigating others, or watering only some portions of fields).

Starvation diet: Deficit-irrigate the entire acreage during the crop season (less water per irrigation or fewer irrigations).

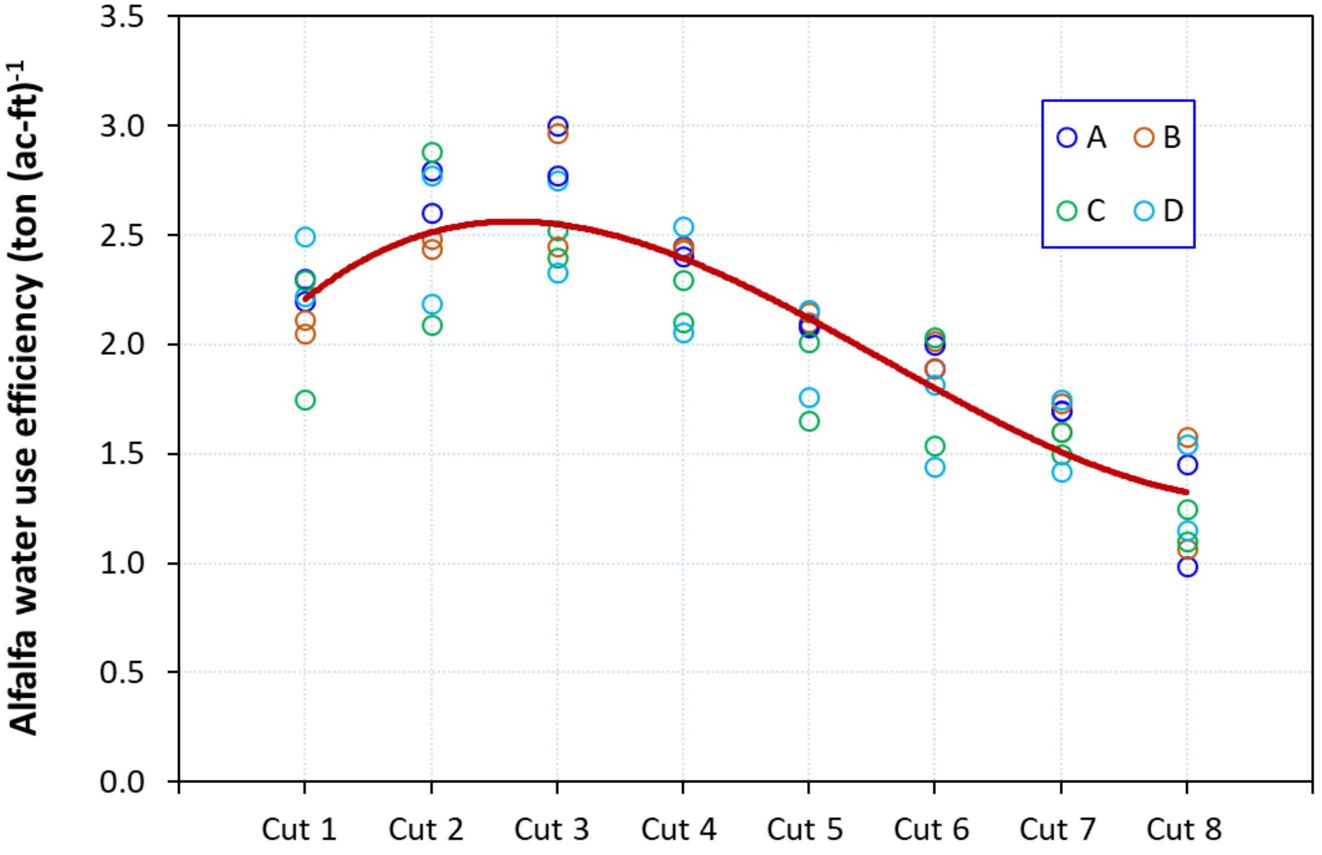
Partial-season irrigation: Fully irrigate all fields for the early cuttings, then cease irrigation partway through the season.

Moderate partial-season irrigation: skip a couple of irrigation events during a specific period.

Alfalfa seasonal yield patterns

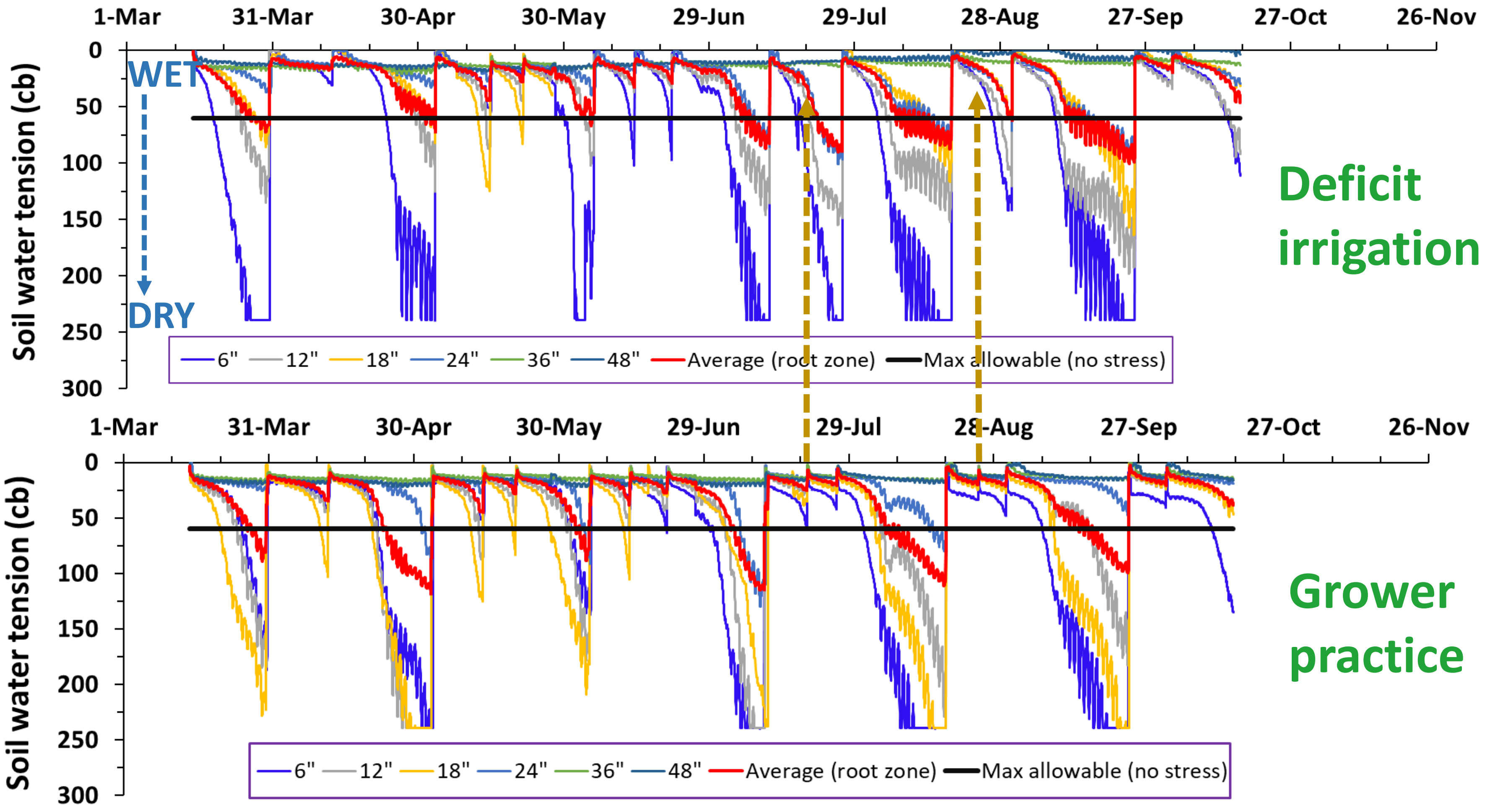


Alfalfa water use efficiency over the season (desert region)

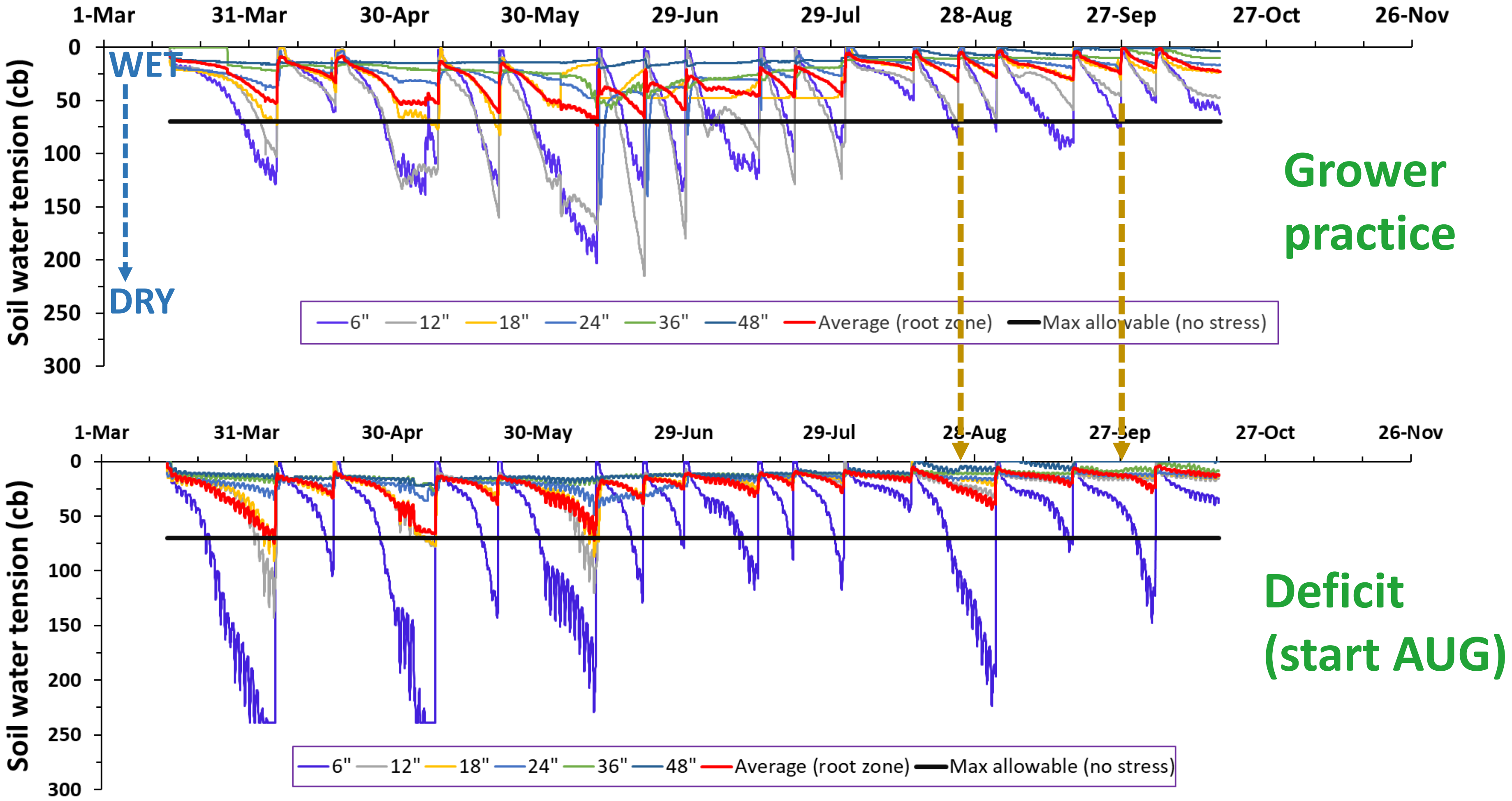


Alfalfa has higher water use efficiency in early to mid-season (Mar-Jul) than mid- to late season (Aug-Dec).

Soil Water Status (alfalfa field with sandy loam soil)

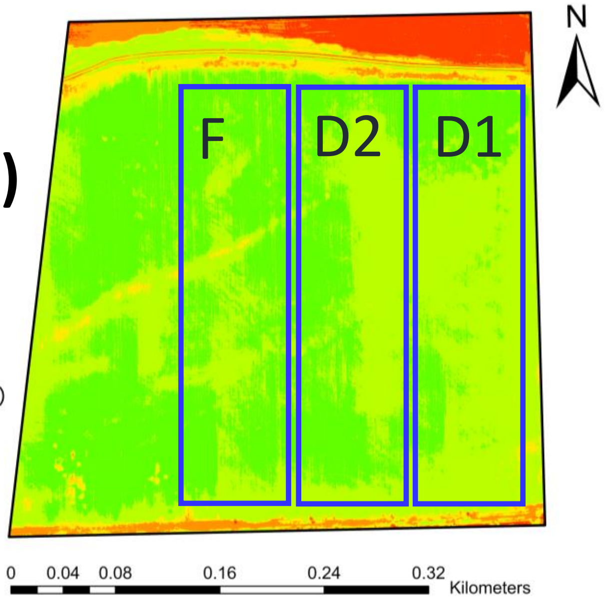


Soil Water Status (alfalfa field with loamy soil)



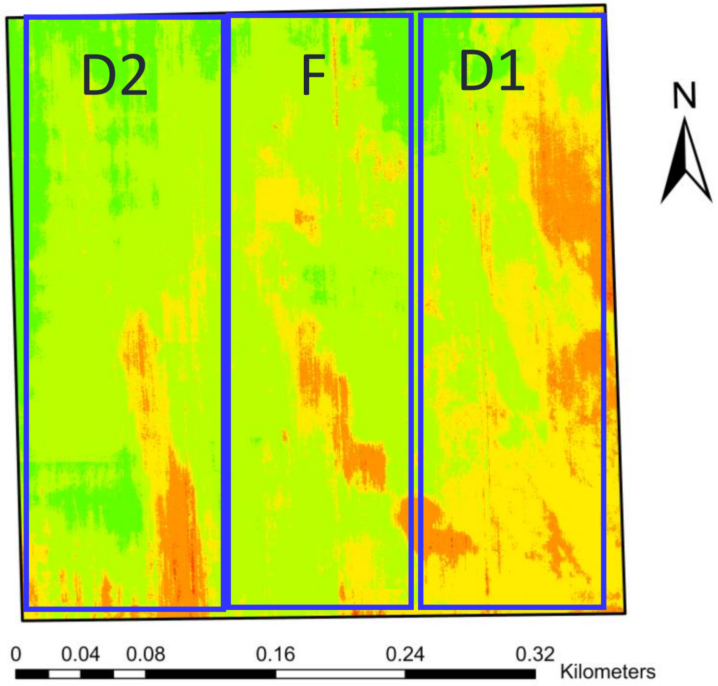
Thermal Maps (September 26, 2020)

Field B (furrow)



Temperature (Celcius)
Value
≤26.09
≤33.48
≤40.87
≤48.27
≤55.66

Loamy soil



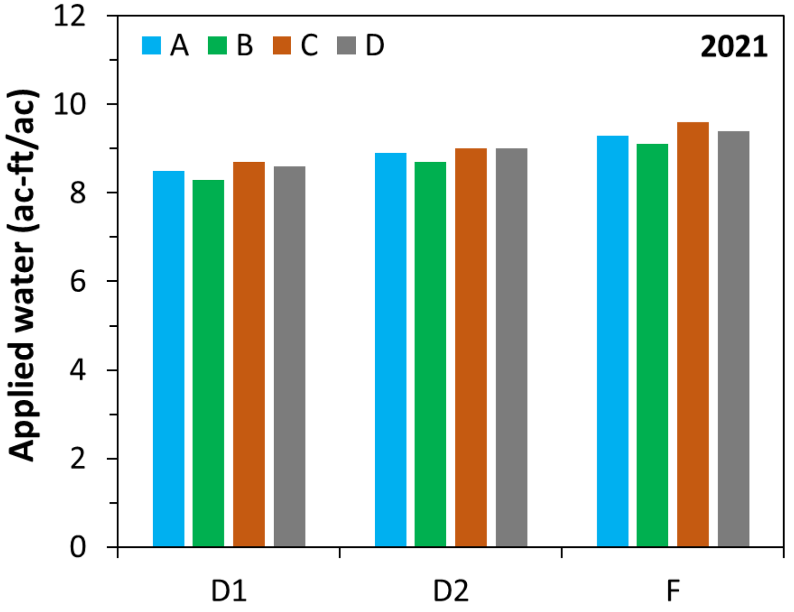
Temperature (Celcius)
Value
≤17.66
≤23.74
≤29.83
≤35.91
≤41.99

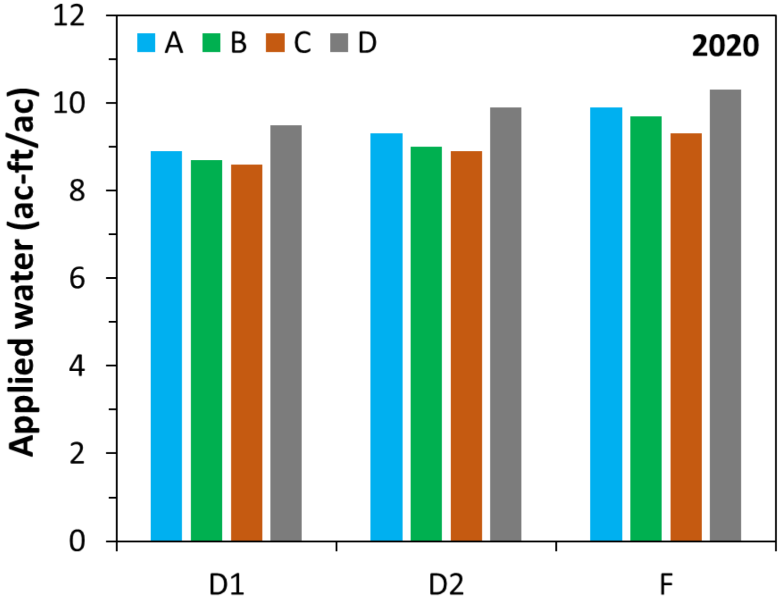
Field D (flat)

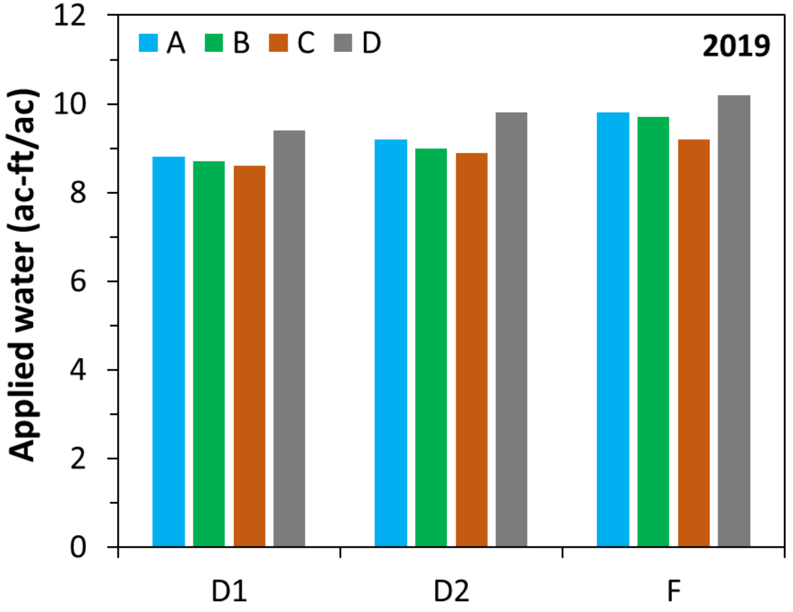
Sandy loam soil

D1: Deficit irrigation plot
D2: Deficit irrigation plot
F: Grower practice plot

Applied Water Comparisons (different seasons/fields)



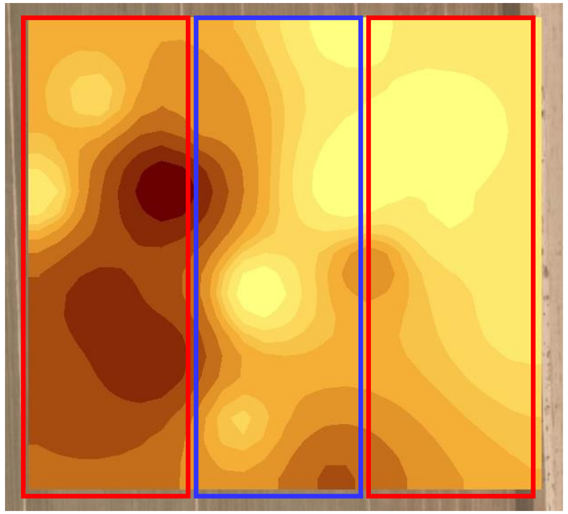




An average of 0.35-1.0 ac-ft/ac water conserved as a result of summer deficit irrigation strategies

Soil Electrical Conductivity Maps

(1 - 2 feet depth)

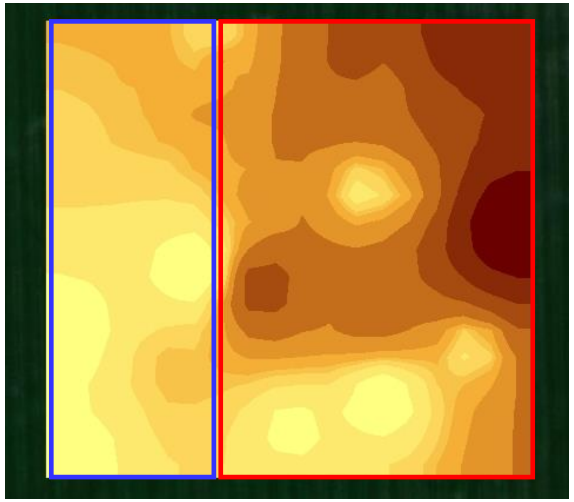


Field D

EC_e in dS/m

0.27 - 0.49	0.94 - 1.08
0.5 - 0.64	1.09 - 1.3
0.65 - 0.75	1.31 - 1.6
0.76 - 0.82	1.61 - 2.02
0.83 - 0.93	2.03 - 2.61

Meters
0 15 30 60 90 120



Field B

EC_e in dS/m

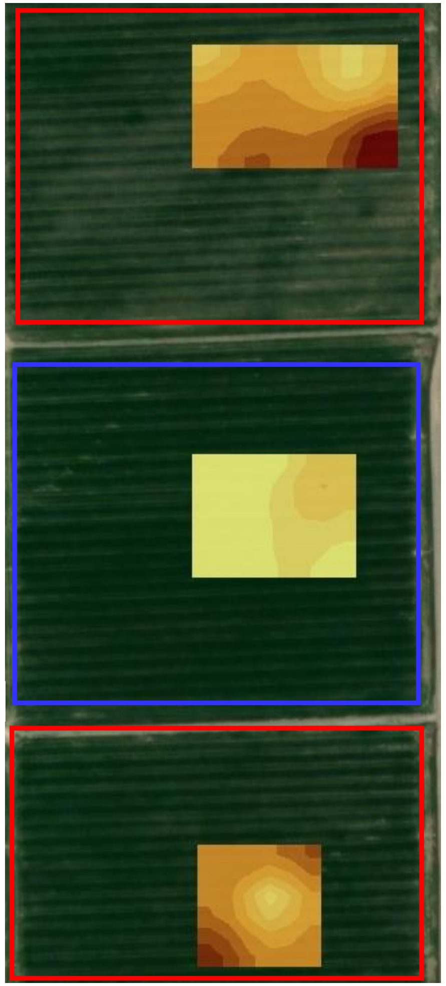
0.69 - 0.98	1.33 - 1.47
0.99 - 1.13	1.48 - 1.75
1.14 - 1.2	1.76 - 2.31
1.21 - 1.24	2.32 - 3.38
1.25 - 1.32	3.39 - 5.46

Meters
0 15 30 60 90 120

EC_e in dS/m

0.68 - 1	2.3 - 2.61
1.01 - 1.32	2.62 - 2.94
1.33 - 1.64	2.95 - 3.26
1.65 - 1.97	3.27 - 3.58
1.98 - 2.29	3.59 - 3.91

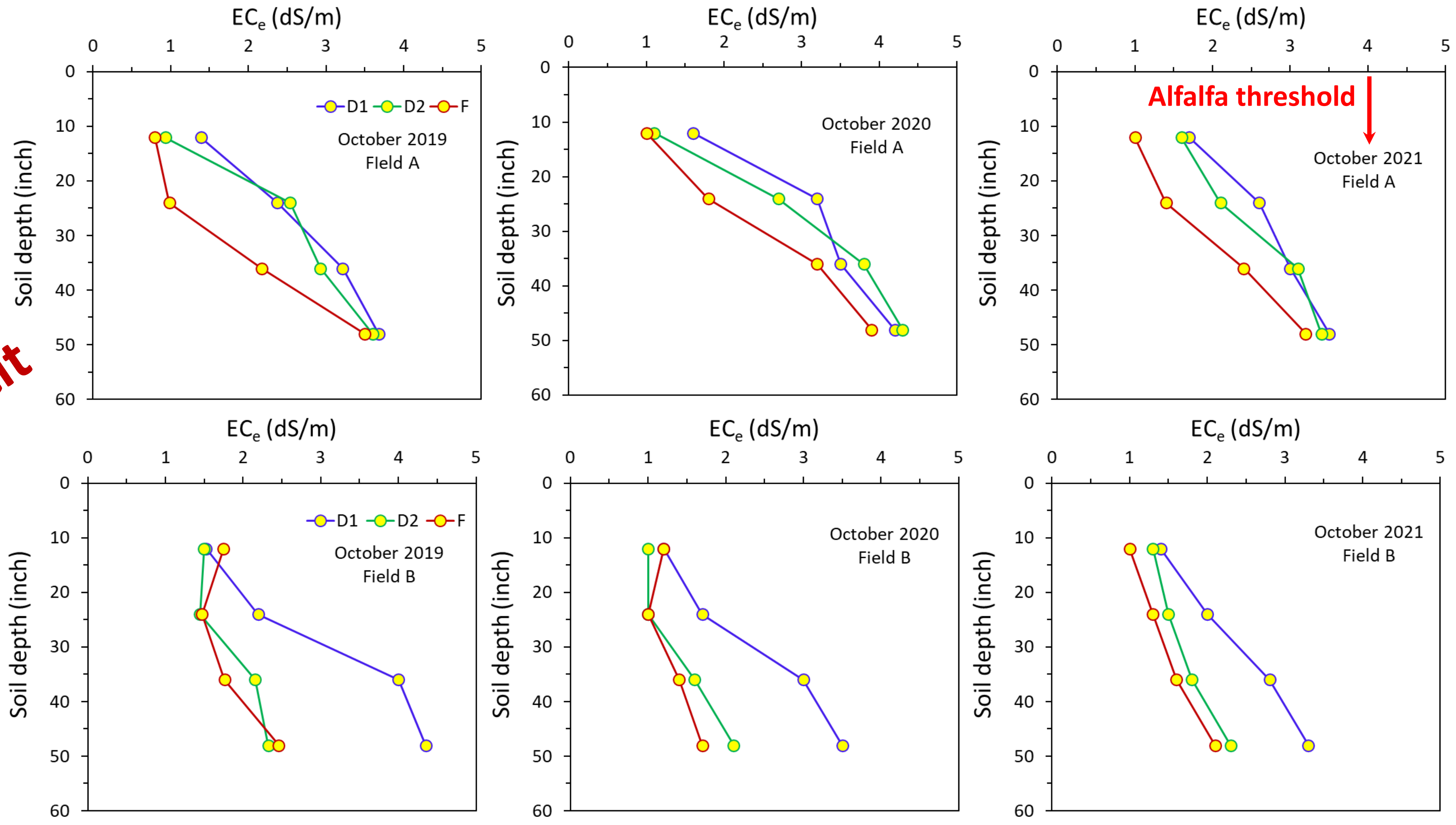
Meters
0 25 50 100 150 200



Field A

"More salt buildup was observed at the furrow irrigated fields"

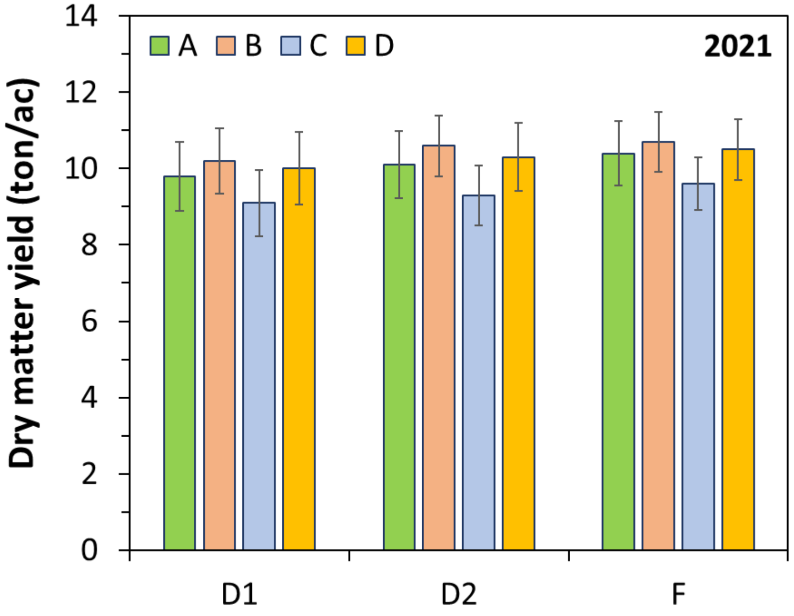
Salinity assessment over a three-year period

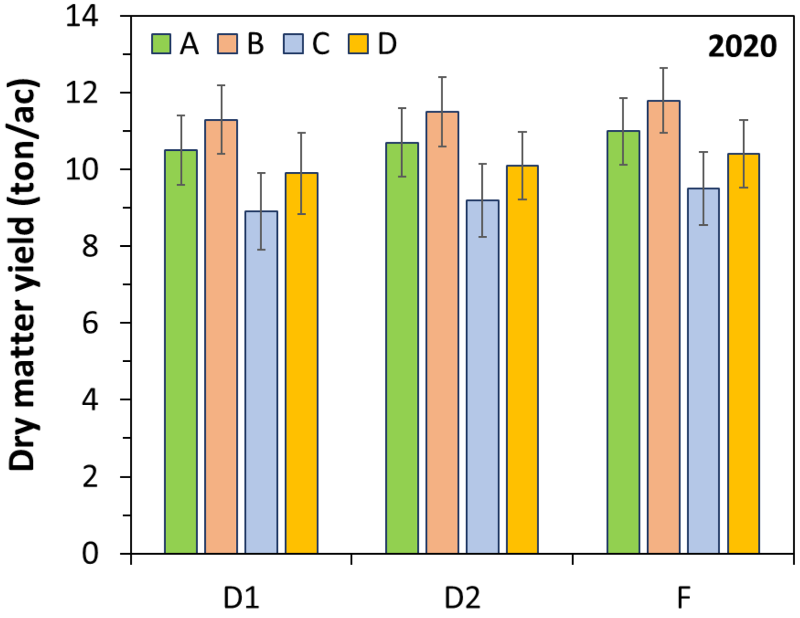


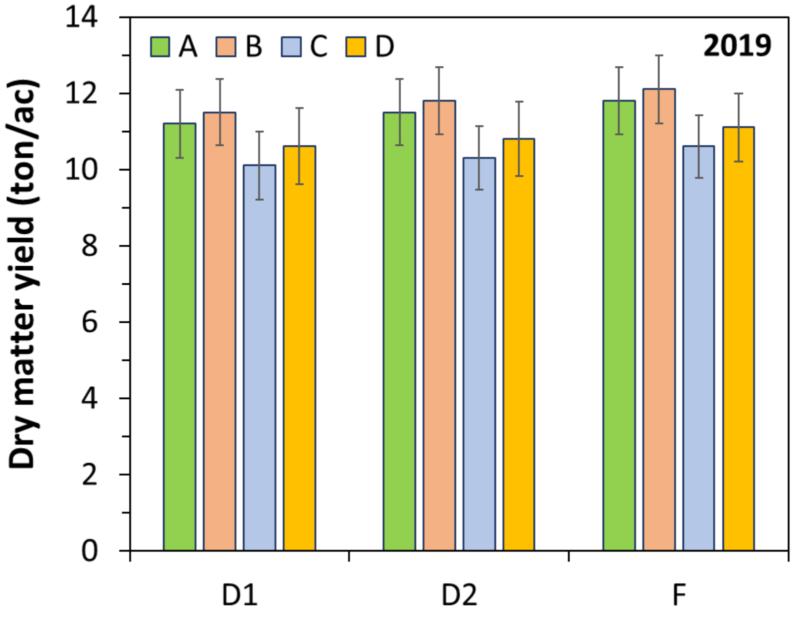
Moderate deficit irrigation

<u>**Salt buildup**</u> is manageable with subsequent normal irrigation practices, following deficit irrigations.

Alfalfa Dry Matter Yield Comparisons (different seasons/fields)







- **D**ifferent potential yields at different fields (9.5-12.1 ton/ac)
- **A**n average yield penalty of 0.3-0.6 ton/ac was observed as a result of summer deficit irrigation strategies

Forage Quality Comparisons (90% dry matter)

Site	Acid Detergent Fiber (%)					Crude Protein (%)					Lignin (%)				
	F	DI1	DI2	DI3	DI4	F	DI1	DI2	DI3	DI4	F	DI1	DI2	DI3	DI4
A	29.1	28.9 ns	27.8 *	-	-	21.0	20.7 ns	20.8 ns	-	-	5.2	5.1 ns	5.2 ns	-	-
B	31.2	26.4 *	28.2 ns	-	-	19.6	22.5 *	21.2 ns	-	-	5.2	5.1 ns	5.1 ns	-	-
C	27.6	-	-	25.7 ns	27.5 ns	18.3	-	-	19.4 ns	18.4 ns	4.5	-	-	4.6 ns	4.7 ns
D	31.2	-	-	26.5 ns	30.0 ns	17.6	-	-	20.6 *	18.3 ns	5.1	-	-	4.9 ns	5.0 ns

[ns] Non-significant. * Significant at the 5% level of probability.

“Positive impacts on alfalfa forage quality from the deficit irrigation strategies (similar trends over the 3-season)”

[Stem growth reduced more than leaf growth]

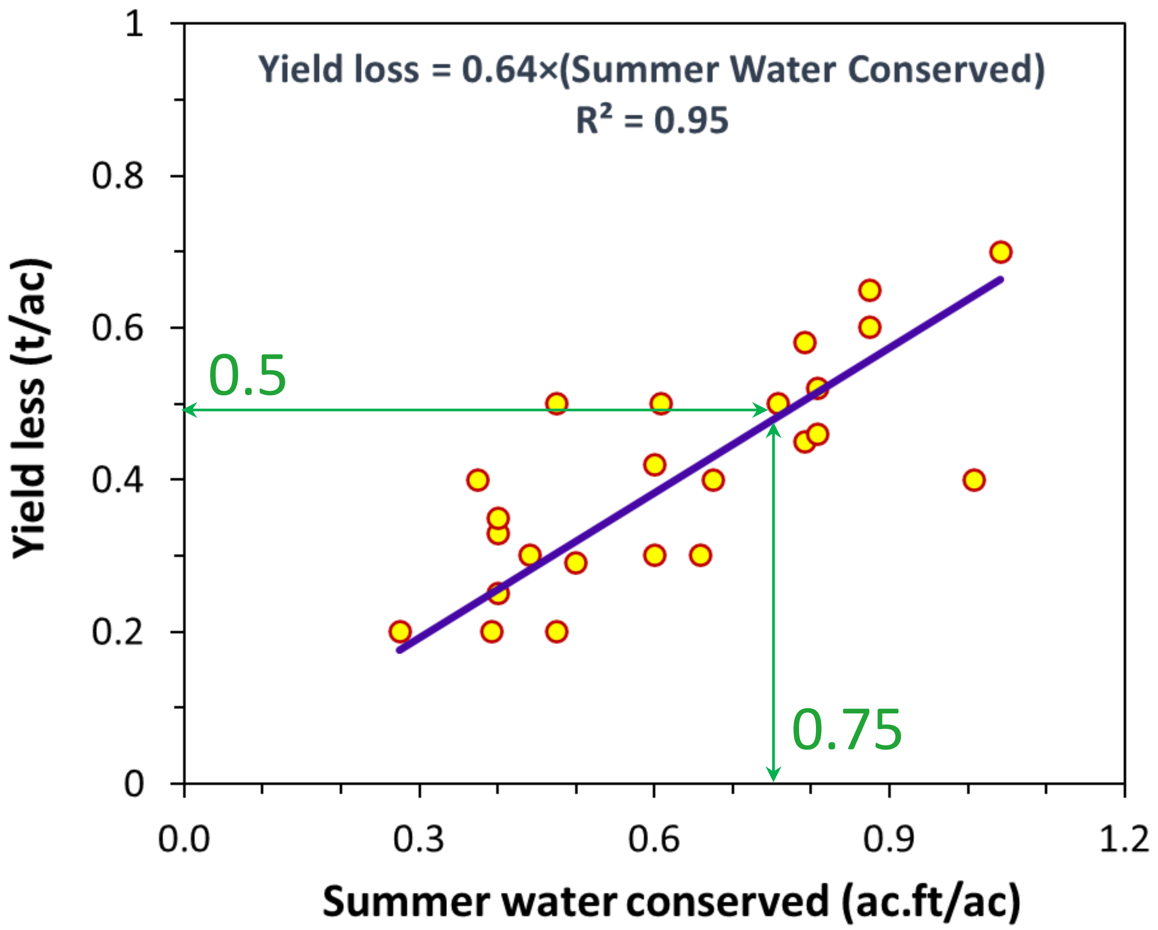
Plant stand evaluation

- No evidence of losing alfalfa plant density from the implemented deficit irrigation strategies (three seasons).

  (mean plant density was 2-5% different among the treatments at the same field … **no specific trend!**)

- No yield reduction was observed from summer deficit irrigation strategies within the first three harvest cuttings of the 2020 and 2021 seasons, indicating full recovery of the crop upon re-watering.

Yield loss as a function of summer water conserved



With skipping each irrigation event during the summer period, we may conserve an average of 0.34 ac-ft/ac.

Guideline 1

Moderate summer deficit irrigation in the Palo Verde alfalfa production system: I. Concepts, Definitions, and Impacts

Ali Montazar, Irrigation and Water Management Advisor, University of California Cooperative Extension Imperial and Riverside Counties, UC Division of Agriculture and Natural Resources

Water deficits in alfalfa

Alfalfa has unique drought tolerance mechanisms that make it biologically suited to deficit irrigation or reduced water supplies. The ability of alfalfa to sustain temporary droughts without significant stand loss is due to specific characteristics of deep roots, high water use efficiency, salinity tolerance, and ability to grant partial yields with less irrigation water applied than required amount. In the desert region, yield and plant stand losses, and soil water depletion due to water deficits can be considerable if one doesn't follow an optimal irrigation strategy.

With limited water supplies in the South-western U.S., deficit irrigation strategies in alfalfa can help farmers meet water conservation objectives. By following an optimal deficit irrigation strategy, a notable amount of water conserved with a low yield penalty and plant stand losses is achievable. As a general strategy, it is advisable to consider the seasonal production patterns of alfalfa and maximize production during early growth periods and allow water deficits during periods of relatively low yield and quality, e.g., the summer harvest cycles. Previous studies conducted, and observations reported by UC researchers indicate a partial-season irrigation, fully irrigate alfalfa field from the early season to the early summer and then cease irrigation partway through the season, could result significant yield and plant stand losses; and consequently, it doesn't appear to be an economically optimal scenario in the low desert.

Figure 1. An alfalfa field under furrow irrigation (top) and a close look of a healthy two-year hay alfalfa field (bottom) in the Palo Verde Valley.

Guideline 2

Moderate summer deficit irrigation in the Palo Verde alfalfa production system: II. Tools to implement and evaluate

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Moderate summer deficit irrigation

Moderate summer deficit irrigation proposes eliminating one to three irrigation events over the summer harvest cycles (July through September) in Palo Verde Valley, alfalfa production systems to reduce annual irrigation water use with minimal yield and stand loss.

How should the deficit irrigation strategy be implemented?

Deficit irrigation in alfalfa should be implemented during the summer harvest cycles, July through September, when crop water use efficiency and yields are lower compared to earlier in the season. Crop yields and stand loss resulting from summer water deficit practices will be minimized while hay quality will be maintained or slightly improved. This practice can be adopted for first-year hay alfalfa established during fall (typically October planted) and for any field at second year hay and/or older. The deficit irrigation approach should not be implemented before July.

After identifying an alfalfa field to implement summer deficit irrigation, one decides which parts (checks) of the field to apply the water saving strategy, or if the entire field will receive the practice. Head gates of the selected checks/or the entire field need to be kept closed for the irrigation events planned to be eliminated. It is recommended to skip the second irrigation event after each harvest. If the practice is

Figure 1. An alfalfa deficit irrigation trial in the Palo Verde Valley. Moderate summer deficit irrigation was started from July at this commercial site.

Thank You (Q & A)

Special Thanks to the Cooperating Farms
NRCS, CDFA, several commodity boards
(leafy greens, garlics and onions, carrots)