



Water Use of Lettuce: Balancing Yield and Water Quality

Michael Cahn, Arnett Young and Sharid Kamal,
UC Cooperative Extension, Monterey Co

Randal Hauptmann, Diego Celis, George
Thacher, FreshExpress



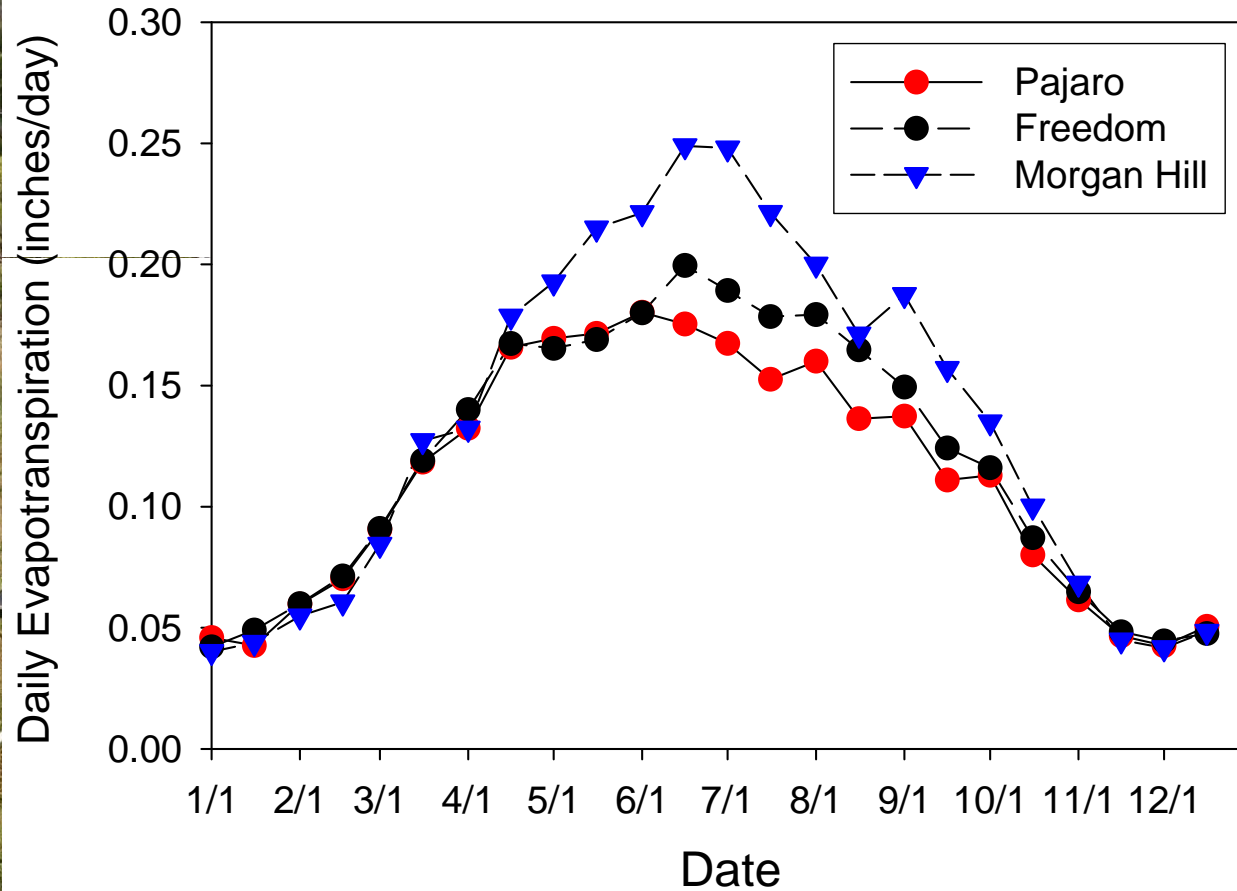
Improving Irrigation Scheduling

Are there opportunities to apply less water?

- Weather based scheduling
- Soil moisture monitoring
- Flow meter

Weather-based Irrigation Scheduling

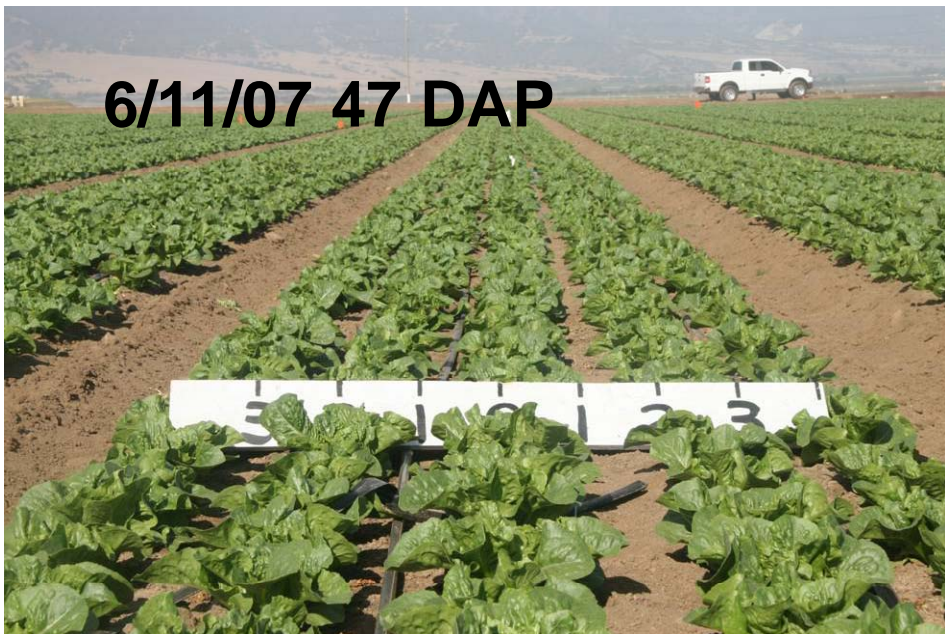
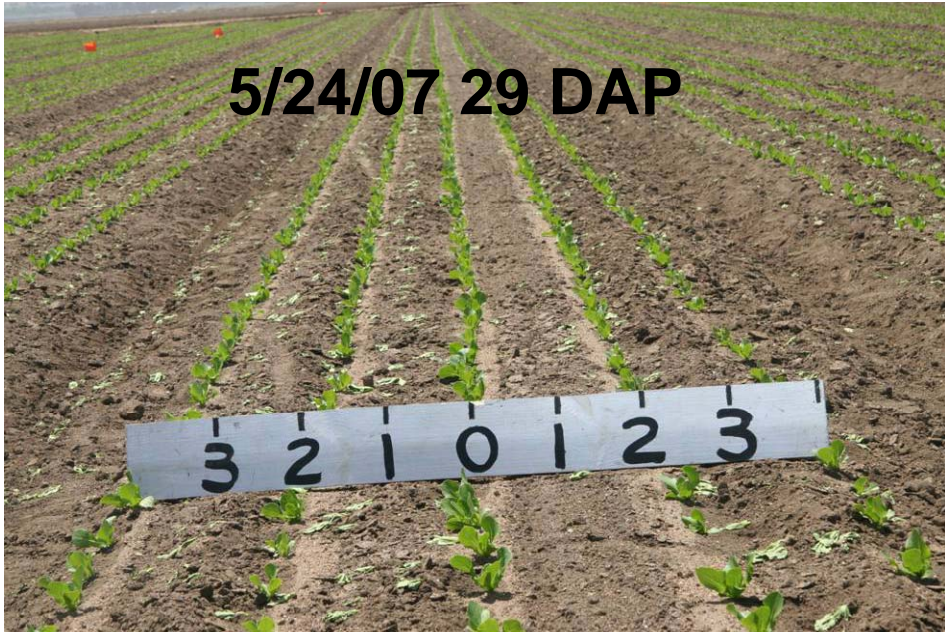
CIMIS weather network



Converting Reference ET to Crop ET:

$$ET_{\text{crop}} = ET_{\text{ref}} \times K_{\text{crop}}$$

K_c can vary from 0.1 to 1.2



Soil Moisture Monitoring

Watermark Block



Tensiometer



Capacitance Sensor



2007 Irrigation Management Trials: Romaine

- 10 irrigation field trials
- 2 trials with ET treatments
- 8 trials with cut-off treatments
- ET treatments: 75%, 100%, and 125% of ET_c
- Cut-off treatments: 1, 5, 10 days before harvest

2007 Irrigation Management Trials:

- **Randomized Complete Block design with 4 replications**
- **Plot size: 3, 80-inch beds x 100 ft**
- **Romaine variety: Greenforest**
- **Established with sprinklers, surface drip installed after thinning**
- **Monitored applied water, irrigation schedule, and soil moisture**
- **Evaluated yield for cut product**

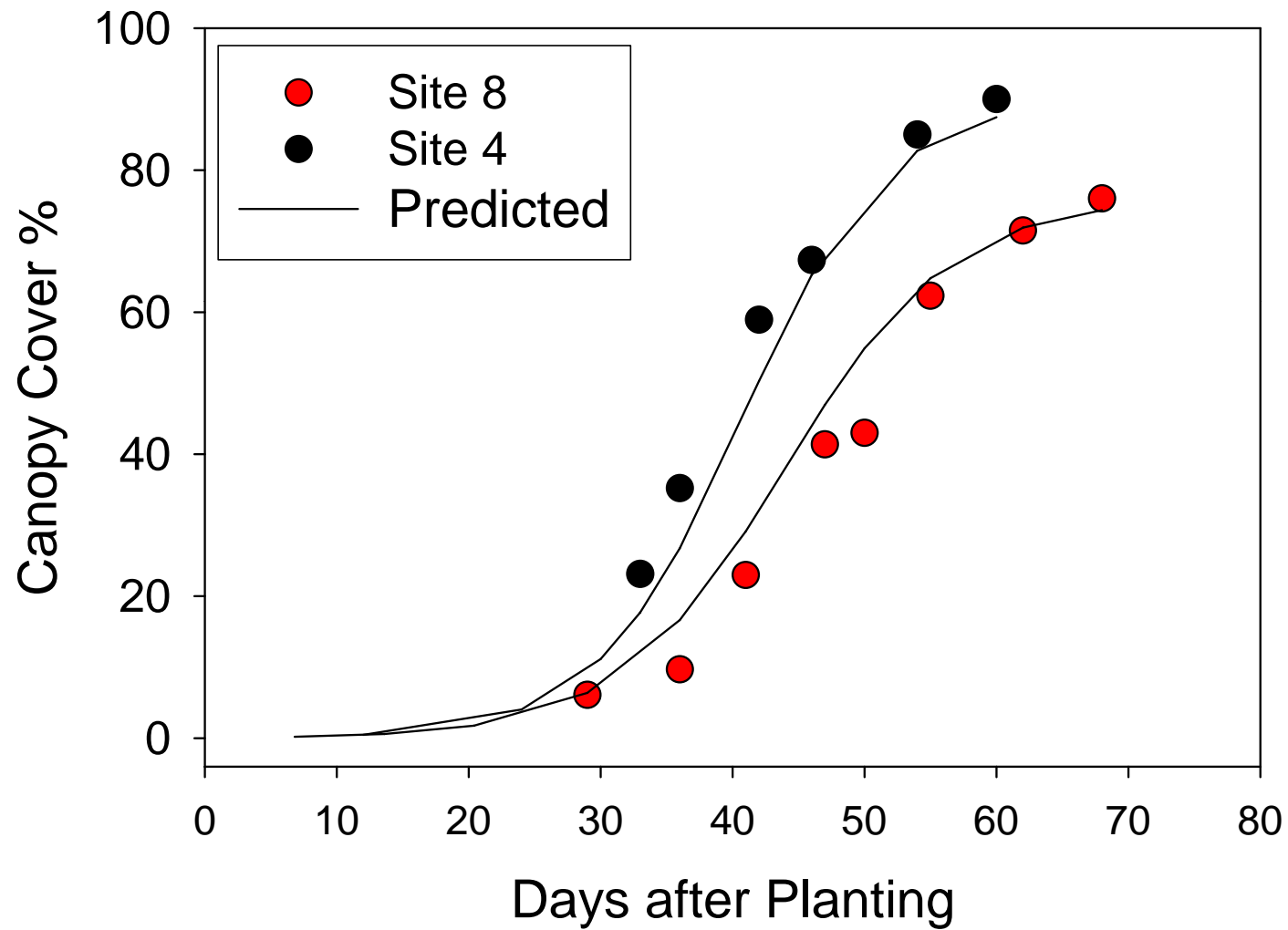
Trial Summary

Trial Number	Trial Type	Wet Date	Harvest Date	Days to Harvest
1	Cut-off	11-Jul	17-Sep	68
2	Cut-off	17-Apr	23-Jun	67
3	Cut-off	24-May	23-Jul	60
4	ET	24-May	23-Jul	60
5	Cut-off	23-May	28-Jul	66
6	Cut-off	20-Jun	23-Aug	64
7	Cut-off	16-Jun	17-Aug	62
8	ET	25-Apr	2-Jul	68
9	Cut-off	25-Apr	2-Jul	68
10	Cut-off	10-Jul	17-Sep	69

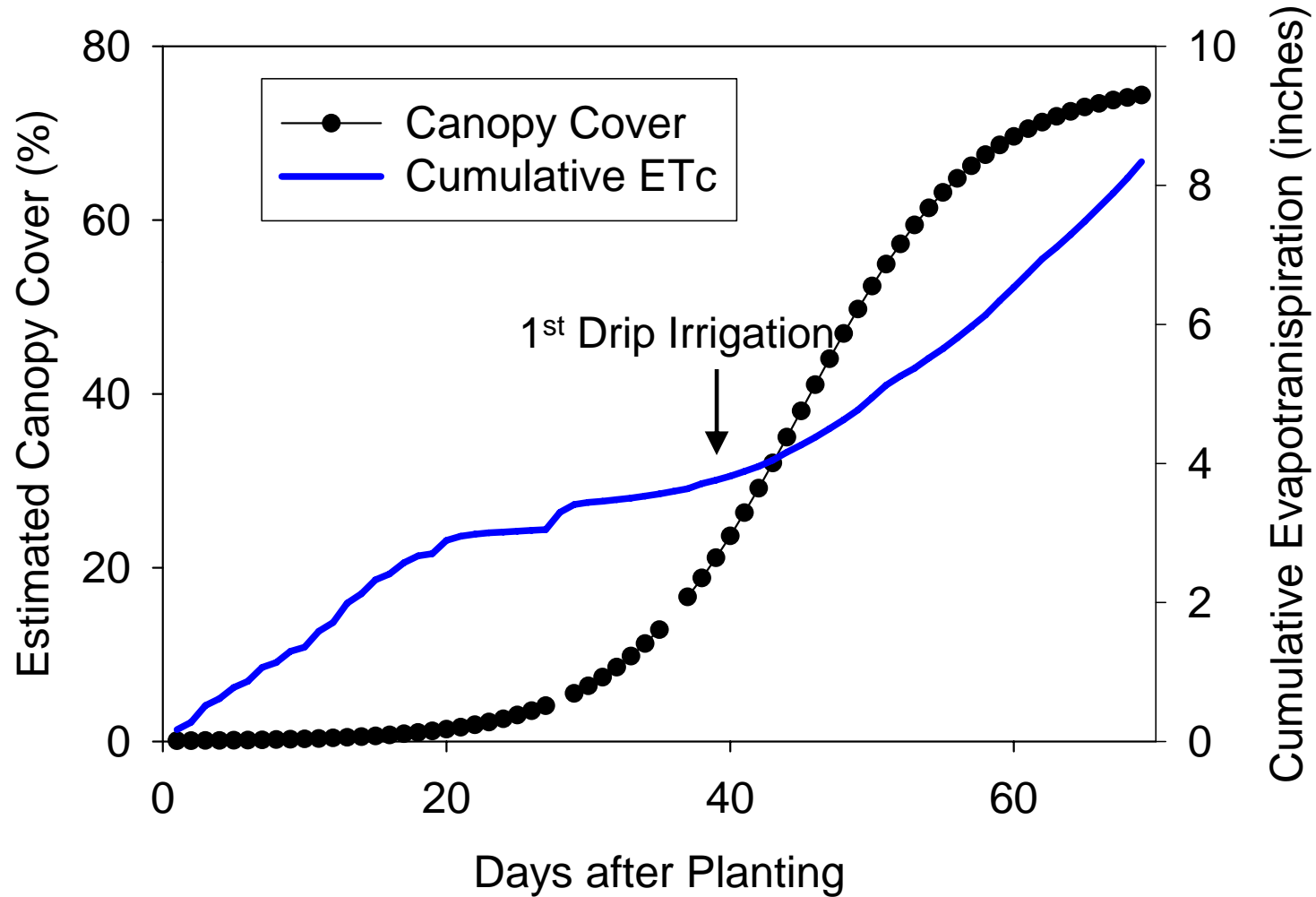
Soil Texture at Irrigation Trials

Trial	Soil texture	Particle Size Distribution			Soil Moisture Retention		
		Sand	Silt	Clay	30 cbar	100 cbar	500 cbar
		----- % -----			----- % H ₂ O -----		
1	Sandy Loam	59	21	20	15.9	12.0	9.0
2	Sandy Clay Loam	55	20	25	17.1	14.2	11.4
3 and 4	Loam	46	37	17	22.9	16.8	12.9
5	Sandy Clay Loam	51	25	24	22.6	17.0	12.8
6	Sandy Loam	63	21	16	15.1	11.7	8.8
7	Loam	53	28	19	20.0	14.9	11.0
8 and 9	Sandy Loam	75	15	10	10.1	7.7	5.8
10	Silty Clay Loam	13	48	39	34.1	26.9	22.9

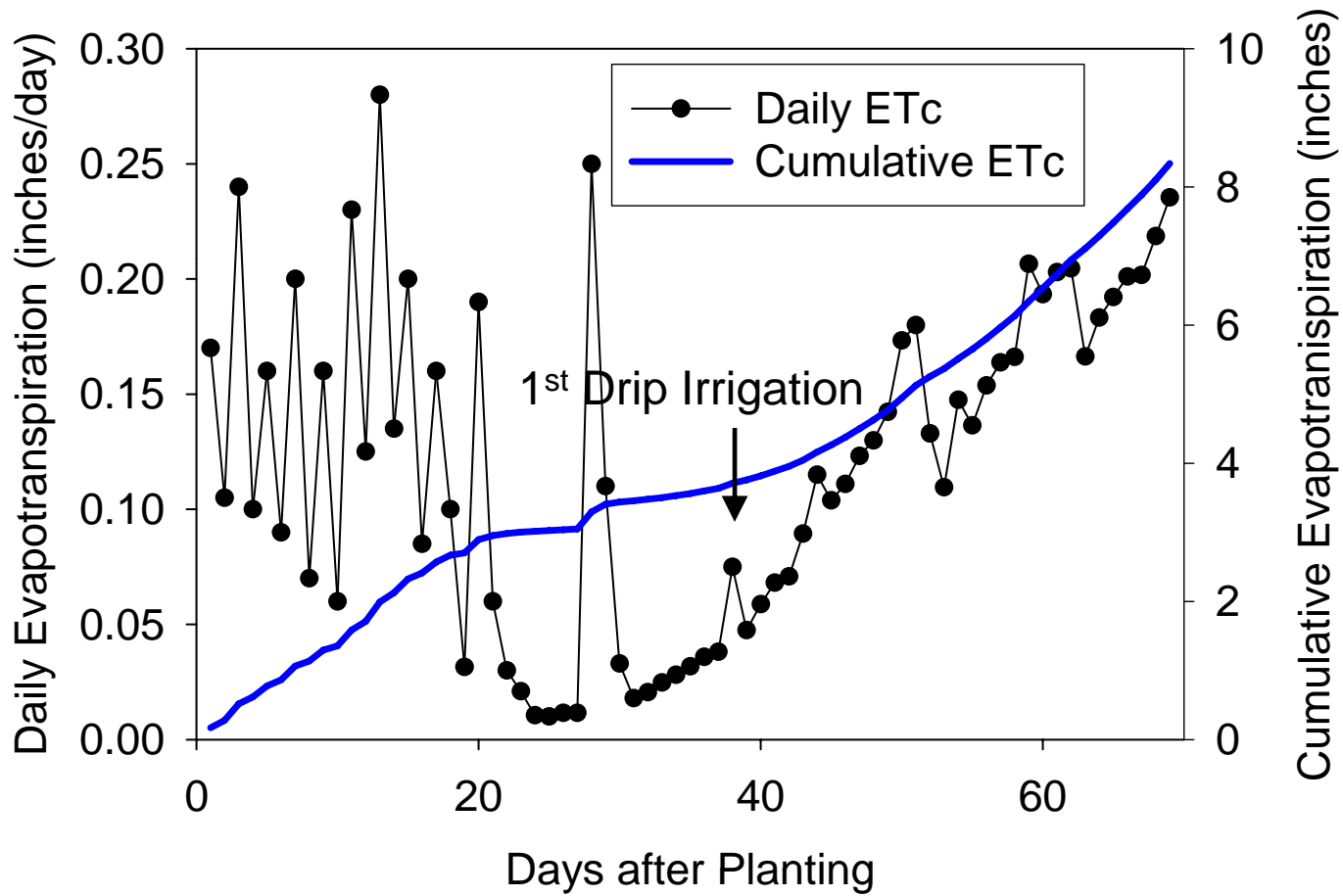
Canopy Cover at Trials 4 and 8



Cumulative Evapotranspiration and Canopy Cover for Romaine Lettuce (Trial 8)



Daily and Cumulative Evapotranspiration for Romaine Lettuce



Evapotranspiration of Romaine Lettuce (Summary of 8 sites)

Irrigation Method	Estimated Crop Evapotranspiration		
	Average	Maximum	Minimum
	----- inches -----		
Sprinkler ETc	1.9	3.3	1.4
Drip ETc	4.5	5.0	4.1
Total ETc	6.4	8.3	5.5

Irrigation Method	Applied Water			
	Average		Maximum	Minimum
	inches	% of ETc	----- inches -----	
Sprinkler Applied	9.1	475	13.2	5.1
Drip Applied	8.2	183	11.2	6.2
Total Applied Water	17.3	270	24.4	11.2

Irrigation Cut-off Trials

Applied Water vs Crop ET

(Average of 8 trials)

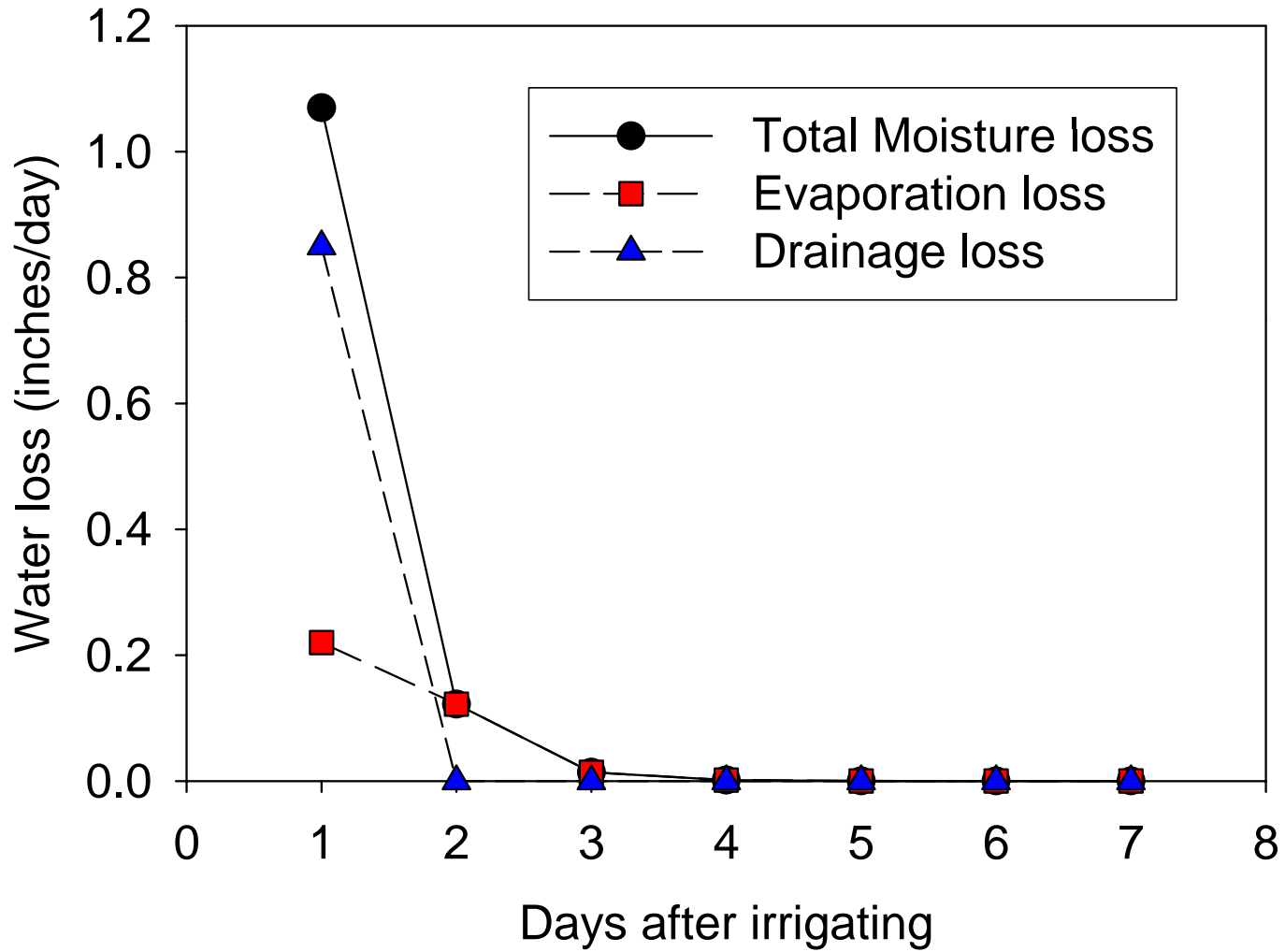
Irrigation Method/Treatment	Applied Water			
	Average inches	% of ET _c	Maximum ----- inches	Minimum -----
Sprinkler Applied	9.0	578	13.2	5.1
Drip Applied				
10 day cut-off	6.5	142	9.9	3.2
5 day cut-off	7.7	168	10.9	4.3
1 day cut-off	8.9	196	11.4	6.2
Total Applied Water	17.9	293	20.4	11.2

Applied Water vs Crop ET at Trial 8






Irrigation Method/Treatment	Applied	Estimated	Applied Water
	Water	Crop ET	as a Percentage of Crop ET
	----- inches -----		%
Total Applied Water (0-68 days) ^x	18.3	8.3	219
Sprinkler Applied (0-28 days)	13.2	3.3	400
Drip Applied (29 - 68 days)			
75% ETc treatment	3.3	5.0	65
100% ETc treatment	5.1	5.0	101
125% ETc treatment	7.5	5.0	148

^x based on 100% ETc treatment

Moisture Loss from 0-6 inch Soil Layer after Irrigating with Sprinklers (Trial 8)



Water Budget for ET Trials 4 and 8

Irrigation Source	Site 4	Site 8
	----- inches -----	
Total ETc	6.3	8.3
Sprinkler ETc	1.8	3.3
Drip ETc	4.5	5.0
Total Applied	10.4	18.2
Sprinkler applied	5.1 	13.2 
Drip applied	5.4	5.1
Sprinkler ETc + drainage	5.1 	11.8
Sprinkler drainage	3.4 	8.5 
Total ETc + Sprinkler drainage	9.6	16.8

Irrigation Treatment Effects on Crop Yield



Yield Effects of ET Treatments (Average of 2 Trials)

Treatment	Marketable Yield	Marketable Dry Matter Yield	Biomass Yield	Dry Matter Content	Whole Plant Weight	Trimmed Plant Weight
	-----	tons/acre	-----	%	-----	kg/plant
75% ET _c	10.3	0.71	25.8	6.91	0.65	0.27
100% ET _c	12.3	0.72	30.4	5.90	0.74	0.31
125% ET _c	13.1	0.72	33.4	5.61	0.83	0.32
LSD _{0.05}	1.2	NS	2.1	0.40	0.05	0.03

Yield Effects of Cut-off Treatments (Average of 7 Trials)

Treatment	Marketable Yield	Marketable Dry Matter Yield	Biomass Yield	Dry Matter Content	Whole Plant Weight	Trimmed Plant Weight
	----- tons/acre -----			%	----- kg/plant -----	
10 day-cutoff	11.5	0.72	28.1	6.38	0.72	0.31
5 day-cutoff	13.3	0.70	33.0	5.41	0.84	0.35
1 day-cutoff ^x	14.7	0.72	35.1	4.92	0.89	0.38
LSD _{0.05}	0.8	NS	1.3	0.25	0.03	0.02

Irrigation Treatments Effects on Final Stand

Treatment	Preharvest head count	Preharvest diseased head count	Post-harvest head count	Harvested heads
	----- plants/acre -----			
75% ET _c	36901	343	1002	35899
100% ET _c	37244	327	556	36689
125% ET _c	37358	458	752	36607
LSD _{0.05}	NS	NS	NS	NS

Treatment	Preharvest head count	Preharvest diseased head count	Post-harvest head count	Harvested heads
	----- plants/acre -----			
10 day-cutoff	37673	387	1480	36194
5 day-cutoff	37683	308	1218	36465
1 day-cutoff	37603	336	929	36674
LSD _{0.05}	NS	NS	343	NS

Cut-off Treatment Effects on Soil Moisture Near Harvest

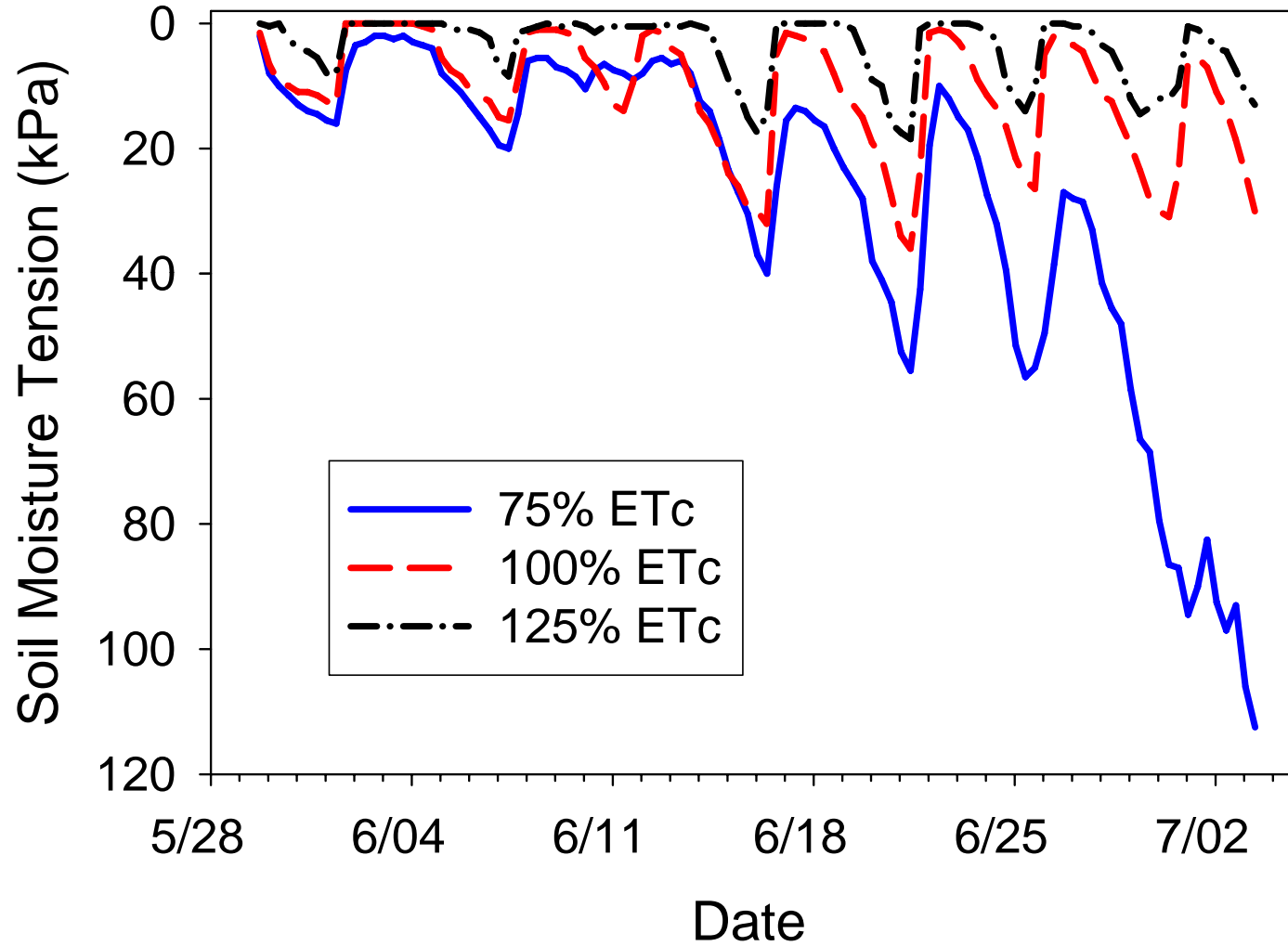
Treatment Description	Volumetric Soil Moisture		Soil Moisture
	Neutron probe --- % volumetric moisture --- ----- cut-off treatment -----	Theta-probe	Tension ^x cbar
10 day cut-off	16.4	17.5	42.3
5 day cut-off	19.7	19.6	22.6
1 day cut-off	20.3	23.1	13.0

^x high values indicate low soil moisture

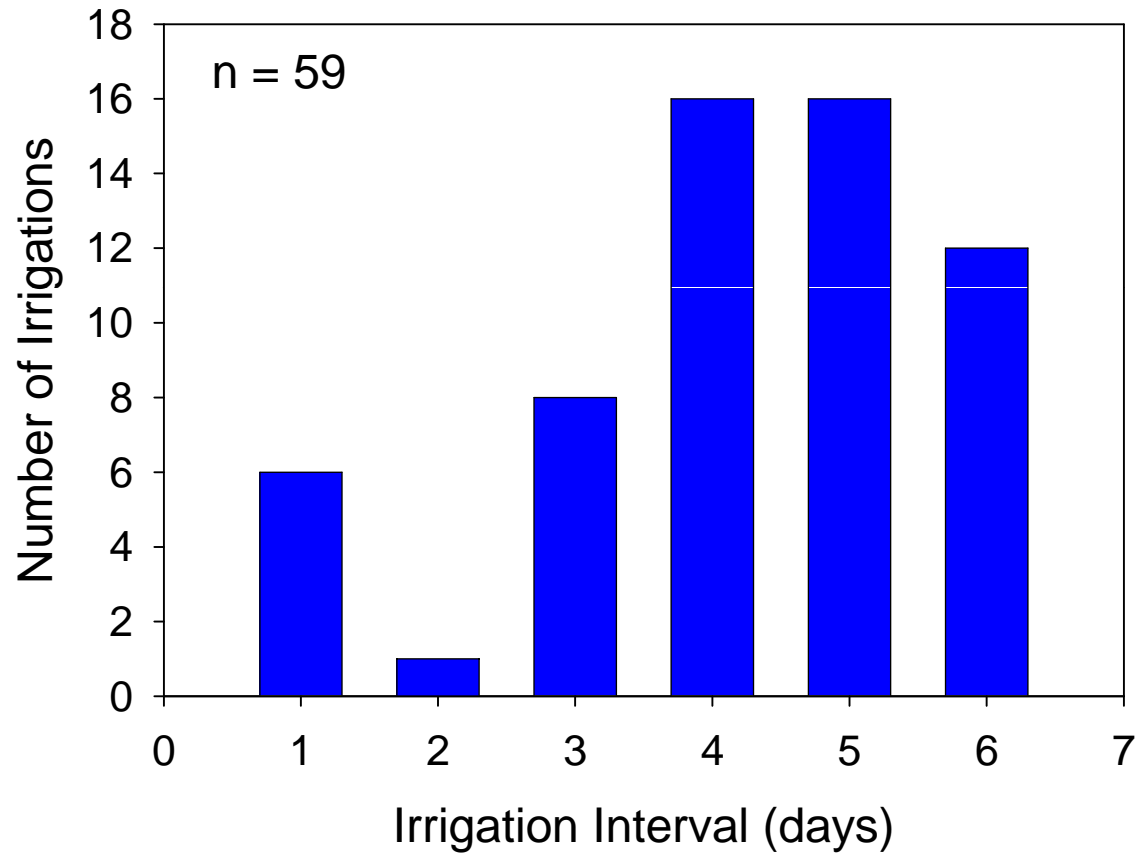
Irrigation Treatment Effects on Soil Moisture



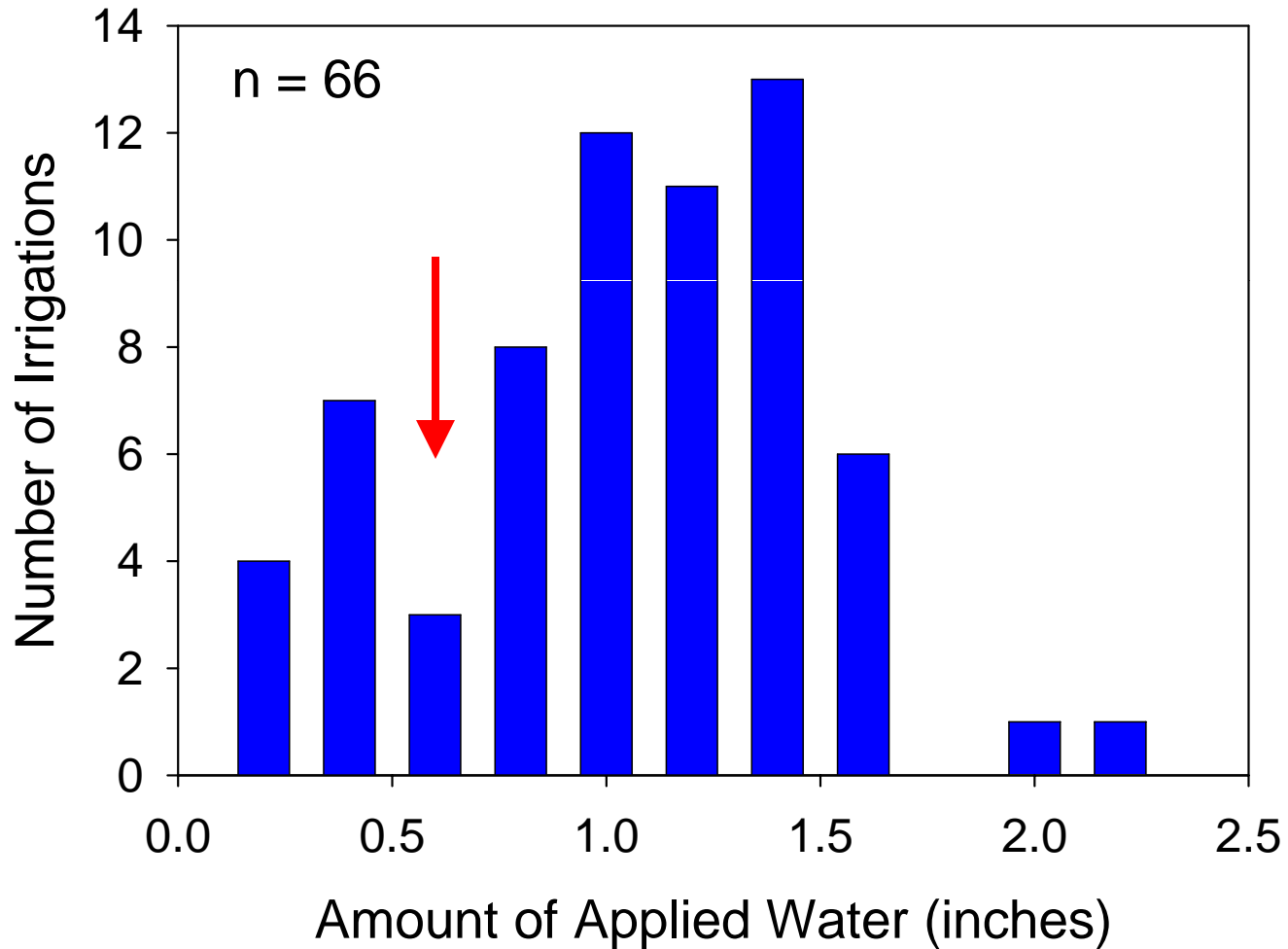
ET Treatment Effects on Soil Moisture Tension (Trial 8)



Intervals between Drip Irrigations



Amount of Water Applied per Irrigation (Drip)



Summary: Opportunities for Improving Irrigation Management

Stand establishment (sprinklers)

- Applied water was much greater than estimated Crop ET (200% – 400% of ET)
- Drainage from sprinkler irrigations was a major loss of applied water.

After thinning (drip)

- Applied water was usually greater than estimated crop ET (~180%)
- Highest yields were found at lowest soil moisture tensions (< 15 cbars)
- Highest yields were associated with highest rates of applied water which may indicate that the intervals between irrigations are too long (4 – 6 days)

Thank you !