

SALINITY MANAGEMENT IN PROCESSING TOMATOES

Brenna Aegerter and
Michelle Leinfelder-Miles
UC Cooperative Extension
San Joaquin County

WHERE DO SALTS COME FROM?

- Irrigation water is the primary source of salts in agricultural systems
- Also from fertilizers, manures, composts
- Shallow saline water tables
- Salts can accumulate in the root zone and damage crops

WHAT SALTS ARE IN THE WATER?

- Sodium (Na^+)
- Calcium (Ca^{2+})
- Magnesium (Mg^{2+})

Cations

- Chloride (Cl^-)
- Sulfate (SO_4^{2-})
- Bicarbonate (HCO_3^-)

Anions

Boron (B), Carbonate (CO_3^{2-}), Nitrate (NO_3^-), Potassium (K^+)

HOW IS SALINITY MEASURED?



Electrical Conductivity (EC)

EC_w = salinity of the water

EC_e = salinity of the soil

Total Dissolved Solids (TDS)

mg/L = ppm

Exchangeable Sodium Percentage (ESP): % of soil cation exchange sites occupied by sodium

Sodium adsorption ratio (SAR): a ratio of Na, Ca and Mg concentrations



HOW DOES SALT EFFECT PLANTS?

A wide-angle photograph of a lush green agricultural field, likely a vegetable or fruit crop, stretching to a flat horizon under a bright blue sky with scattered white clouds. The foreground shows rows of plants with some soil visible between them.

Overall salinity causes osmotic stress

Specific ion toxicity (Na, Cl, B)

Physical changes to the soil; water infiltration problems

HOW DOES SALT EFFECT PLANTS?

Overall salinity → Osmotic stress

- High salt restricts osmotic flow
 - more energy used to exclude salt in the root zone and take in water
- Water stress symptoms
 - Stunting
 - Reduced yields

SALINITY VS SODICITY

- Salinity is a condition where the salt concentration is sufficiently high to reduce crops yields or quality (Electrical conductivity, EC)
- Sodicity is a condition where the water is dominated by sodium (Na^+); affects soil structure; poor aeration; water infiltration; affects plant health (measured as Sodium Adsorption Ratio, SAR; or Exchangeable Sodium Percentage, ESP)

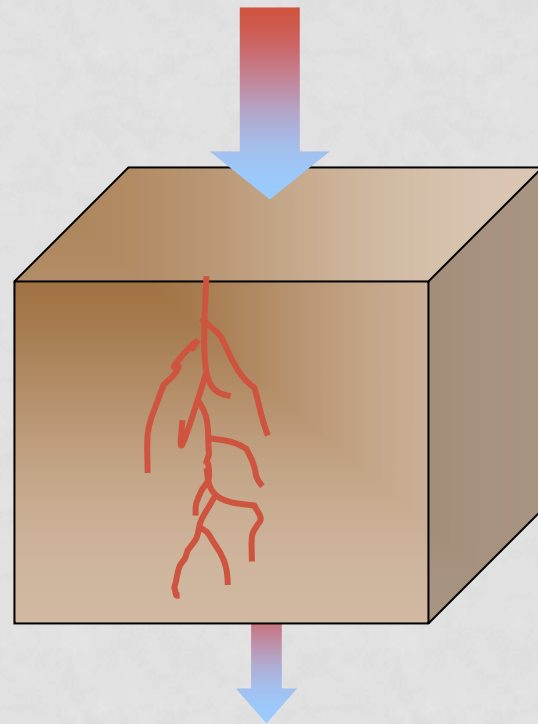
SAR & EC_w TOGETHER AFFECT PERMEABILITY

Permeability	No Problem	Increasing Problem	Severe Problem
SAR = 0-3 & EC _w =	> 0.7	0.7 – 0.2	< 0.2
SAR = 3-6 & EC _w =	> 1.2	1.2 – 0.3	< 0.3
SAR = 6-12 & EC _w =	> 1.9	1.9 – 0.5	< 0.5
SAR = 12-20 & EC _w =	> 2.9	2.9 – 1.3	< 1.3
SAR = 20-40 & EC _w =	> 5.0	5.0 – 2.9	< 2.9

SALINITY MANAGEMENT

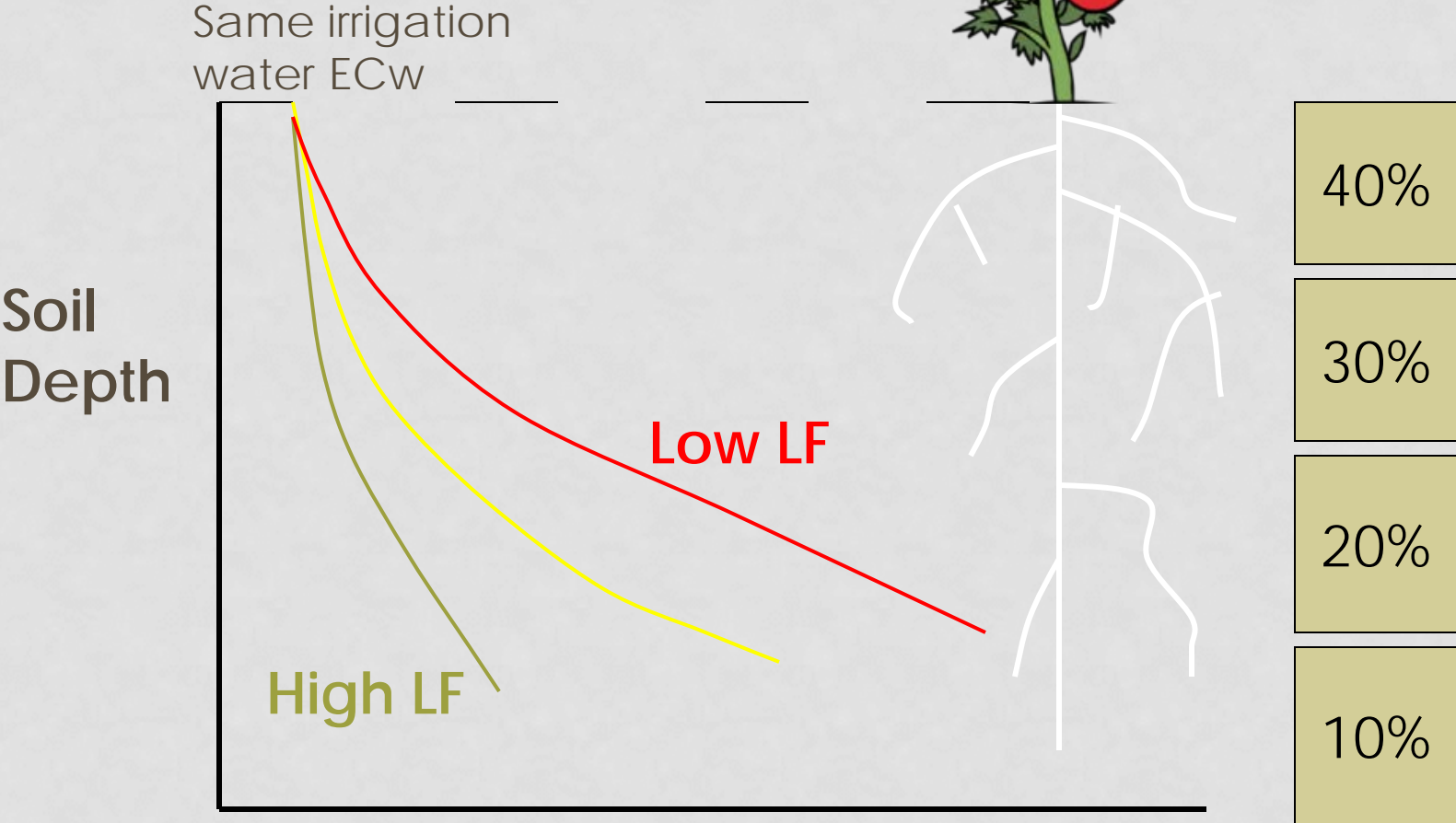
Leaching Fraction
(LF) = volume of
water that drains
below the rootzone
/ volume of water
that infiltrates the
ground

Amount of water applied



Amount of water drained

Salinity distribution in relation to various leaching fractions



EC_e →

AMENDMENTS

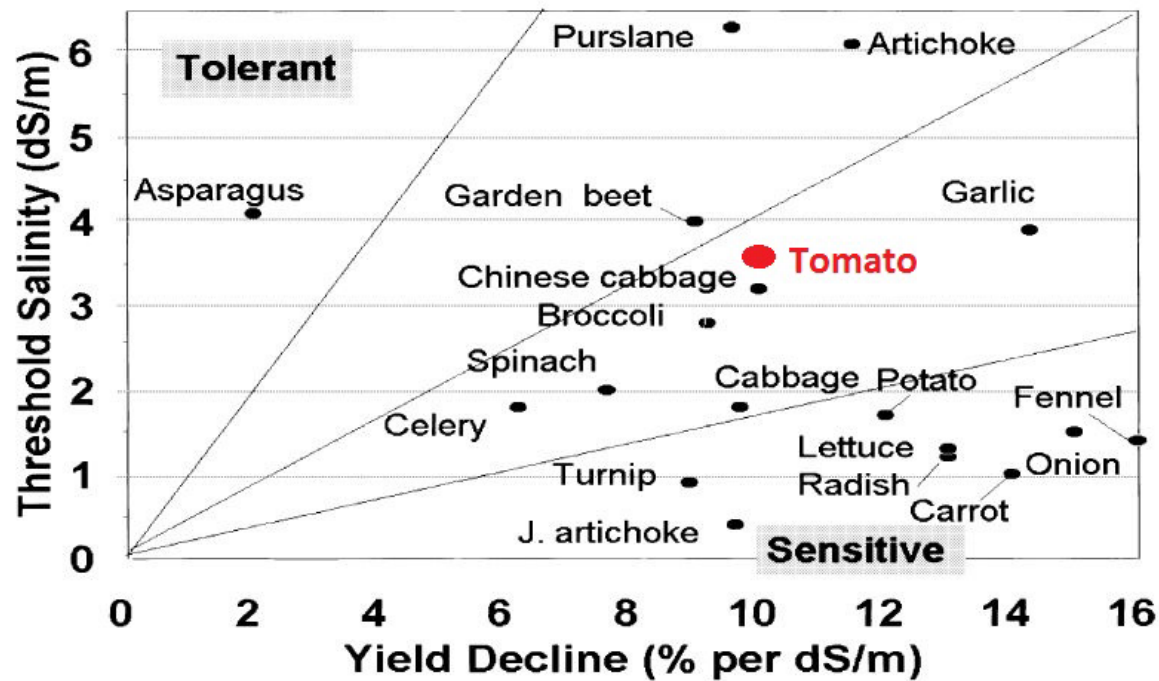
- Gypsum (CaSO_4)
- Sulfuric Acid (H_2SO_4)
 - In soils containing lime (CaCO_3)

Calcium

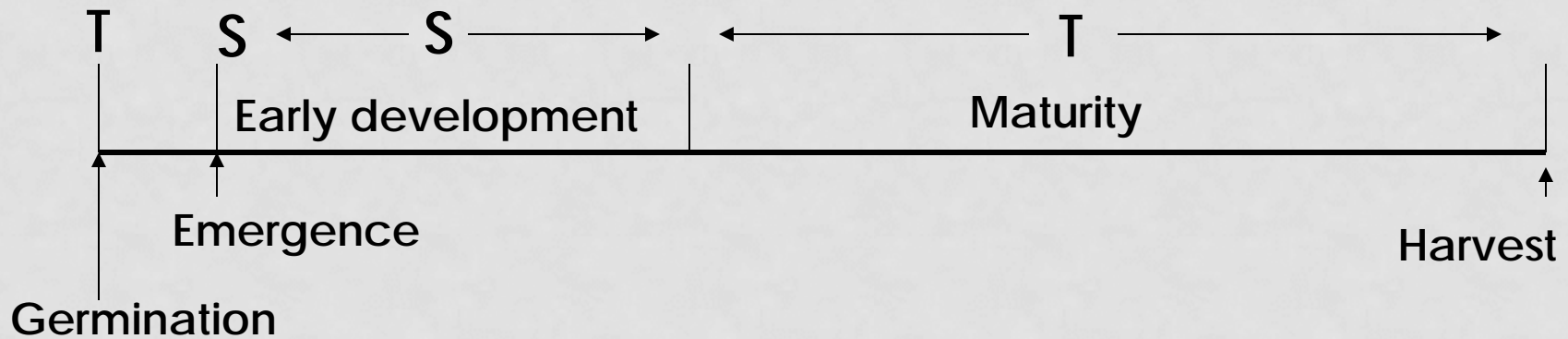
- Improves soil aggregation & structure
- Improves root function & ion transport across membranes
- Plants can tolerate higher ECe (+ 1-3 dS/m) in soils with high levels of gypsum

TOMATOES ARE MODERATELY SENSITIVE TO SALINITY

M.C. Shannon, C.M. Grieve/Scientia Horticulturae 78 (1999) 5–38

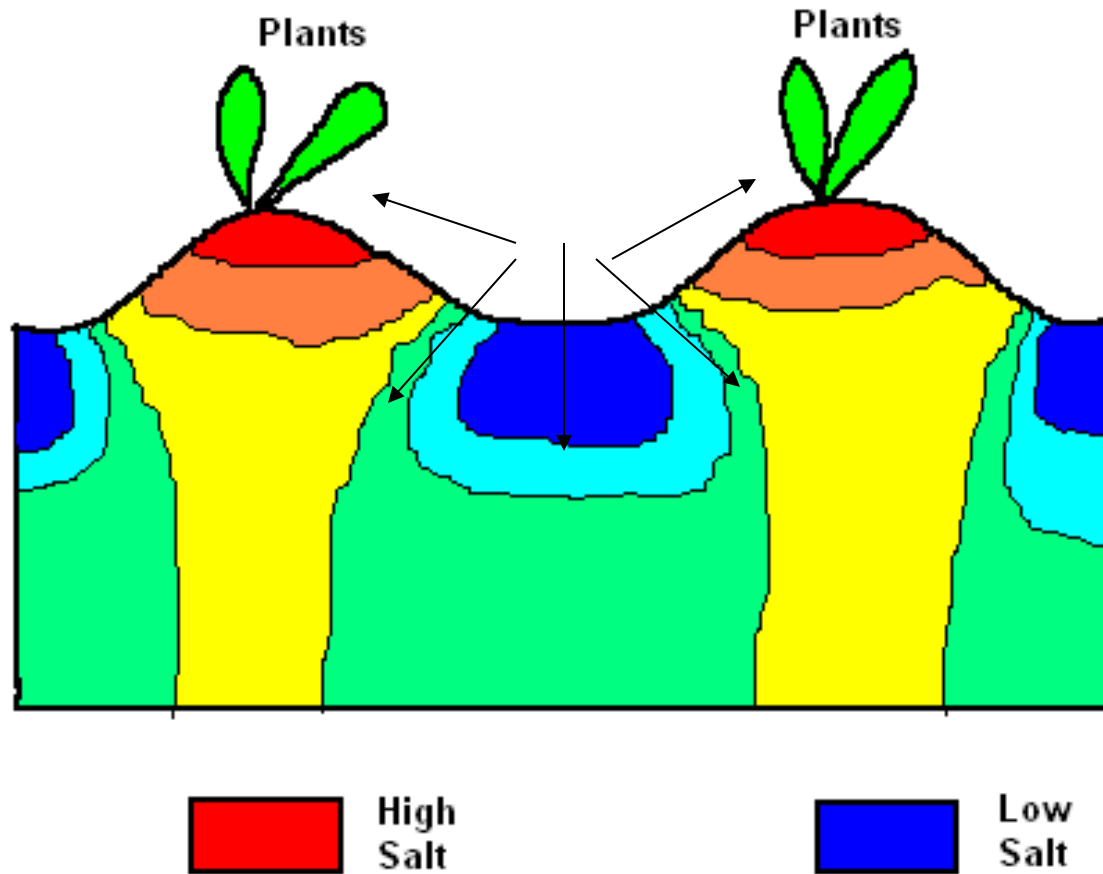


Crop Sensitivity to Salinity in Relation to Stage of Growth

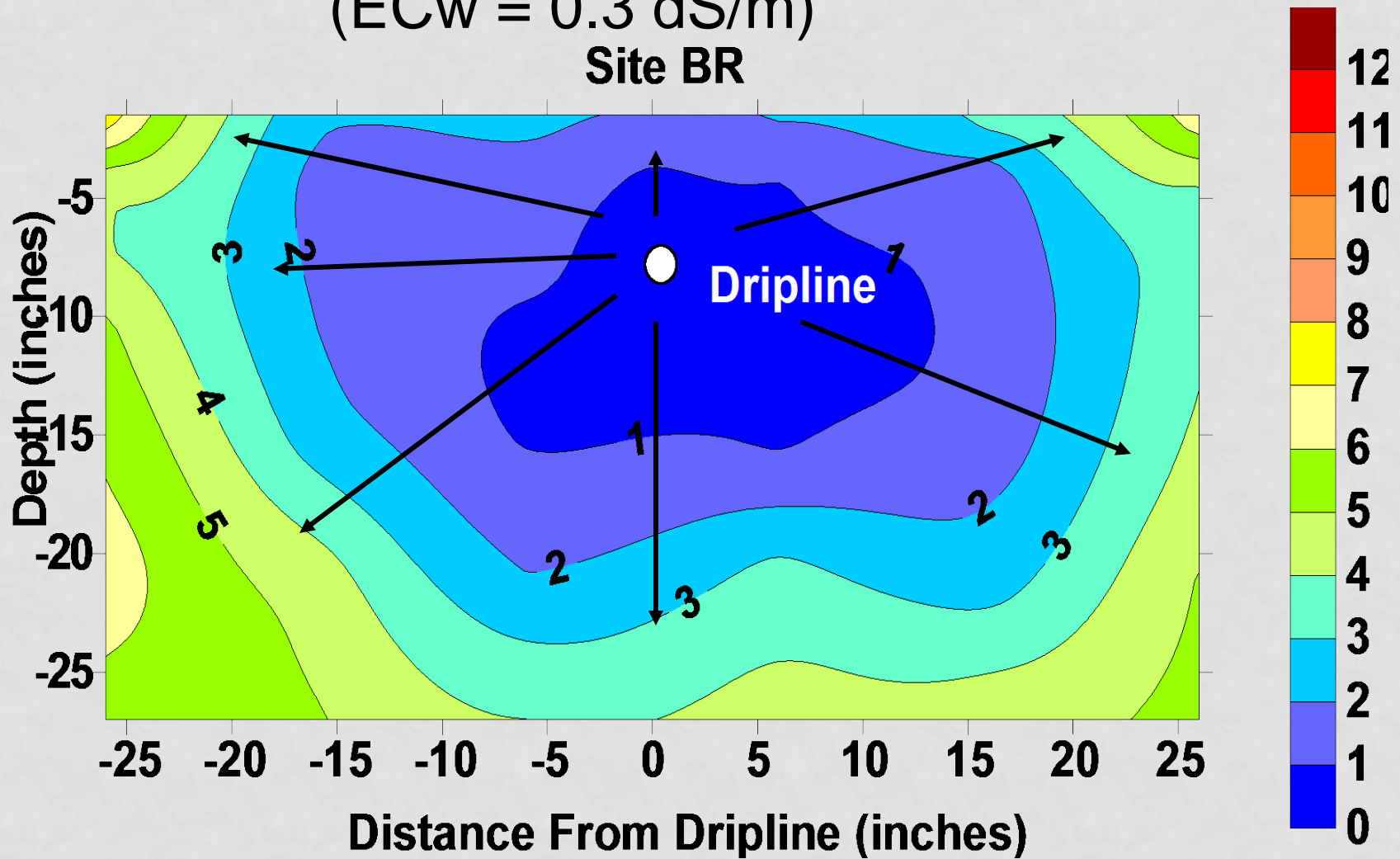


After Maas and Grattan, 1999

FURROW IRRIGATION



Salt pattern under drip irrigation ($EC_w = 0.3$ dS/m) Site BR



Soil salinity around the drip line for water depth of about

(A) 6 feet, $EC_w = 0.3$ dS/m, EC

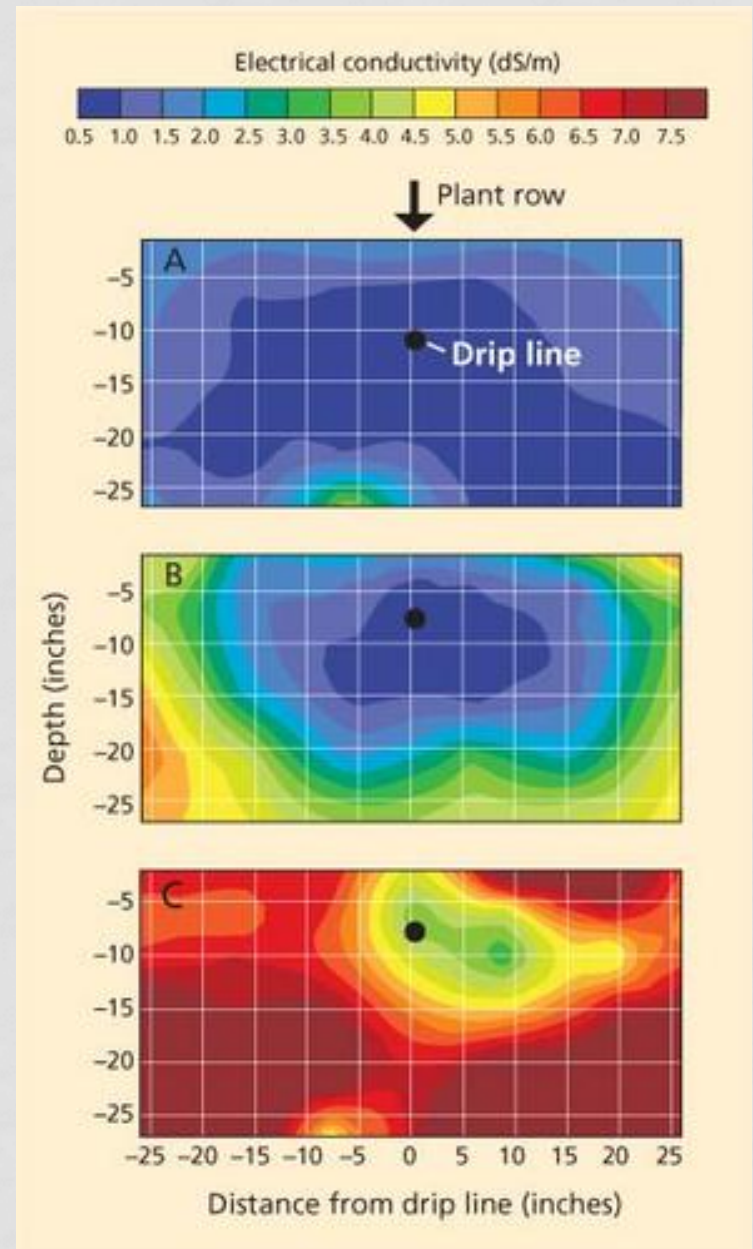
groundwater = 8 to 11 dS/m;

(B) 2 to 3 feet, $EC_w = 0.3$ dS/m, EC

groundwater = 5 to 7 dS/m

(C) 2 to 3 feet, $EC_w = 1.1$ dS/m, EC

groundwater = 9 to 16 dS/m



PROCEDURES

Two commercial field sites in the Delta region

- Furrow irrigated field
- Drip irrigated field (2014 was second year)
 - Grower's schedule
 - Full irrigation in the early season followed by a deficit irrigation strategy

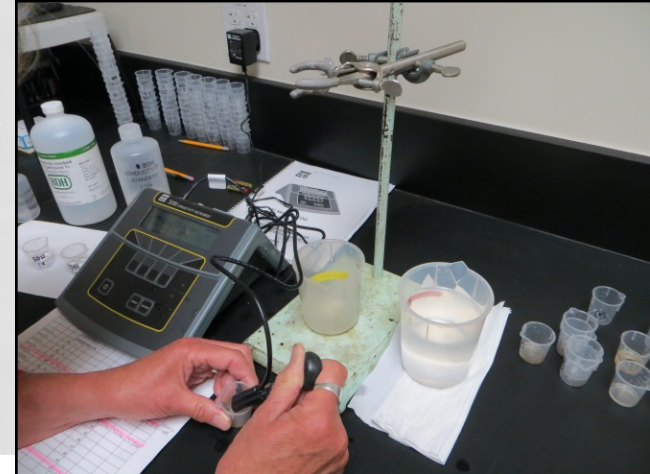
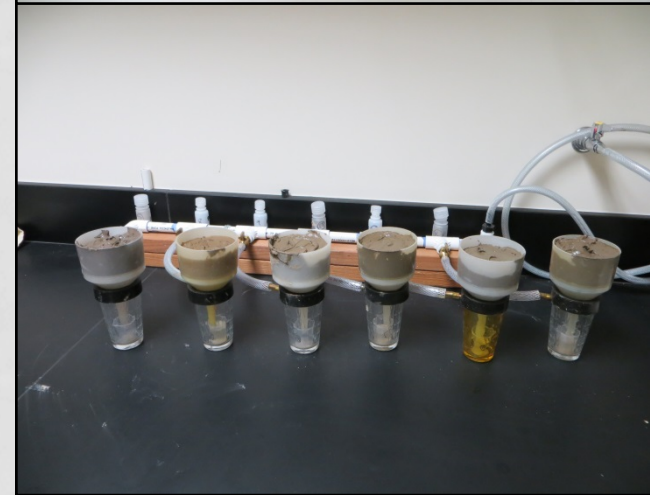
Both sites were transplanted with 60" bed configuration with single plant rows

Both sites sourced water from Middle River near Howard Road bridge, soils of both are categorized as Egbert series

PROCEDURES

Measurements:

- Fruit yield and quality
- Applied water volumes (drip field)
- Groundwater salinity
- Depth to water table
- Irrigation water salinity
- Soil salinity

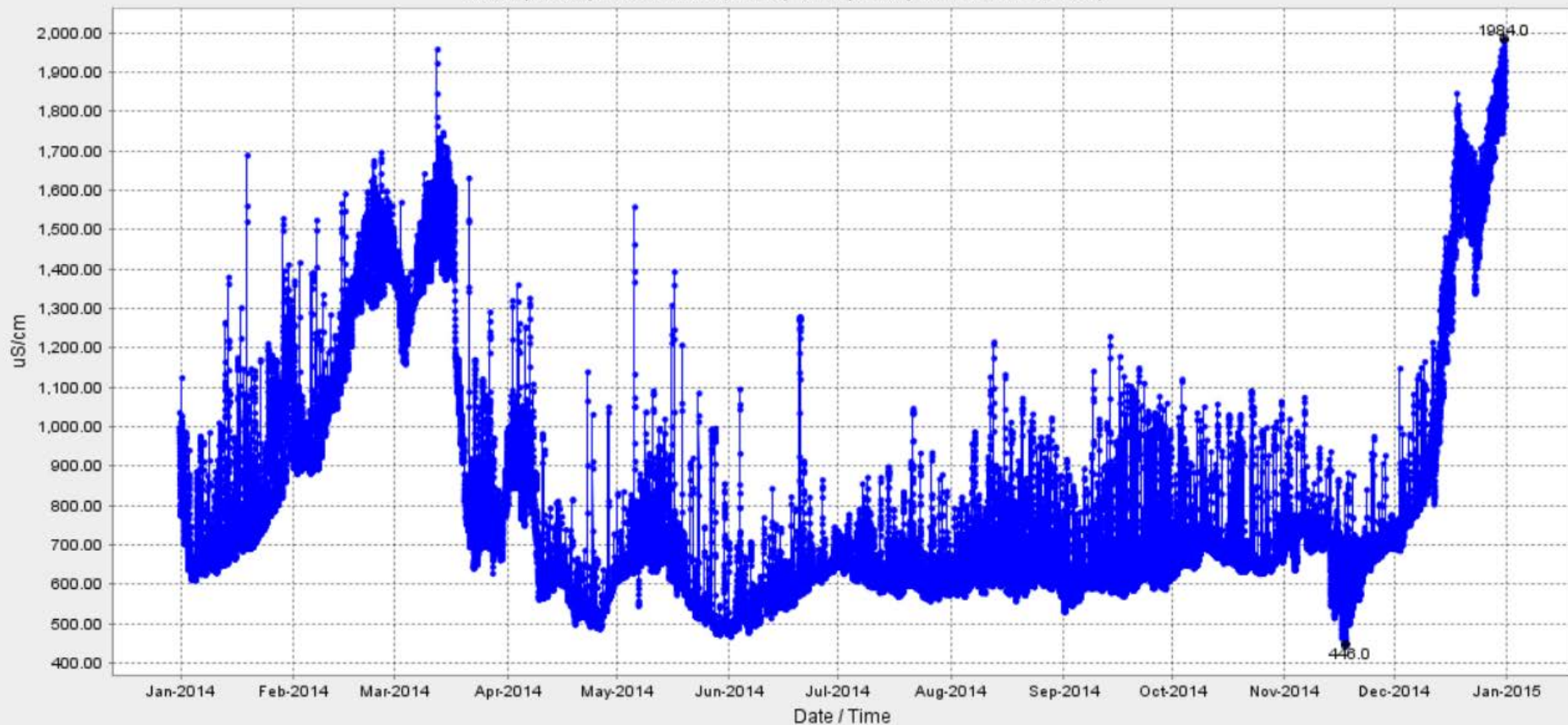


EC_W VARIES OVER THE SEASON

MIDDLE RIVER NEAR HOWARD ROAD BRIDGE (MHO)

Date from 12/31/2013 12:00 through 12/31/2014 12:00 Duration : 365 days

Max of period : (12/31/2014 04:45, 1984.0) Min of period : (11/17/2014 12:15, 446.0)

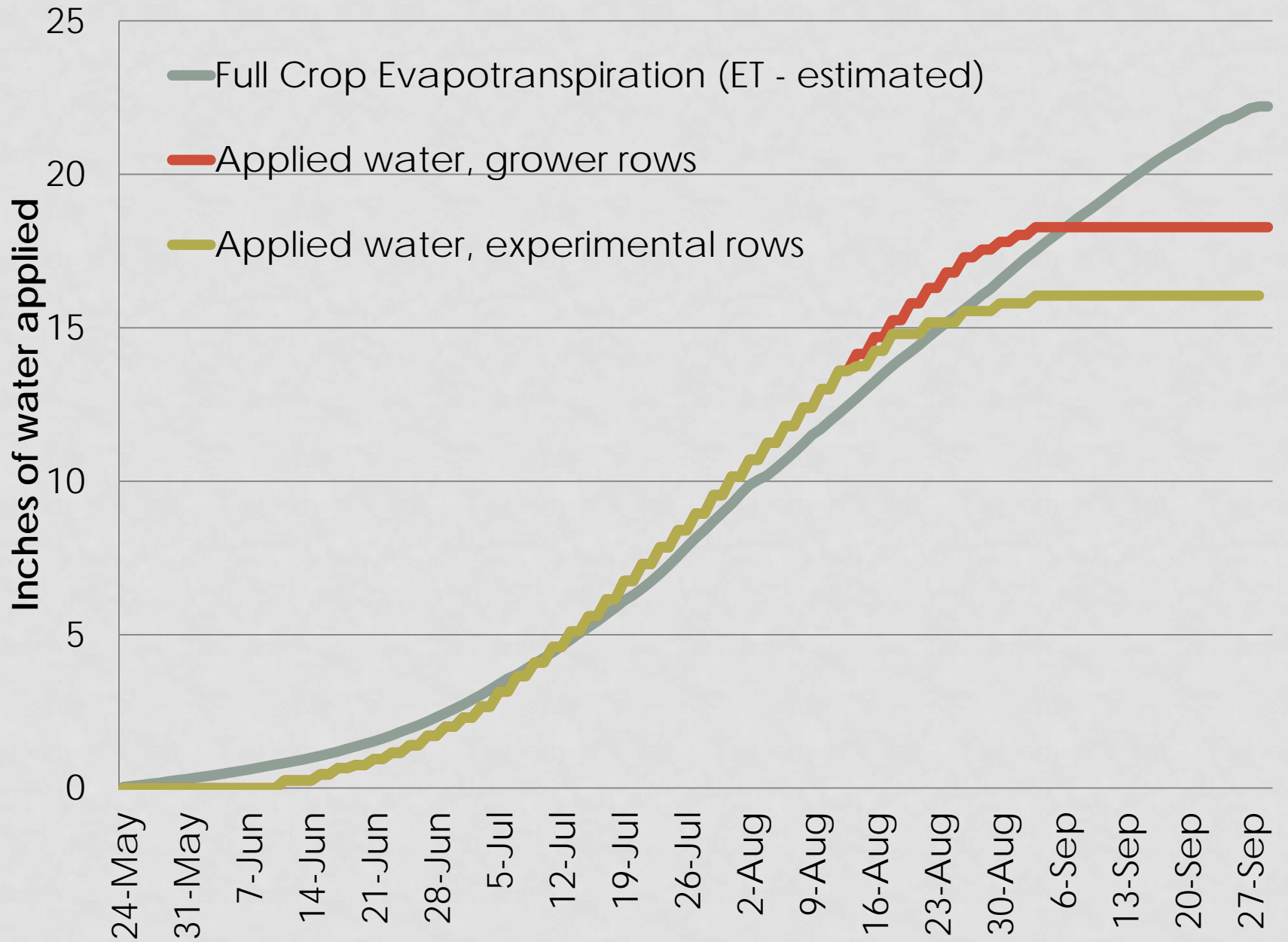






DRIP-IRRIGATED FIELD

- Soil sampled on May 13 after pre-irrigation
- Transplanted to UG 19406 on May 23
- Irrigation cutbacks initiated on Aug. 14, 7 weeks before harvest
- Soil sampled and harvested on Sept 29-30
- EC of irrigation water averaged 0.6 dS/m



WATER BALANCE, DRIP FIELD

	Grower irrigation program	Experimental irrigation program
Stored soil moisture (inches in top 3 ft)		
Soil moisture at transplanting	17.6	17.3
Soil moisture at harvest	14.9	13.0
Stored soil moisture used	2.7"	4.3"
Irrigation water applied via drip system*	18.3"	16.0"
Consumptive water use (stored plus applied)	21.0"	20.3"
Estimated full crop ET**	22.2"	22.2"

* does not include one pre-irrigation, which is captured by the soil moisture measurements.

** Estimate based on 2014 CIMIS data and crop coefficients of Hanson & May (2006).

YIELD AND FRUIT QUALITY

Irrigation Program	Yield (tons/acre)	Soluble solids (°Brix)	PTAB color	pH
Grower irrigation program	53.7	5.15	22.5	4.23
Experimental irrigation program	58.0	5.30	23.5	4.23

Drip field - Electrical Conductivity (dS/m)

Pre-transplant May 13, 2014

Harvest Sept 29, 2014

Change in EC from spring to fall 2014

Deficit irrigation row

	BED CENTER						FURROW	
depth	↓						↓	
0 - 4"	1.75	1.62	1.33	1.60	1.65	1.86		
4 - 8"	1.43	1.16	1.03	1.20	1.57	1.47	1.39	1.07
8 - 12"	1.44	1.12	1.42	1.25	1.20	1.32	1.43	1.05
12 - 16"	1.3	1.32	1.33	0.98	1.00	1.08	0.94	0.96
16 - 20"	1.27	1.14	0.94	0.98	1.19	0.98	1.03	0.96
20 - 24"	1.26	1.08	1.14	1.14	1.01	1.24	1.02	0.93
24 - 28"	0.92	1.26	1.29	1.19	1.48	1.05	1.33	0.98
28 - 32"	1.55	1.23	1.32	1.35	1.53	1.18	1.39	1.14
32 - 36"	1.13	1.17	1.13	1.17	1.10	1.05	1.05	1.25
36 - 40"	1.13	1.27	1.28	1.14	1.16	1.30	1.17	1.14

	BED CENTER						FURROW	
depth	↓						↓	
0 - 4"	2.80	3.73	2.41	2.24	2.81	5.12		
4 - 8"	1.74	1.42	1.39	1.29	1.2	1.54	5.09	3.69
8 - 12"	1.12	0.96	0.94	0.89	1.18	1.06	1.13	1.19
12 - 16"	0.82	0.74	0.79	0.87	1.03	1.06	0.93	0.84
16 - 20"	0.61	0.85	0.73	0.78	0.82	0.89	1.50	0.92
20 - 24"	0.91	0.85	1.14	0.80	0.80	1.03	1.45	0.86
24 - 28"	0.72	0.94	0.95	0.90	0.95	1.52	0.92	1.18
28 - 32"	0.97	1.13	1.14	1.20	1.33	1.14	1.04	1.03
32 - 36"	0.94	1.14	1.36	1.75	1.58	1.41	1.41	1.46
36 - 40"	1.13	1.26	1.70	1.46	1.26	1.22	1.54	1.24

	BED CENTER						FURROW	
depth	↓						↓	
0 - 4"	1.05	2.11	1.08	0.65	1.16	3.26		
4 - 8"	0.31	0.26	0.37	0.09	-0.36	0.07	3.70	2.62
8 - 12"	-0.32	-0.16	-0.49	-0.37	-0.02	-0.26	-0.30	0.15
12 - 16"	-0.48	-0.59	-0.54	-0.10	0.03	-0.02	-0.01	-0.12
16 - 20"	-0.66	-0.29	-0.21	-0.20	-0.37	-0.09	0.47	-0.04
20 - 24"	-0.35	-0.23	0.00	-0.34	-0.21	-0.21	0.43	-0.06
24 - 28"	-0.20	-0.32	-0.34	-0.30	-0.53	0.47	-0.41	0.20
28 - 32"	-0.58	-0.11	-0.19	-0.16	-0.20	-0.05	-0.35	-0.11
32 - 36"	-0.19	-0.03	0.24	0.59	0.48	0.37	0.36	0.21
36 - 40"	0.00	-0.01	0.41	0.32	0.11	-0.08	0.37	0.10

Grower irrigation row

	BED CENTER						FURROW	
depth	↓						↓	
0 - 4"	2.01	1.90	1.77	1.66	1.56	1.55		
4 - 8"	1.86	1.63	1.64	1.58	1.56	1.41	1.58	1.40
8 - 12"	1.46	1.20	1.45	1.51	1.56	1.30	1.14	1.22
12 - 16"	1.31	1.14	1.08	1.53	1.31	1.13	1.07	1.07
16 - 20"	1.15	1.01	1.27	1.07	1.12	0.88	0.95	1.07
20 - 24"	1.17	1.01	1.05	1.05	1.22	1.01	1.32	1.39
24 - 28"	1.12	1.02	1.13	1.33	1.20	1.15	1.00	1.02
28 - 32"	1.09	1.14	1.05	1.26	1.33	1.17	1.27	1.14
32 - 36"	1.10	1.17	0.95	1.12	1.19	1.12	1.15	1.12
36 - 40"	0.83	0.9	0.81	0.94	1.15	0.92	0.94	0.91

	BED CENTER						FURROW	
depth	↓						↓	
0 - 4"	2.69	2.58	1.58	1.10	1.44	3.95		
4 - 8"	1.35	0.98	0.8	0.74	1.13	1.10	1.66	2.46
8 - 12"	0.98	0.86	1.08	0.85	0.91	0.95	0.87	0.74
12 - 16"	0.90	1.09	1.00	0.98	0.80	0.71	0.70	0.61
16 - 20"	0.87	0.86	0.87	0.79	0.85	1.10	1.03	0.77
20 - 24"	1.14	1.11	1.14	1.33	1.04	1.08	0.86	0.82
24 - 28"	1.34	1.41	1.48	1.30	1.55	1.22	1.20	1.44
28 - 32"	1.19	1.67	1.32	1.41	1.65	1.68	1.65	1.27
32 - 36"	1.05	1.20	1.25	1.18	1.30	1.26	1.03	0.91
36 - 40"	0.89	0.94	1.08	0.95	1.05	0.94	0.92	0.78

	BED CENTER						FURROW	
depth	↓						↓	
0 - 4"	0.68	0.67	-0.20	-0.56	-0.12	2.40		
4 - 8"	-0.51	-0.65	-0.84	-0.84	-0.43	-0.31	0.09	1.06
8 - 12"	-0.48	-0.34	-0.38	-0.66	-0.65	-0.36	-0.28	-0.48
12 - 16"	-0.41	-0.05	-0.08	-0.55	-0.51	-0.42	-0.37	-0.46
16 - 20"	-0.29	-0.14	-0.40	-0.28	-0.27	0.22	0.09	-0.31
20 - 24"	-0.03	0.10	0.09	0.28	-0.17	0.07	-0.46	-0.57
24 - 28"	0.22	0.39	0.36	-0.03	0.35	0.06	0.21	0.41
28 - 32"	0.09	0.53	0.27	0.15	0.32	0.52	0.38	0.12
32 - 36"	-0.05	0.02	0.30	0.06	0.11	0.14	-0.11	-0.21
36 - 40"	0.06	0.04	0.27	0.01	-0.10	0.02	-0.02	-0.13

Drip field - Chloride (ppm)

Deficit irrigation row

Pre-transplant May 13, 2014

	BED CENTER					FURROW		
depth	↓					↓		
0 - 4"	137	133	134	174	182	201		
4 - 8"	141	135	146	135	175	146	117	69.3
8 - 12"	168	144	191	152	136	147	102	77.4
12 - 16"	162	191	202	129	117	127	99.1	94.9
16 - 20"	194	180	151	151	171	130	124	114
20 - 24"	221	201	201	266	159	182	130	116
24 - 28"	202	237	242	222	258	173	197	132
28 - 32"	304	246	232	226	257	179	203	159
32 - 36"	203	208	202	193	177	161	156	186
36 - 40"	203	229	225	191	195	208	183	179

Harvest Sept 29, 2014

	BED CENTER					FURROW		
depth	↓					↓		
0 - 4"	372	544	271	245	304	576		
4 - 8"	243	203	192	162	131	144	340	517
8 - 12"	147	119	104	103	134	97.7	91.4	92.8
12 - 16"	120	111	107	111	128	130	109	83
16 - 20"	102	155	120	133	128	140	215	123
20 - 24"	177	195	236	155	152	202	260	147
24 - 28"	152	191	191	180	187	317	179	236
28 - 32"	222	238	217	220	244	207	193	198
32 - 36"	208	236	264	329	284	255	258	273
36 - 40"	249	270	341	279	230	220	292	230

Change in chloride concentration from spring to fall 2014

	BED CENTER					FURROW		
depth	↓					↓		
0 - 4"	236	411	137	71	123	375		
4 - 8"	102	68	46	27	-43	-3	223	448
8 - 12"	-21	-25	-87	-49	-2	-50	-11	15
12 - 16"	-42	-81	-95	-18	12	2	10	-12
16 - 20"	-92	-25	-30	-18	-43	10	91	9
20 - 24"	-44	-6	36	-111	-7	20	131	32
24 - 28"	-50	-46	-50	-42	-71	144	-18	104
28 - 32"	-83	-7	-15	-6	-13	27	-10	40
32 - 36"	5	28	62	136	107	94	103	88
36 - 40"	46	41	116	88	35	12	109	51

Grower irrigation row

	BED CENTER					FURROW		
depth	↓					↓		
0 - 4"	166.6	151.9	155.4	145.3	130.6	131.6		
4 - 8"	175.7	164.5	175.0	166.6	149.8	131.6	131.3	96.6
8 - 12"	169.8	136.9	172.9	175.0	159.3	131.6	96.3	87.5
12 - 16"	161.4	139.3	134.4	186.2	152.3	125.0	107.5	137.2
16 - 20"	183.8	144.2	142.1	113.1	104.3	155.4	115.2	108.2
20 - 24"	181.3	152.3	167.7	164.2	188.3	147.0	184.1	181.3
24 - 28"	178.9	161.7	188.3	241.2	203.0	191.5	149.1	140.7
28 - 32"	183.8	192.5	186.2	226.5	231.7	195.7	197.8	169.8
32 - 36"	180.6	202.3	155.8	197.4	204.8	186.6	184.5	161.4
36 - 40"	133.0	144.2	125.0	147.0	184.1	139.3	143.9	134.8

	BED CENTER					FURROW		
depth	↓					↓		
0 - 4"	378.4	429.1	209.7	113.8	171.9	468.0		
4 - 8"	173.6	115.9	91.0	90.3	138.6	109.6	146.3	286.3
8 - 12"	109.2	107.1	129.5	99.4	99.4	87.9	71.1	69.3
12 - 16"	138.6	180.6	142.8	139.7	112.0	106.8	94.2	84.4
16 - 20"	183.1	177.5	171.2	155.1	175.0	224.4	202.3	147.7
20 - 24"	258.7	391.0	246.4	291.6	231.7	244.7	183.1	188.7
24 - 28"	290.2	298.6	317.8	279.0	353.9	261.5	272.3	326.2
28 - 32"	240.1	331.8	265.0	295.1	353.5	376.6	361.9	260.8
32 - 36"	205.8	226.5	253.4	241.5	274.1	273.7	216.7	177.8
36 - 40"	171.2	177.1	216.3	193.2	218.4	198.5	195.0	155.1

	BED CENTER					FURROW		
depth	↓					↓		
0 - 4"	212	277	54	-32	41	336		
4 - 8"	-2	-49	-84	-76	-11	-22	15	190
8 - 12"	-61	-30	-43	-76	-60	-44	-25	-18
12 - 16"	-23	41	8	-47	-40	-18	-13	-53
16 - 20"	-1	33	29	42	71	69	87	40
20 - 24"	77	239	79	127	43	98	-1	7
24 - 28"	111	137	130	38	151	70	123	186
28 - 32"	56	139	79	69	122	181	164	91
32 - 36"	25	24	98	44	69	87	32	16
36 - 40"	38	33	91	46	34	59	51	20

FURROW FIELD

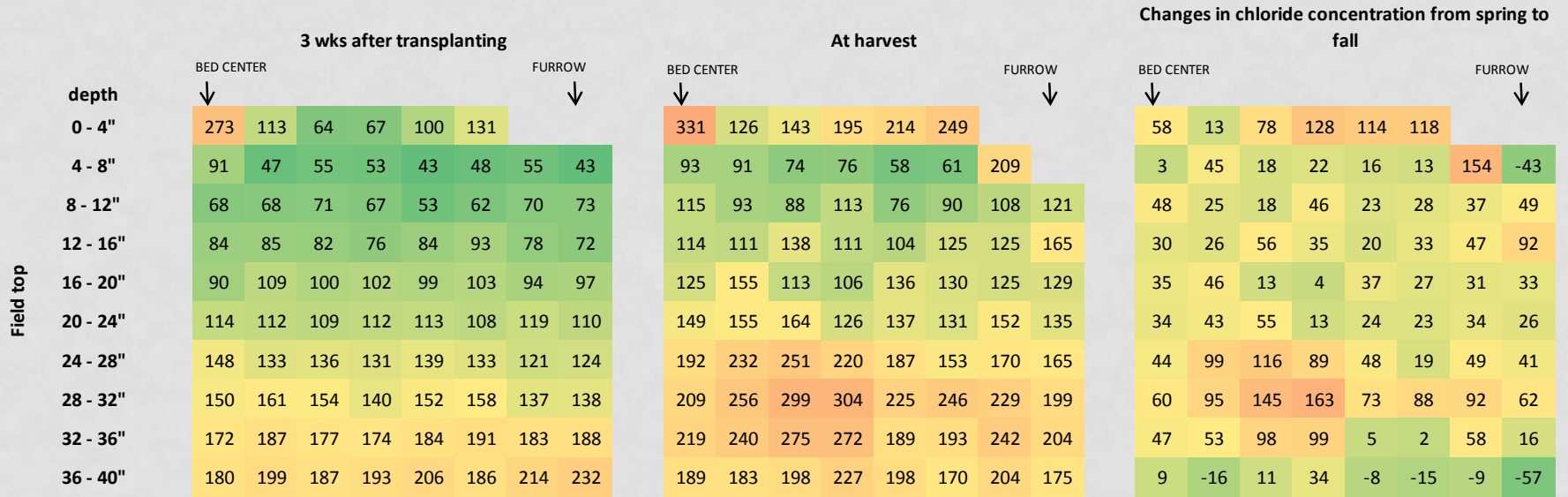
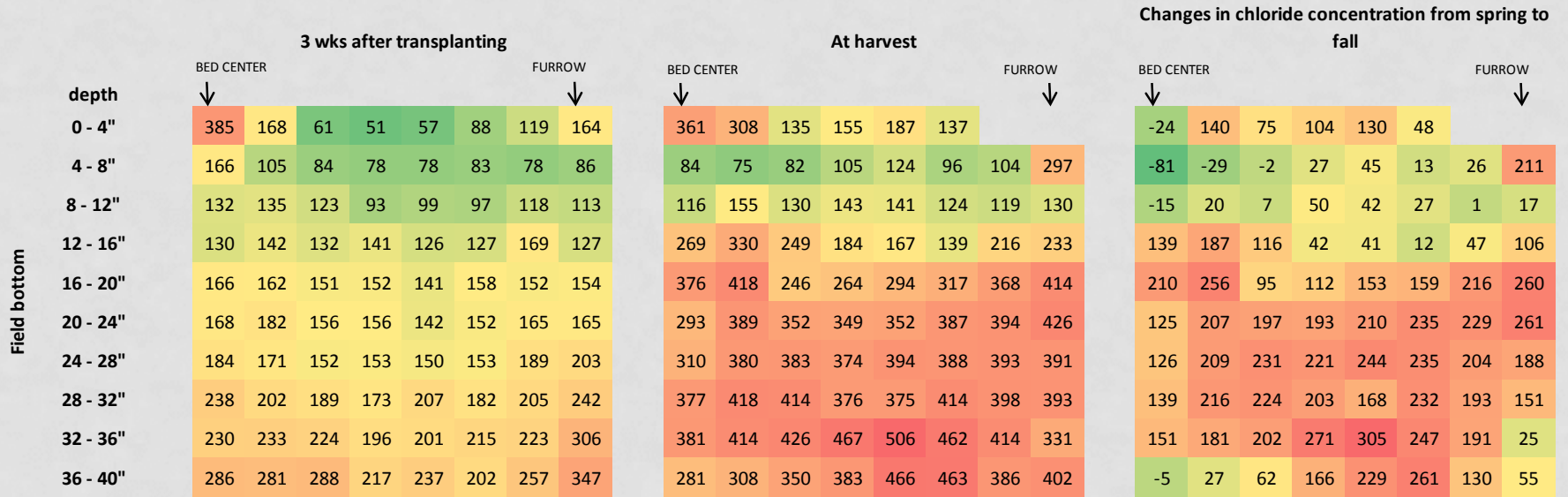
- Transplanted with H5608 on Apr 29
- Soil sampled on May 20
- Irrigated weekly using alternate furrows
- EC_w averaged 0.62
- Last irrigation July 30
- Soil sampled Aug 29
- Harvested Sept 2



Furrow field - Electrical Conductivity (dS/m)



Furrow field - Chloride (ppm)



RESULTS

- Furrow field: Adequate leaching towards top of field, much poorer leaching towards bottom
- Drip field: Even with drip irrigation application volumes lower than estimated crop ET, localized leaching occurred around the drip tape (top 20 to 32 inches depending on soil texture)
- Slightly greater irrigation cutbacks with drip system did affect salinity increases somewhat
- High variability of Delta soils apparent even over short distances within the study area; soil texture and organic matter affect leaching ability

SALINITY MANAGEMENT

- Leach salts out of root zone
 - Drip tape aligned with plant row
 - Winter rainfall or irrigation
 - In-season irrigation in excess of ET
- More frequent in-season irrigations
 - Easier for plant to extract water
- Apply fertilizer modestly

RESOURCES

Free publication:

Drip Irrigation Salinity Management for Row Crops

University of California Agriculture and Natural
Resources Publication #8447

<http://anrcatalog.ucdavis.edu>

ACKNOWLEDGEMENTS

Michelle Leinfelder-Miles, Delta Crops Farm Advisor

Terry Prichard, Emeritus Water Management Specialist

Peter Fahey, Cheryl Gartner

Jacob Loogman, Jeannine Lowrimore

Eric Stockel, Scott Whiteley

Dino Del Carlo

California Tomato Research Institute

