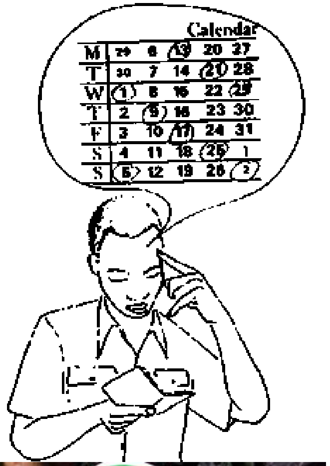
When to irrigate?

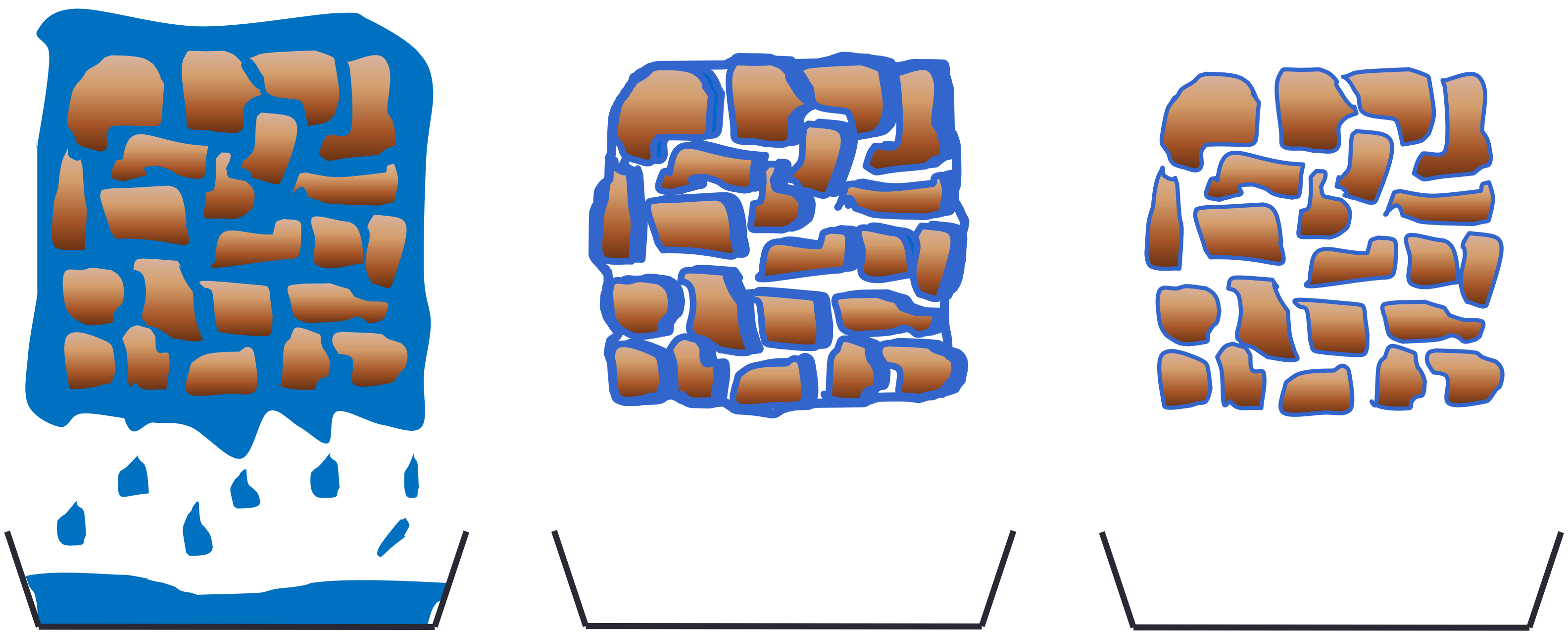


IRRIGATION AND NITROGEN MANAGEMENT OF VEGETABLE CROPS

Dr. Lincoln Zotarelli
Associate Professor
Horticultural Sciences Department
University of Florida

Actual soil moisture on sandy soils

Saturation | **Field Capacity** | **Wilting Point**



Saturation	Field Capacity	Wilting Point
VWC > 30%	VWC approx. 12%	VWC approx. 6%
VWC > 0.3 in^3/in^3	VWC > 0.12 in^3/in^3	VWC > 0.06 in^3/in^3
-1 cbar	-10 cbar	-1500 cbar
-0.001 MPa	-0.01 MPa	-1.5 MPa

An example of irrigation scheduling and how it affects plant nutrition

Water management and vegetable production

- **Two irrigation strategies for Zucchini**
  - Fixed irrigation – 2 hours continuously

    Equivalent to 0.21 inches per day (5.5mm)

  - Controlled irrigation – TARGET WAS TO WET THE TOP 12-16" OF SOIL
    - 5 possible irrigation windows controlled
    - 0.042 inches (1.1 mm) per irrigation event
    - Controlled by soil moisture sensors set at soil field capacity

Source: Zotarelli et al 2008. Scientia Horticulturae

Water management and vegetable production

- ✓ N-rates of
- ✓ 75, 150 and 225 lb/ac

weekly fertigation with calcium nitrate

Obs. In this study all N and K were applied using fertigation.
All phosphorus applied pre-plant

Source: Zotarelli et al 2008. Scientia Horticulturae

Water management and vegetable production

- Two irrigation strategies
  - Fixed irrigation – 2 hours continuously

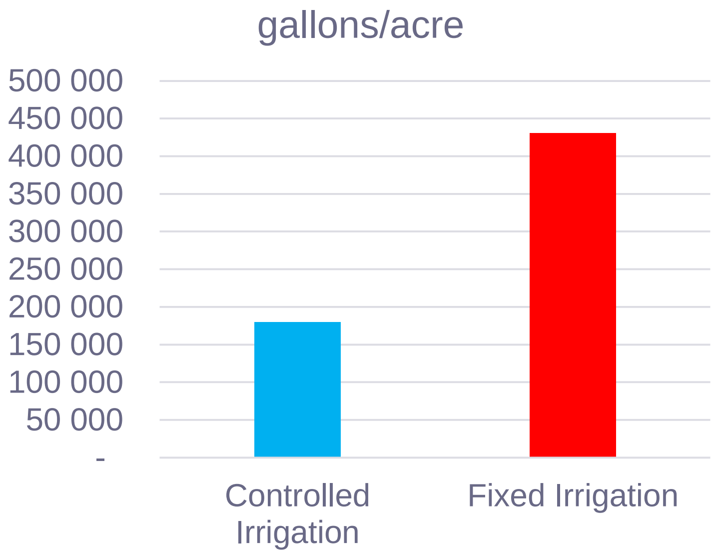
    Equivalent to 79.6 gal/100ft/day

    At the end of the season applied 16.2 in or 5,970 gal/100ft

  - Controlled irrigation – TARGET WAS TO WET THE TOP 12-16” OF SOIL
  - 5 possible irrigation windows controlled
  - by soil moisture sensors set at soil field capacity

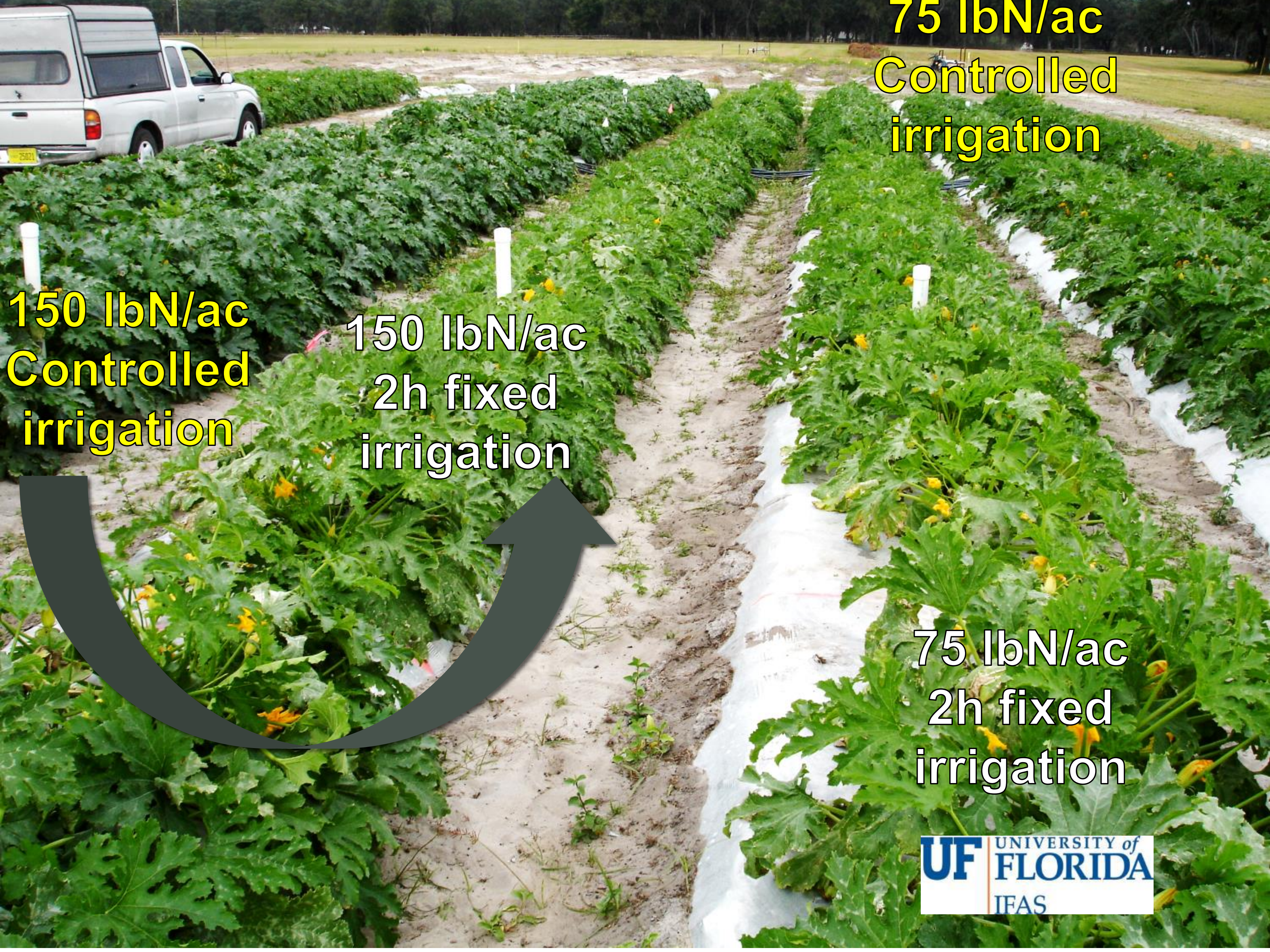
    Equivalent to 33.2 gal/100ft/day

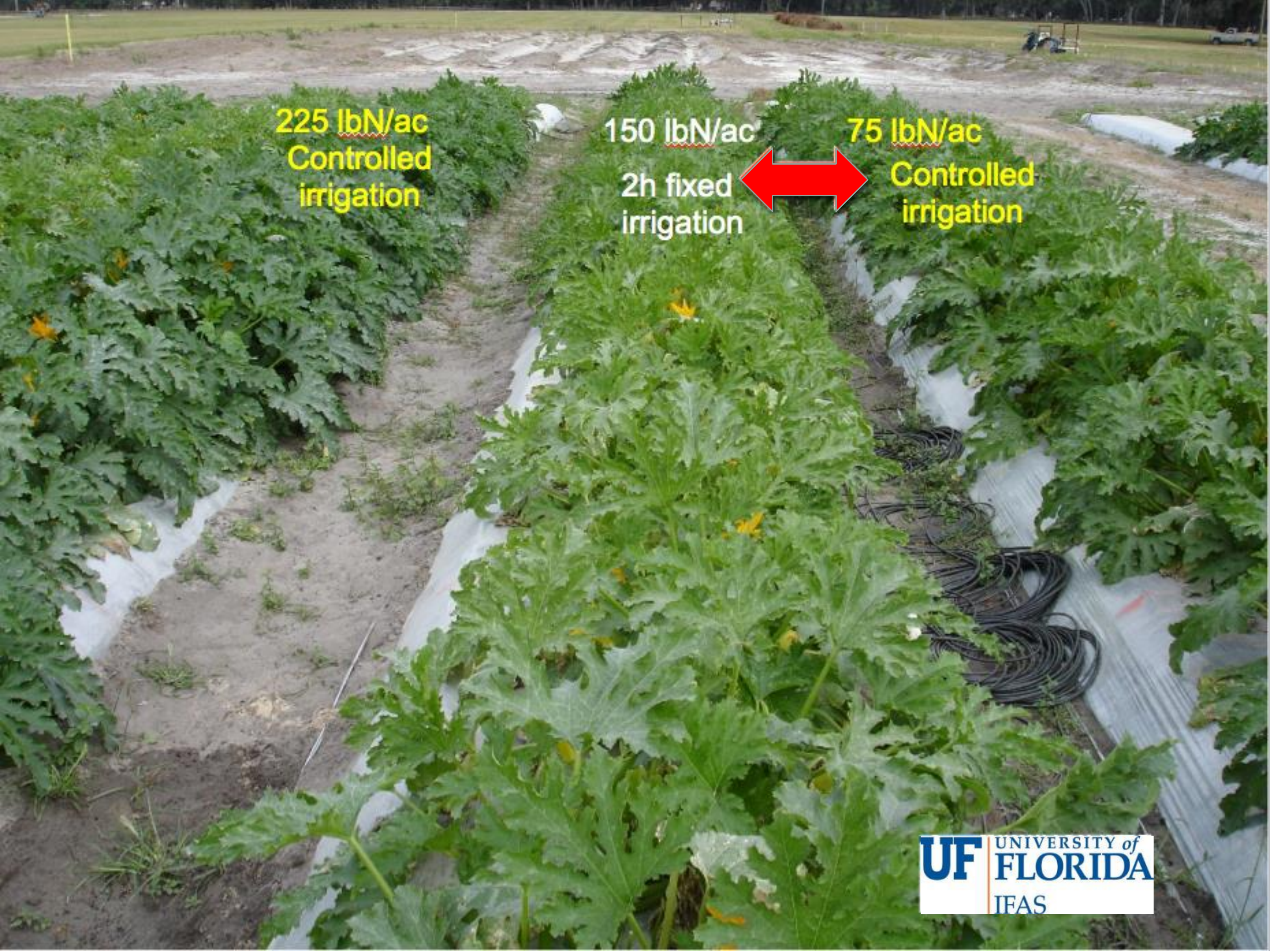
    At the end of the season applied 6.7 in or 2,492 gal/100ft



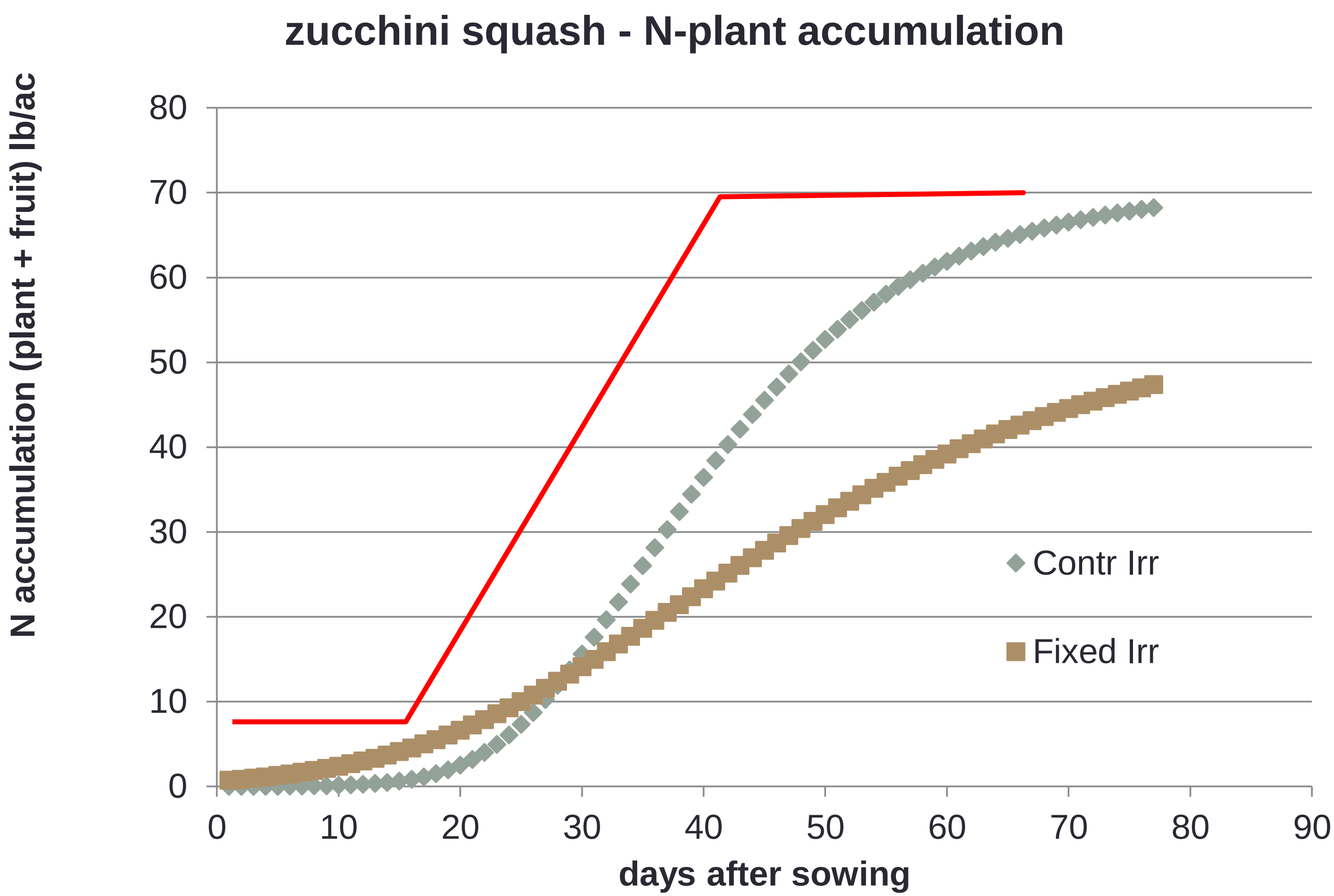
60% IRRIGATION WATER SAVED

Source: Zotarelli et al 2008. Scientia Horticulturae

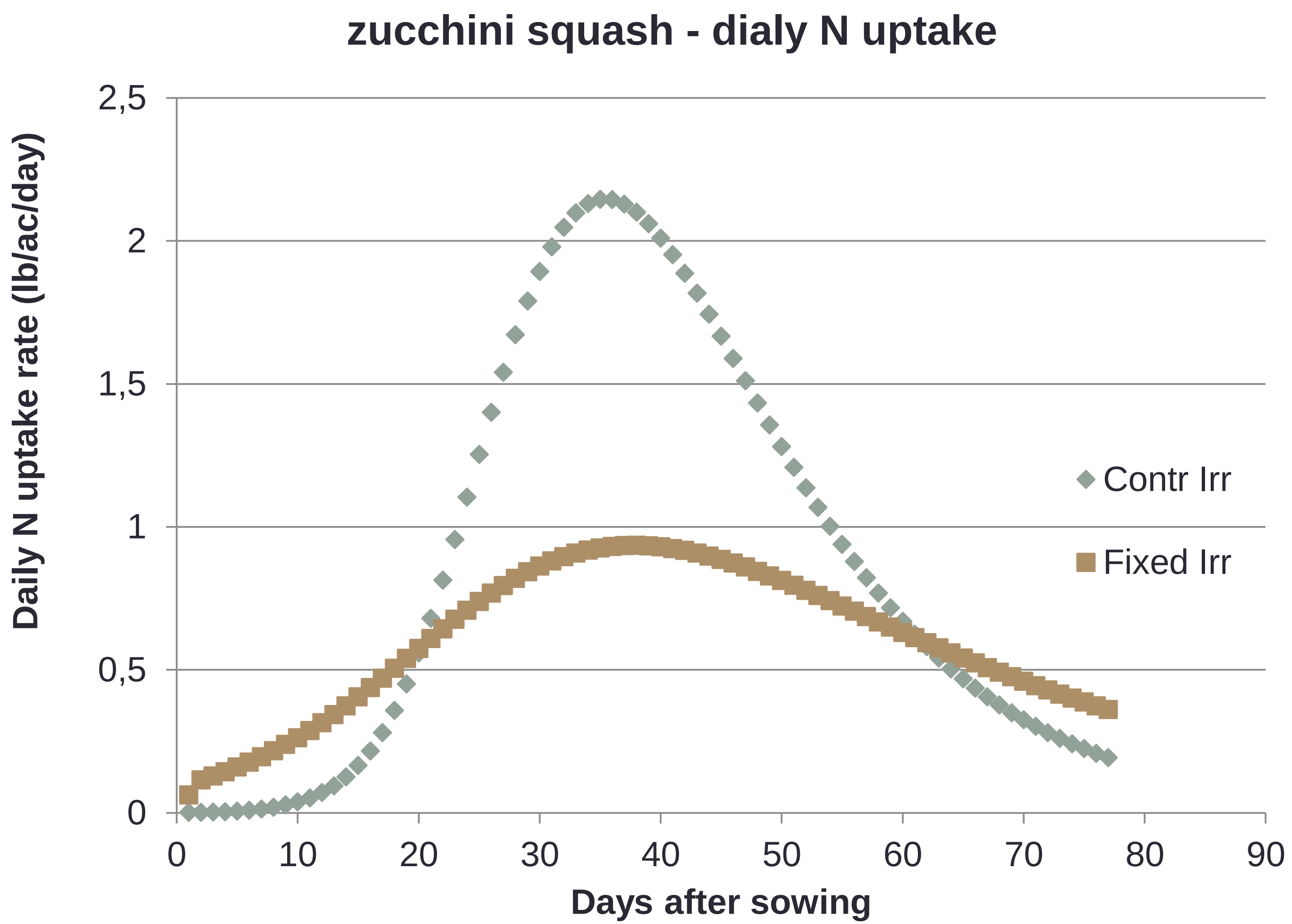

75 lbN/ac
Controlled
irrigation
150 lbN/ac
Controlled
irrigation
150 lbN/ac
2h fixed
irrigation
75 lbN/ac
2h fixed
irrigation
UF UNIVERSITY of FLORIDA
IFAS


225 lbN/ac
Controlled
irrigation
150 lbN/ac
2h fixed
irrigation
75 lbN/ac
Controlled
irrigation
UF UNIVERSITY of FLORIDA
IFAS

Zucchini plant N accumulation



Zucchini daily N uptake



Irrigation vs. N-fertilization on zucchini

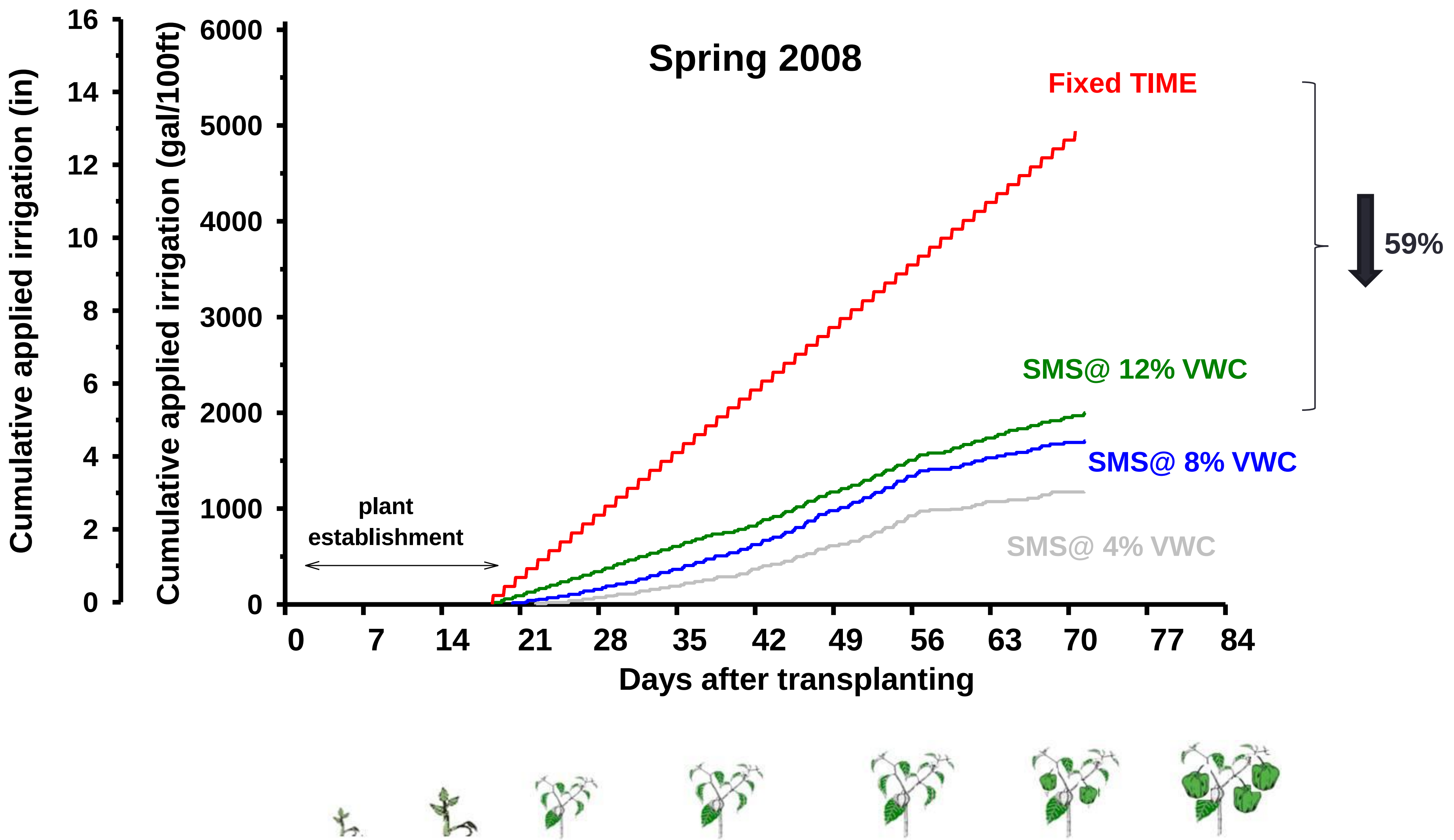
	75 lbN/ac	150 lbN/ac	225 lbN/ac	Average
	Zucchini marketable yield (lb/ac)			
Controlled irrigation – up to 5 irrig. windows/day				**24,649 A**
Fixed irrigation of 2h/day				**18,316 B**
Average	**19,955 B**	**22,478 A**	**23,013 A**	

† Means within columns/lines followed by the same lowercase letters are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

Irrigation vs. N-fertilization on zucchini

	75 lbN/ac	150 lbN/ac	225 lbN/ac	Average
	Zucchini marketable yield (lb/ac)			
Controlled irrigation – up to 5 irrig. windows/day	22,389	25,422	26,135	**24,649 A** 100%
Fixed irrigation of 2h/day	15,525	19,535	19,891	**18,316 B** 74%
Average	**19,955 B** 84%	**22,478 A** 100%	**23,013 A** 102%	

Automated irrigation controlled by soil moisture sensors - PEPPER



Pepper yield and water use efficiency

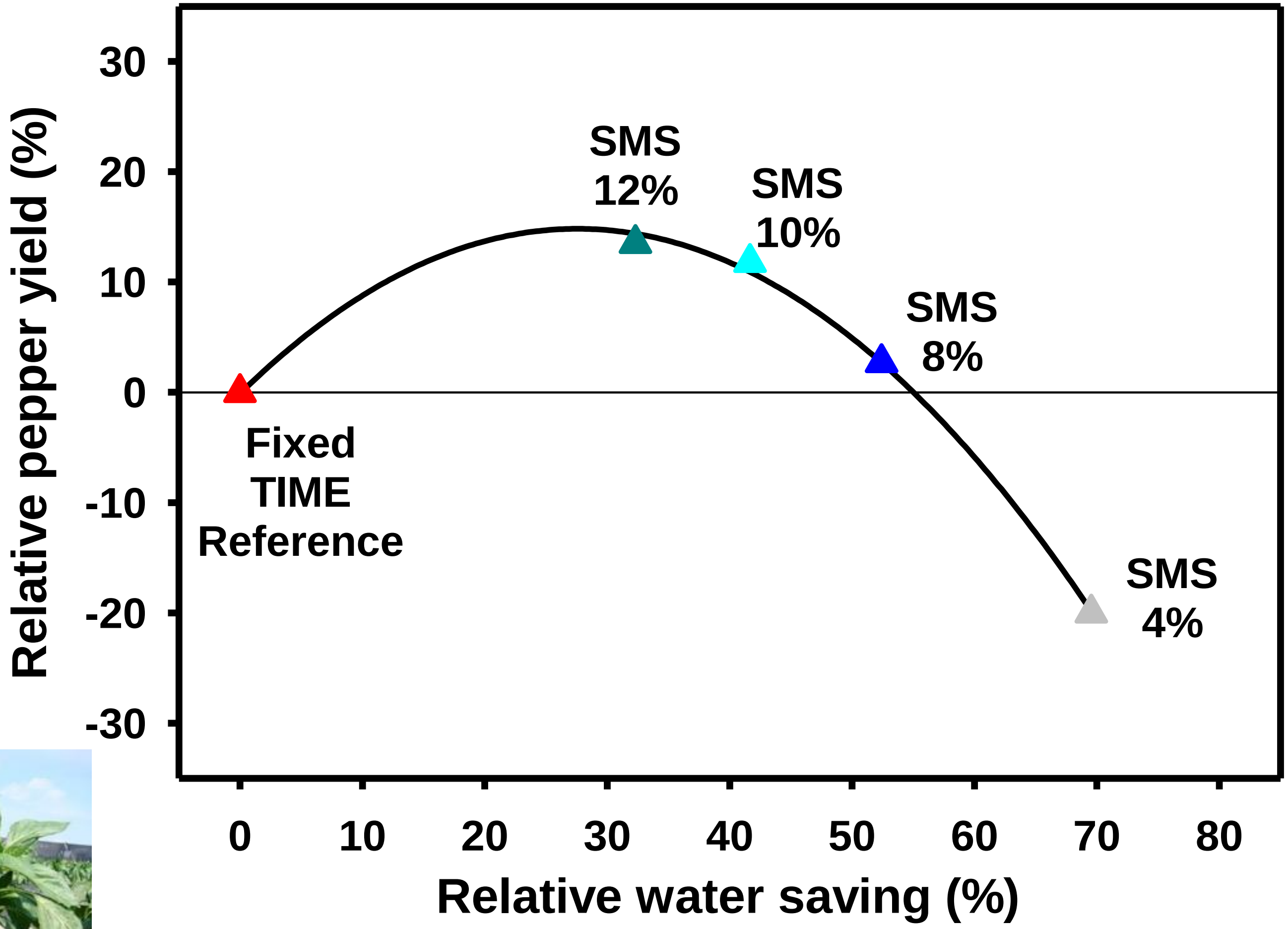
Season/Treat.		Irrigation		Marketable Yield
		inches	gal/100ft	Boxes/ac
2008	SMS@ 4%	3.2	1,173	943 *c*
	SMS@ 8%	4.6	1,695	1,096 *b*
	SMS@ 12%	5.4	2,000	1,264 *a*
	Fixed TIME	13.7	5,042	1,179 *b*
2009	SMS@ 4%	0.9	318	521 *c*
	SMS@ 8%	4.1	1,492	850 *b*
	SMS@12%	5.3	1,927	993 *a*
	Fixed TIME	7.4	2,724	843 *b*

85 boxes (7%) incr.

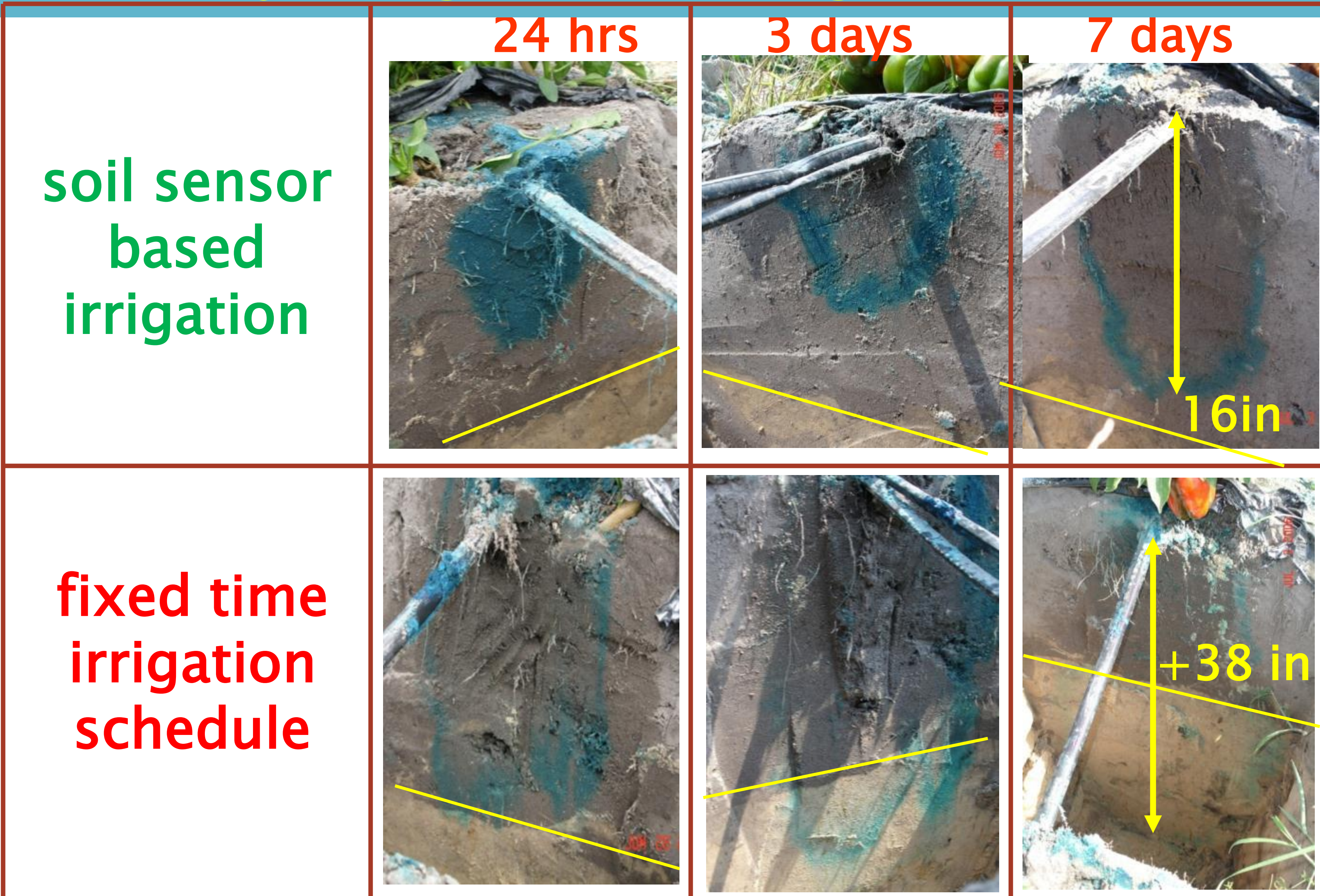
150 boxes (17%) incr.

N-rate of 200 lb/ac

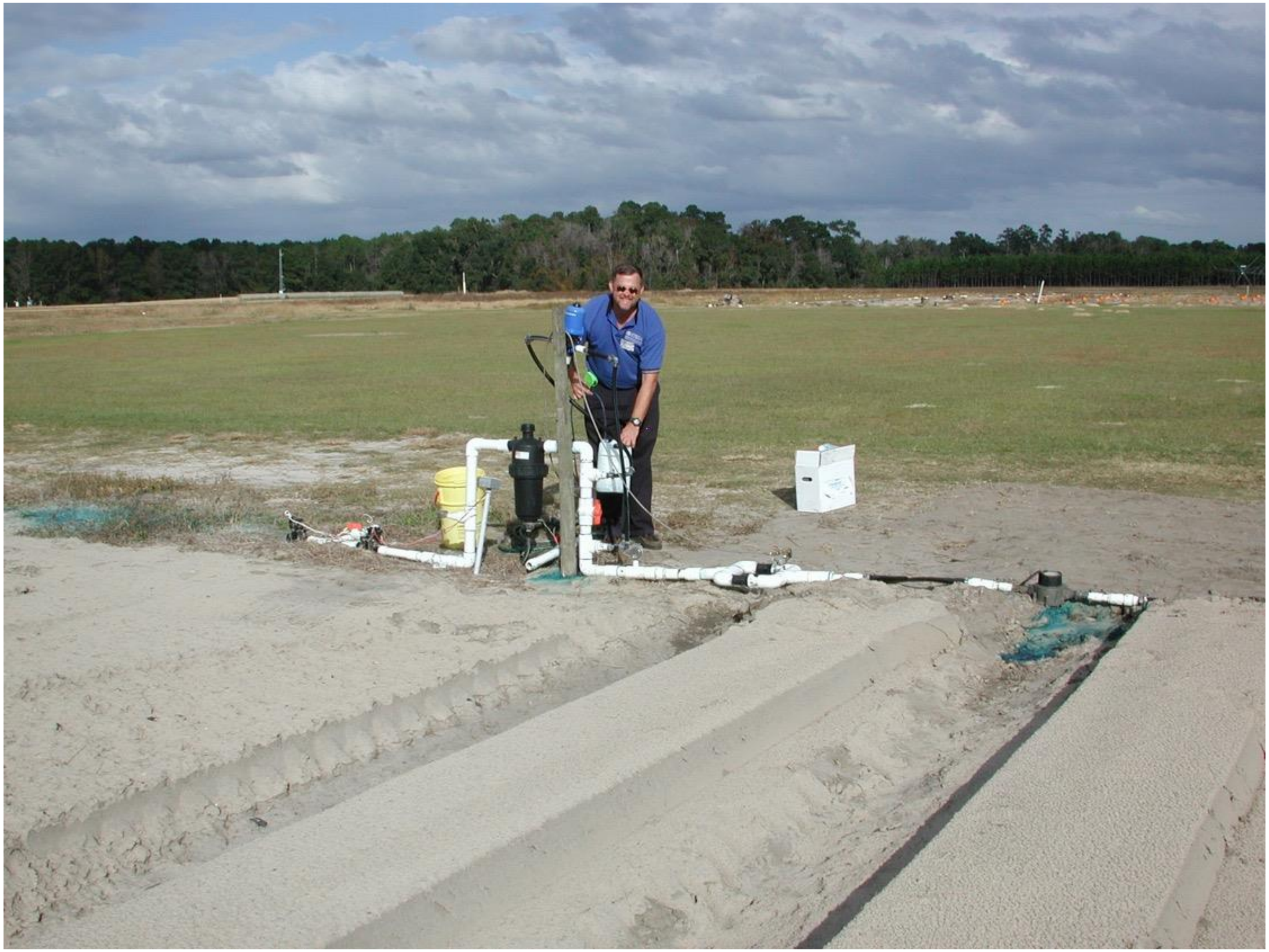
Irrigation regimes and relative pepper yield



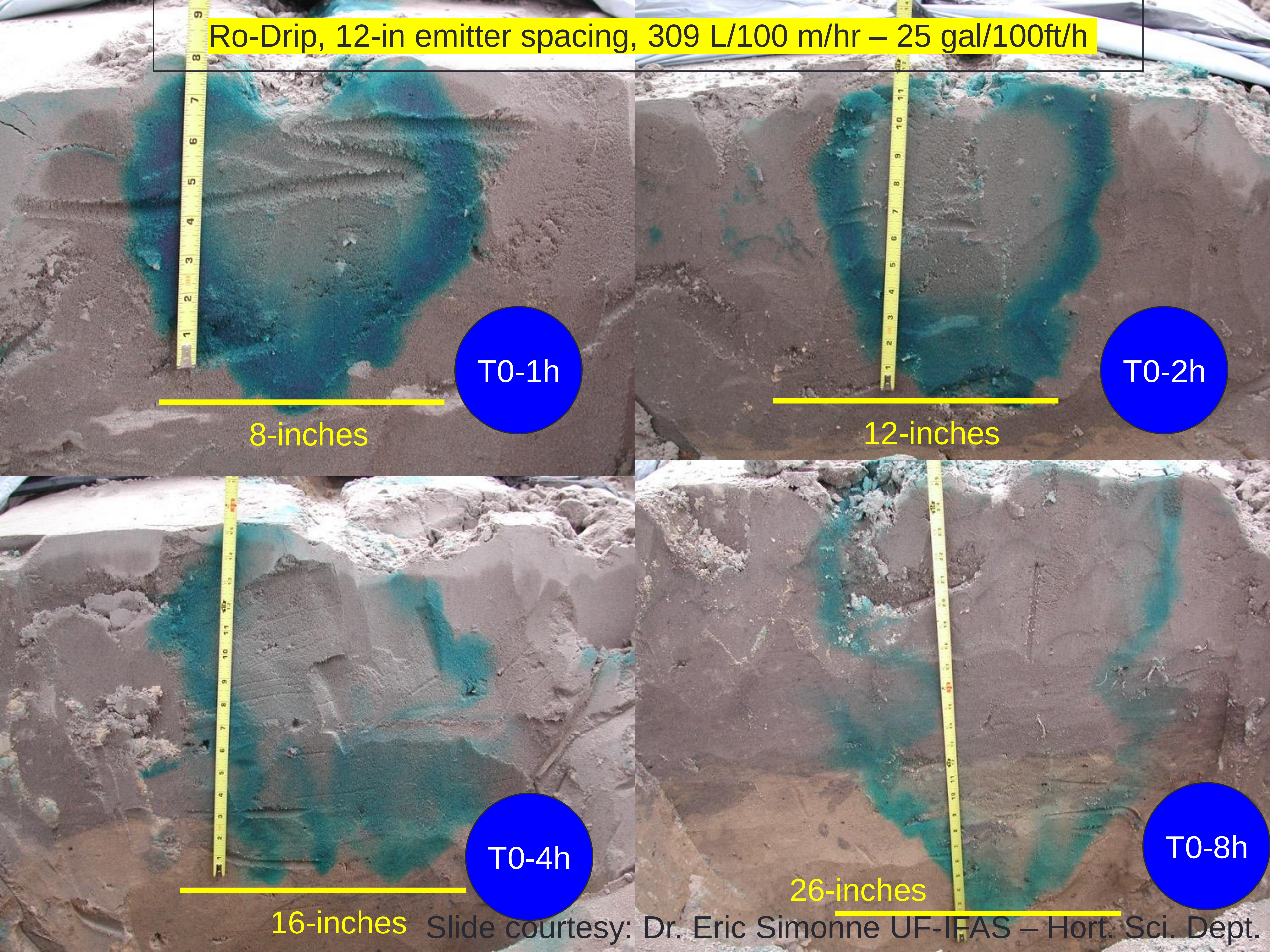
Effect of irrigation on solute displacement (injecting dye in fertigation lines)

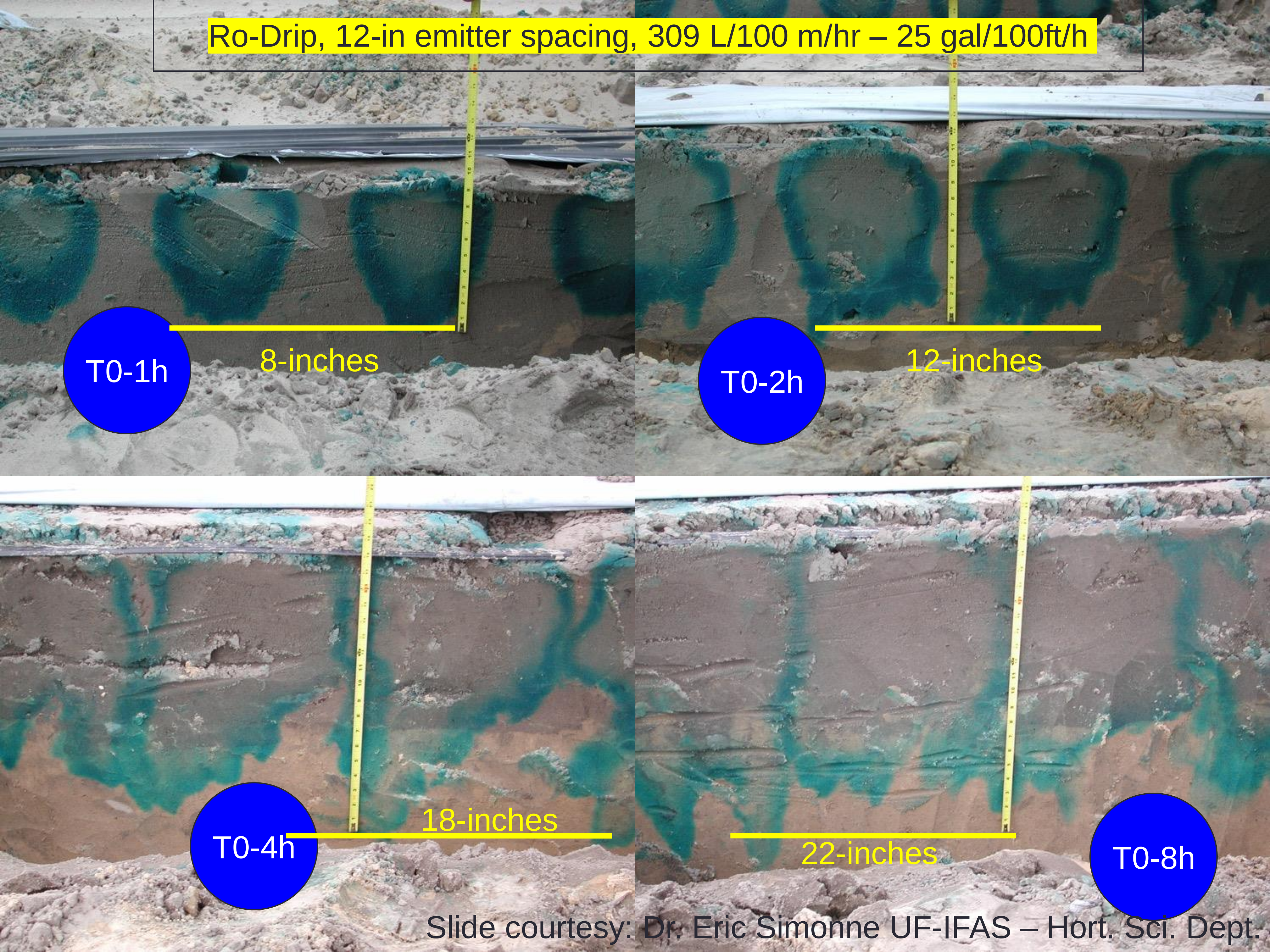


Irrigation management vs N-leaching

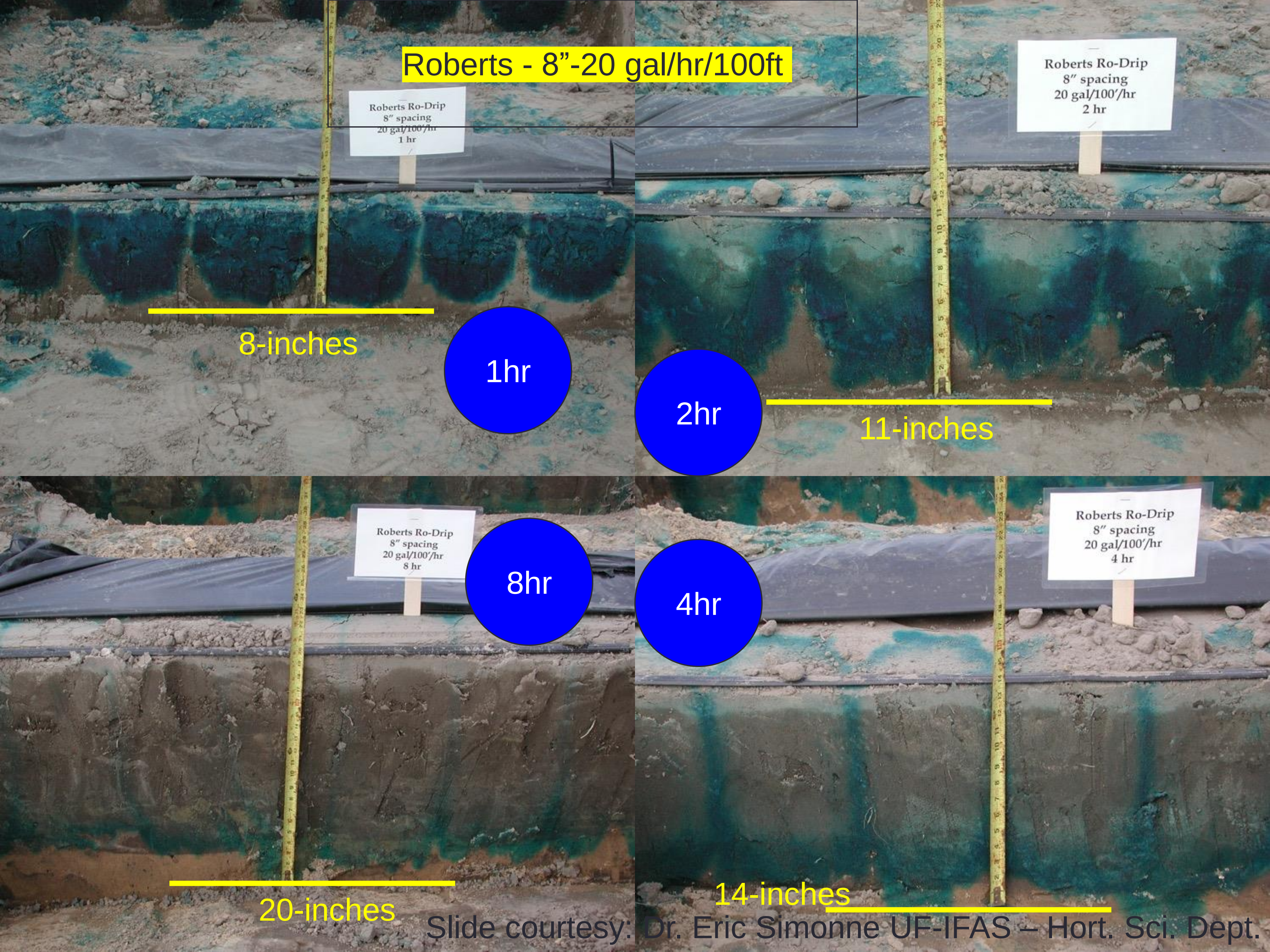


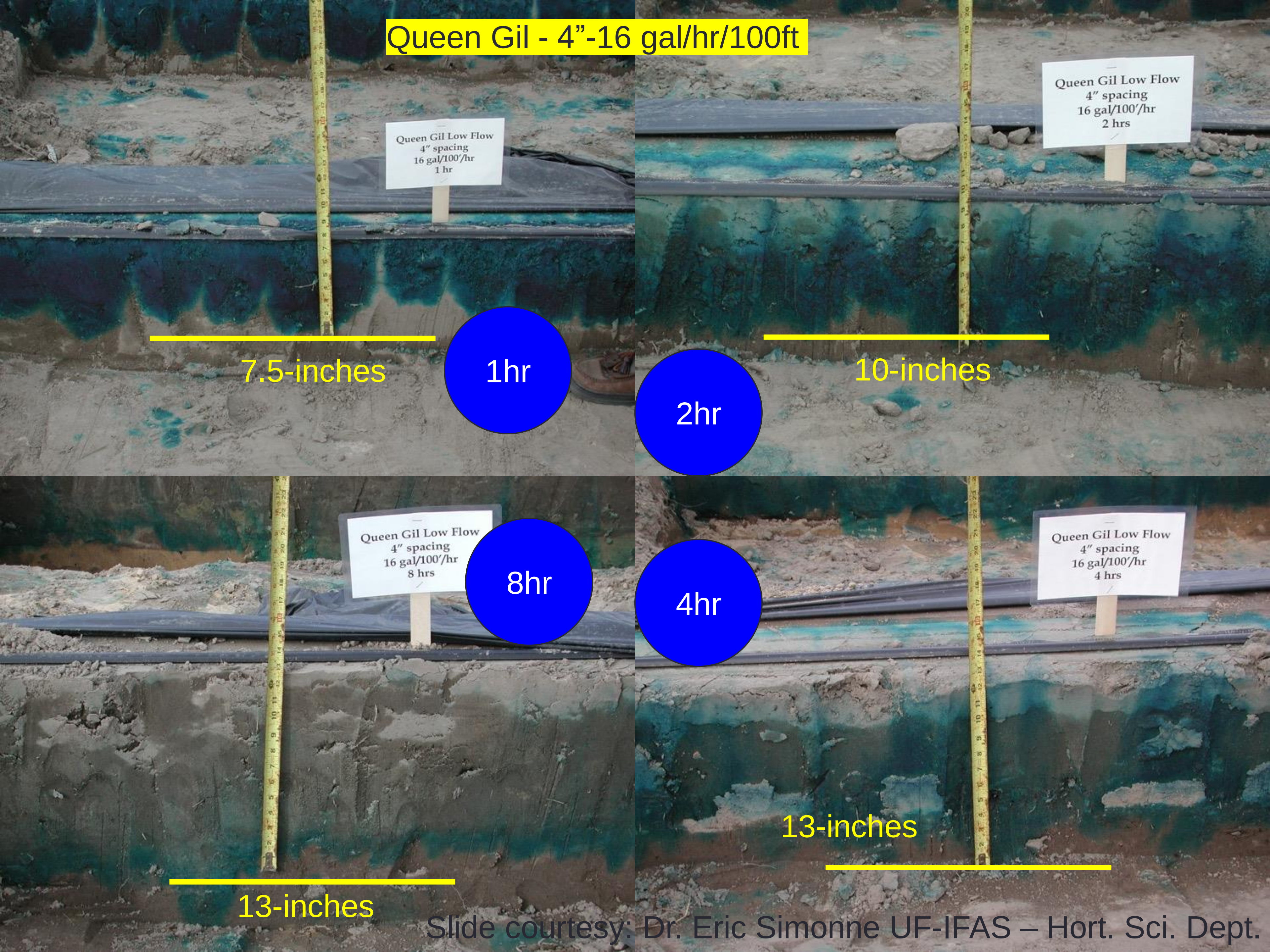
Slide courtesy: Dr. Eric Simonne UF-IFAS – Hort. Sci. Dept.


Ro-Drip, 12-in emitter spacing, 309 L/100 m/hr – 25 gal/100ft/h
T0-1h
8-inches
T0-2h
12-inches
T0-4h
16-inches
T0-8h
26-inches
Slide courtesy: Dr. Eric Simonne UF-IFAS – Hort. Sci. Dept.



Ro-Drip, 12-in emitter spacing, 309 L/100 m/hr – 25 gal/100ft/h
T0-1h
8-inches
T0-2h
12-inches
T0-4h
18-inches
22-inches
T0-8h
Slide courtesy: Dr. Eric Simonne UF-IFAS – Hort. Sci. Dept.


Roberts - 8”-20 gal/hr/100ft
Roberts Ro-Drip
8″ spacing
1 hr
8-inches
1hr
Roberts Ro-Drip
8″ spacing
20 gal/100′/hr
2 hr
2hr
11-inches
Roberts Ro-Drip
8″ spacing
20 gal/100′/hr
8 hr
8hr
Roberts Ro-Drip
8″ spacing
20 gal/100′/hr
4 hr
4hr
20-inches
14-inches
Slide courtesy: Dr. Eric Simonne UF-IFAS – Hort. Sci. Dept.


Queen Gil - 4”-16 gal/hr/100ft
Queen Gil Low Flow
4″ spacing
16 gal/100′/hr
1 hr
7.5-inches
1hr
Queen Gil Low Flow
4″ spacing
16 gal/100′/hr
2 hrs
10-inches
2hr
Queen Gil Low Flow
4″ spacing
16 gal/100′/hr
8 hrs
8hr
13-inches
Queen Gil Low Flow
4″ spacing
16 gal/100′/hr
4 hrs
4hr
13-inches
Slide courtesy: Dr. Eric Simonne UF-IFAS – Hort. Sci. Dept.

How to select the drip tape and emitter spacing?

- Emitter size and clogging risk
- Wetted zone
- ‘Micro’ leaching
- Cost of drip tape

What do you need to know to prepare a IRRIGATION scheduling plan?

- 1. soil type
- 2. crop requirements and critical period
- 3. cultural practices adopted

Sand vs. Loam

~15-35%

~6-12%

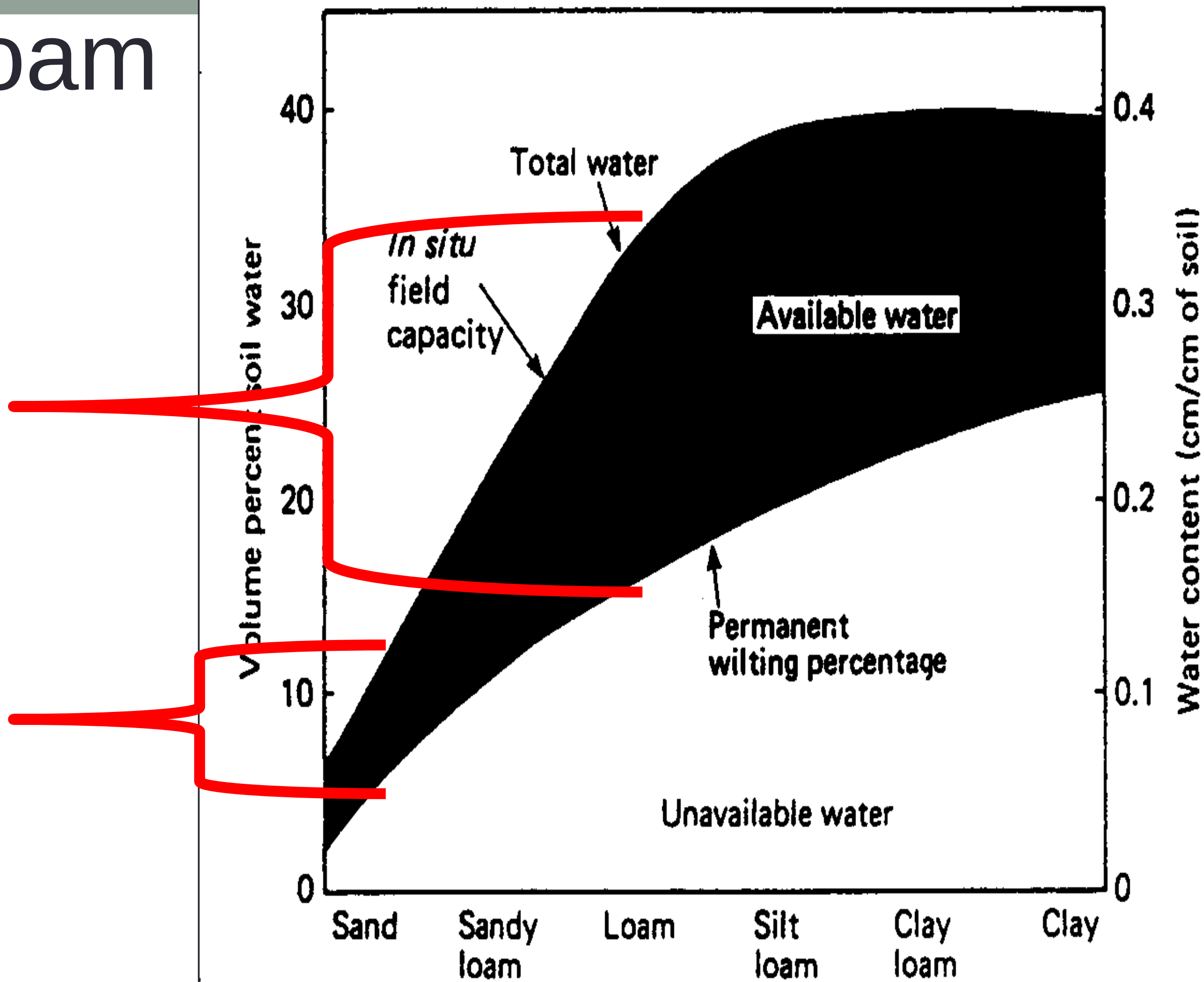


Fig. 1. Diagram showing field capacity, permanent wilting point, and available water in sand, loam, and clay soils. From Kramer, P. J. and J. S. Boyer. 1995. Water Relations of Plants and Soils. Academic Press, New York.

Available water holding capacity based on soil texture

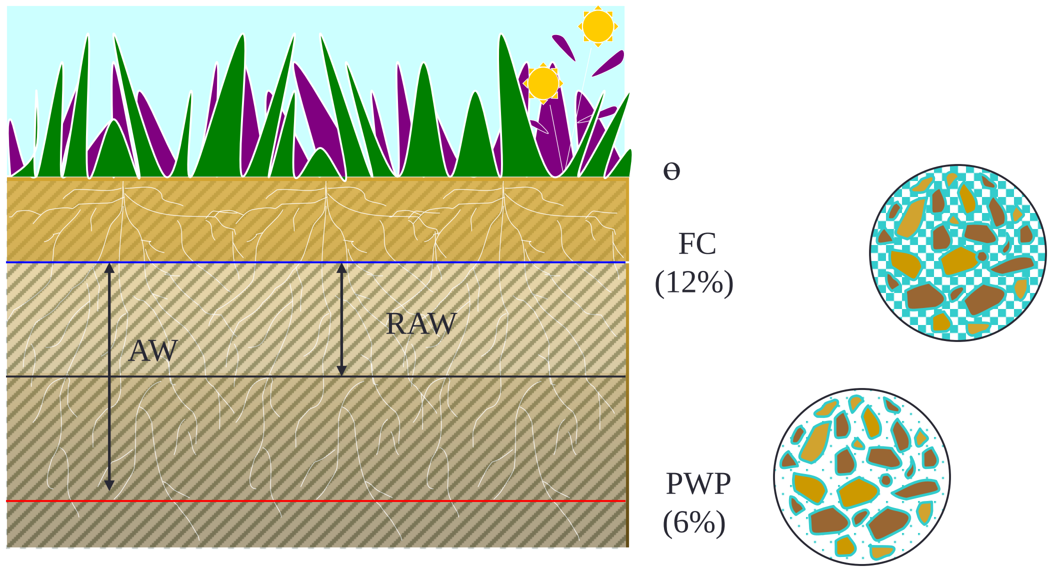
Soil texture	Available water holding capacity (inch of water/inch of soil)
Coarse sand	0.02 – 0.06
Fine sand	0.04 – 0.09
Loam sand	0.06 – 0.12
Sandy loam	0.11 – 0.15
Fine sandy loam	0.14 – 0.18
Loam and silt loam	0.17 – 0.23
Clay loam and silty clay loam	0.14 – 0.21
Silty clay and clay	0.13 – 0.18

"Soils with higher available water-holding capacity require less frequent irrigation than soils with low available water-holding capacities"

Soil Water Holding Capacity

Definitions for water storage in the root zone (RZ).

$$\text{Available water (AW)} = \frac{(FC - PWP) \times RZ}{100}$$



Readily available water (RAW) = Max. Allowed Deplet. X AW

RAW = MAD x AW

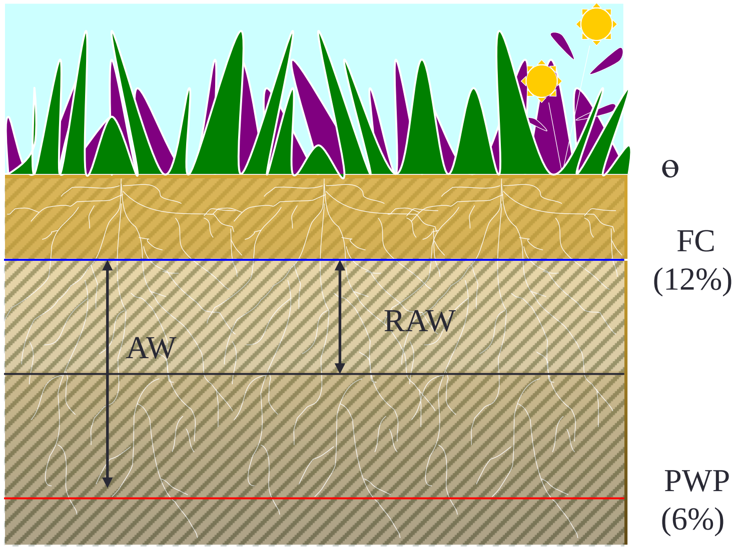
MAD depends on the crop and stage of development.

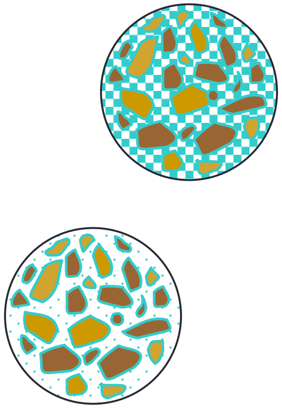
Soil Water Holding Capacity

Definitions for water storage in the root zone.

$$AW = \frac{(12 - 6) \times 10 \text{ in}}{100} = 0.6 \text{ inches}$$

RAW = 50% x 0.6 = 0.30 inches





Metric

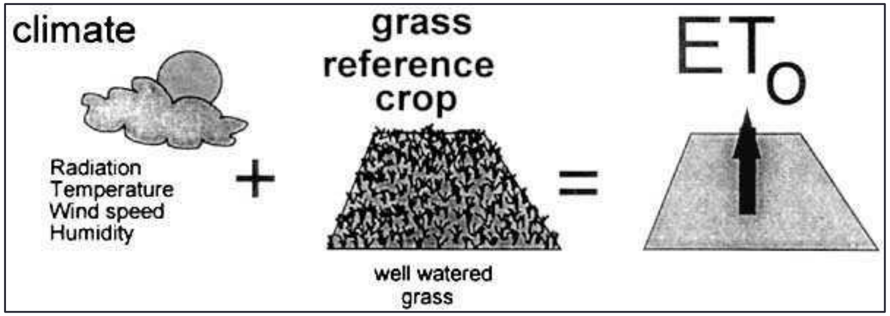
$$AW = \frac{(12 - 6) \times 250 \text{ mm}}{100} = 15 \text{ mm}$$

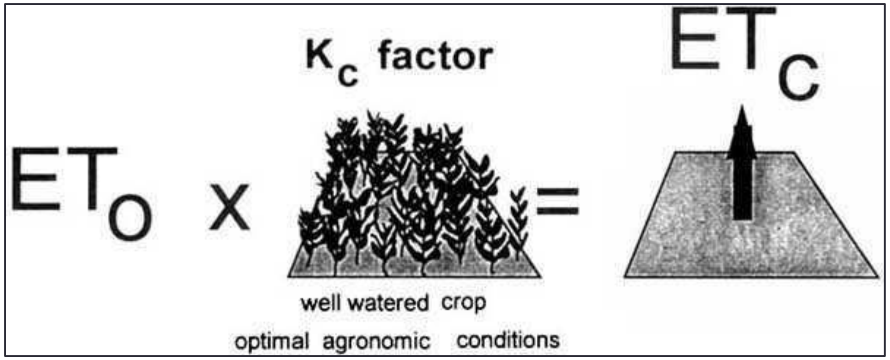
RAW = 50% x 15 = 7.5 mm

Critical periods of water need by crops

Crop	Critical period
Beans: lima	Pollination and pod development
: snap	Pod development
Broccoli	Head development
Cabbage	Head development
Carrots	Root enlargement
Corn	Silking and tasseling, ear development
Cucumbers	Flowering and fruit development
Egg plant	Flowering and fruit development
Lettuce	Head development
Onions	Bulb enlargement
Peppers	Flowering and fruit development
Potatoes	Tuber set and tuber enlargement

Reference Evapotranspiration (ETo)



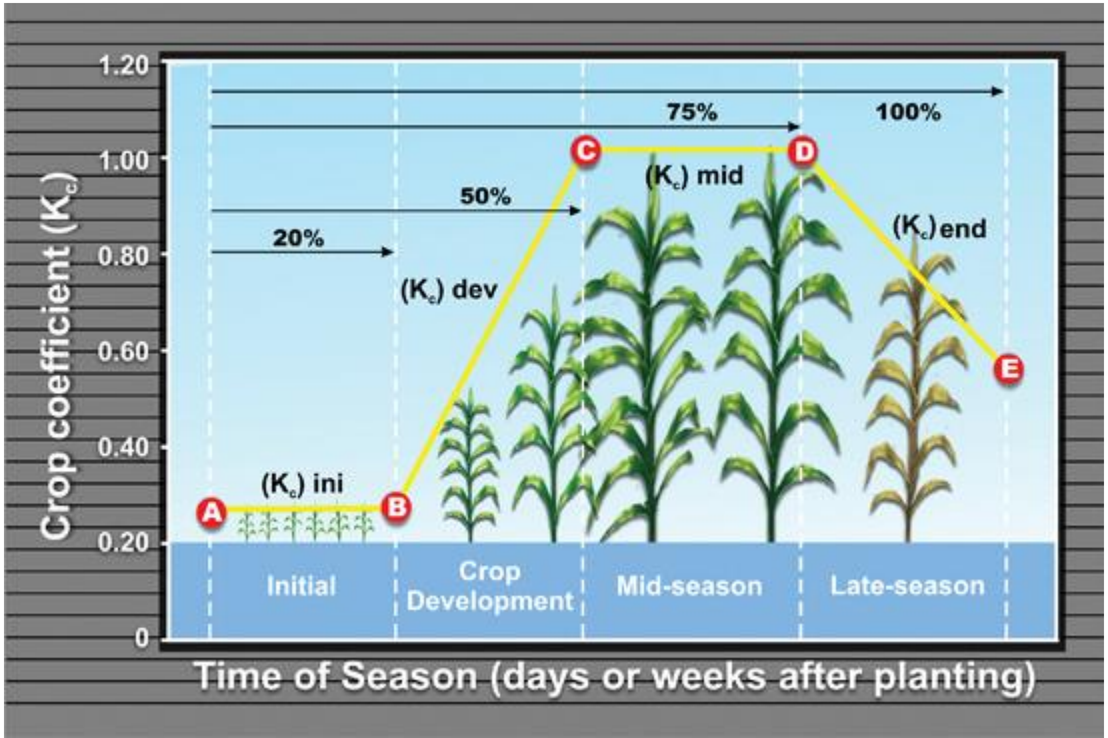


Crop water use (ETc) is related to ETo by a crop coefficient
(Kc) which is the ratio of ETc to the reference value Eto

Crop water requirement = Reference evapotranspiration x Crop coefficient

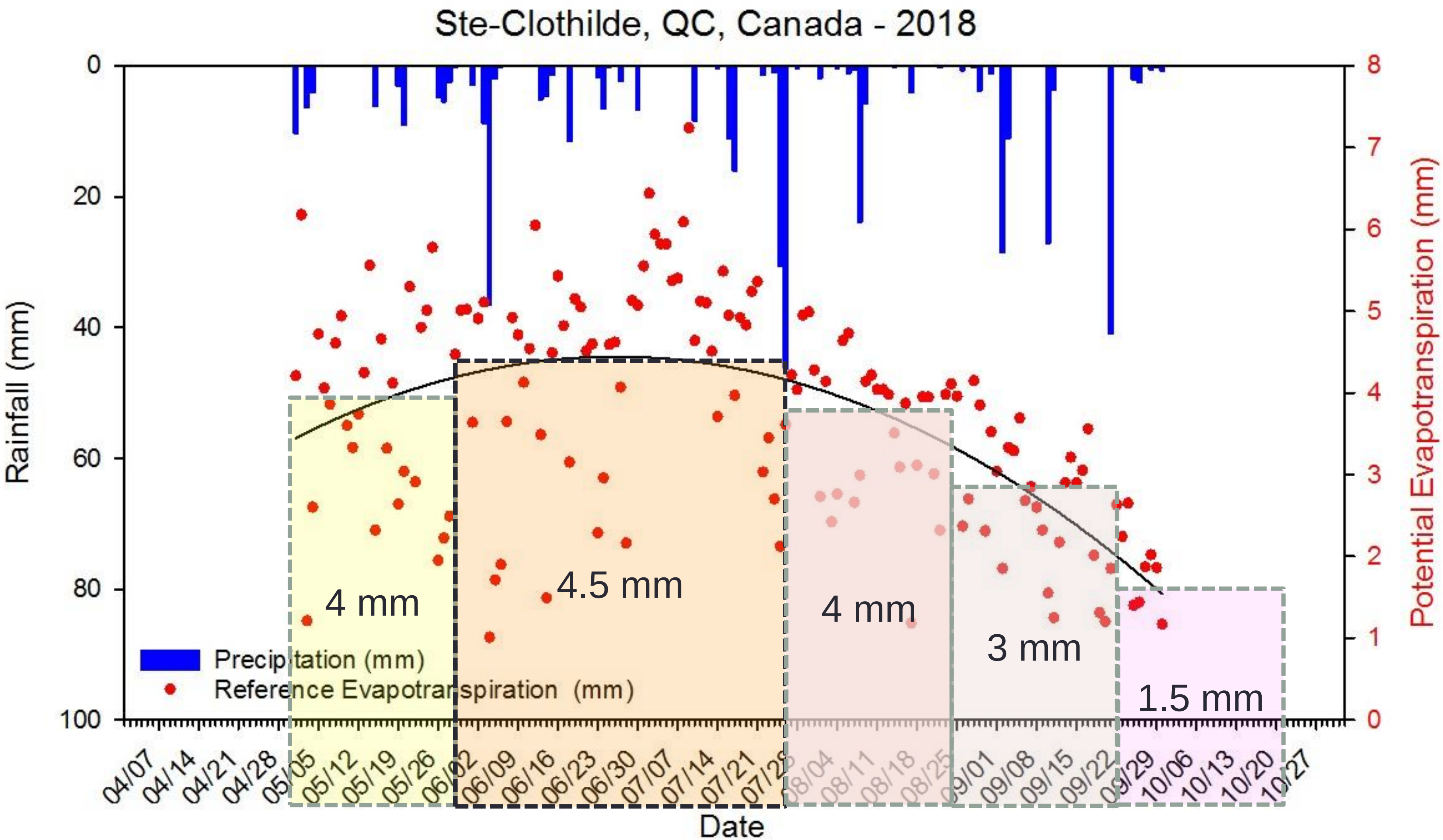
Crop Evapotranspiration (ETc)

- ETc provides reference measure of water use based on plant water demand
- Scalable for specific crop, growth stage, climate, and season of year
- $ET_c = ET_o * K_c$



Agrométéo

http://www.agrometeo.org/indices/category/general



Vegetable Production Handbook for Florida:

Chapter 3: Principles and Practices of Irrigation Management for Vegetables.

Table 7. Crop coefficient estimates (Kc) for use with ETo values in Table 3 and growth stages in Table 4 for selected crops grown in a plasticulture system.[1]

Crop	Growth Stage	Crop Coefficient (Kc)
Cantaloupe[1]	1	0.35
	2	0.6
	3	0.85
	4	0.85
	5	0.85
Cucumber[1]	1	0.25
	2	0.5
	3	0.9
	4	0.75
Summer squash[1]	1	0.3
	2	0.55
	3	0.9
	4	0.8

Crop	Growth Stage	Crop Coefficient (Kc)
Strawberry (4-ft bed centers) [2]	1	0.4
	2	0.5
	3	0.6
	4	0.8
	5	0.8
Tomato (6-ft bed centers) [3]	1	0.4
	2	0.75
	3	1.0
	4	1.0
	5	0.85
Watermelon (8-ft bed center)[1]	1	0.3
	2	0.5
	3	0.7
	4	0.9
	5	0.8

[1] Adapted from Tables 12 and 25 in Allen, R.G., L.S.Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration: guidelines for computing crop water requirements Food and Agriculture Organization of the United Nations, Rome.

[2] Adapted from Clark et al.(1993) Water Requirements and Crop Coeffcients for Tomato Production in Southwest Florida. Southwest Florida Water Management District, Brandon, FL.

[3] Adapted from Clark et al. 1996. Water requirements and crop coefficients of drip-irrigated strawberry plants. Transactions of the ASAE 39:905-913.

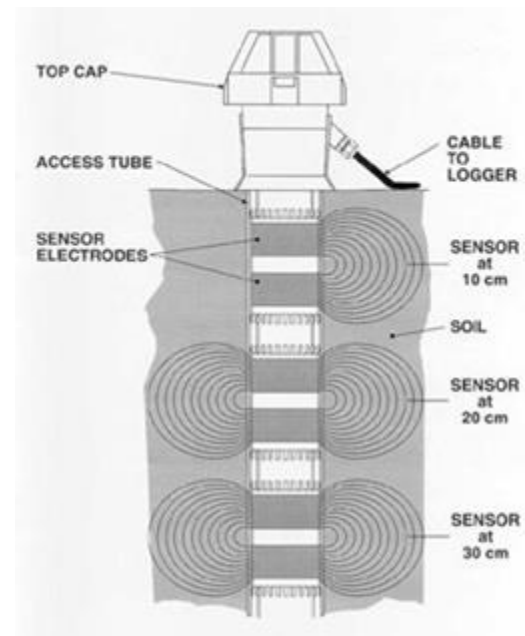
Example of irrigation schedule.

Crop	Growth Stage	Crop Coefficient (Kc)
Strawberry (4-ft bed centers) [2]	1	0.4
	2	0.5
	3	0.6
	4	0.8
	5	0.8
Tomato (6-ft bed centers) [3]	1	0.4
	2	0.75
	3	1.0
	4	1.0
	5	0.85
Watermelon (8-ft bed center)[1]	1	0.3
	2	0.5
	3	0.7
	4	0.9
	5	0.8

Eto.	Irrigation volume/day	run time
X 4.0 mm	= 1.6 mm/day	10 min
X 4.0 mm	= 3.0 mm/day.	18 min
X 4.5 mm	= 4.5 mm/day.	26 min
X 5.5 mm	= 5.5 mm/day.	32 min
X 3.5 mm	= 2.9 mm/day.	17 min

309 L/h/100m – wet width of 30 cm = 10.3 mm/h

Sensors Used to Measure Soil Moisture Content

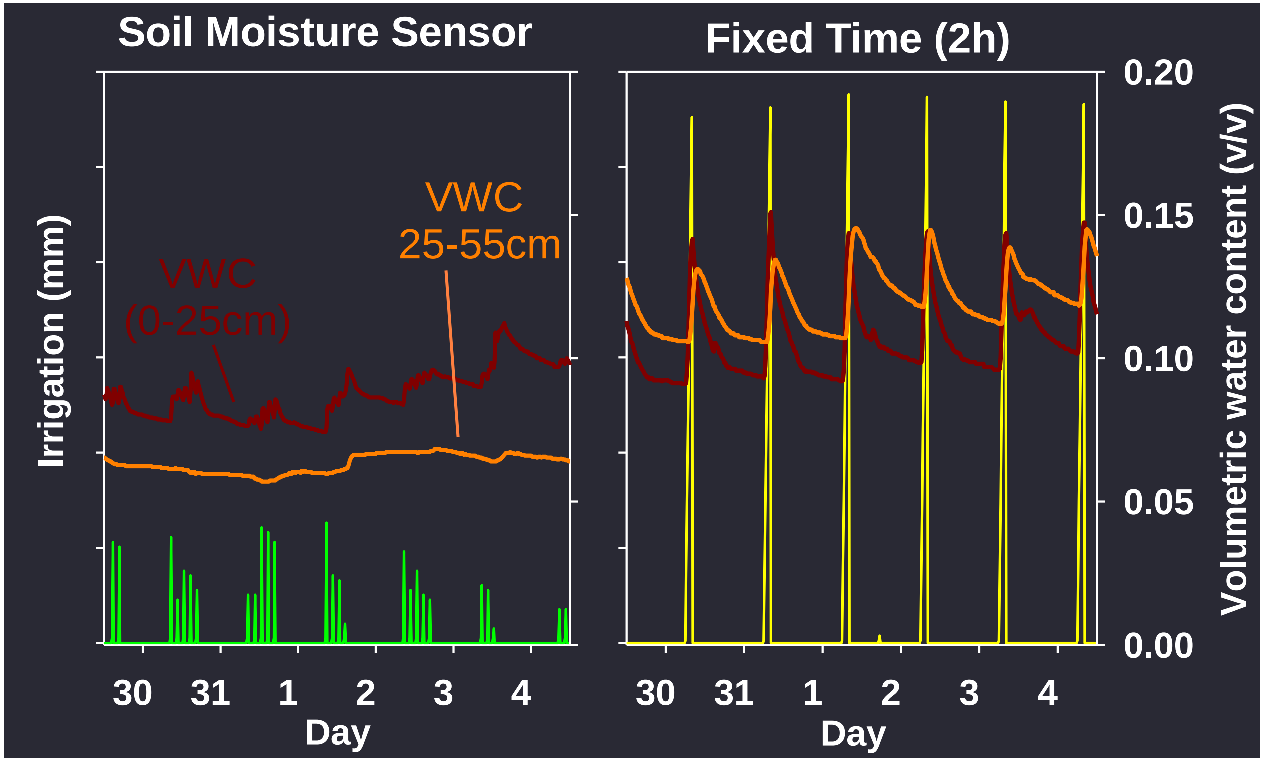


Sensor Based Irrigation Control

Types:

On-demand irrigation

Bypass irrigation



What do you need to know to prepare a FERTIGATION scheduling plan?

- 1. How much nutrients is supplied by soil and water?
- 2. Crop requirements of nutrients and critical period
- 3. When does the plant require nutrients?

Pre-plant fertilizer vs Fertigation

Factors to consider:

- Fertilizer solubility and compatibility when using solid fertilizer to prepare solution
- Are the fertilizers compactible? Precipitation?
- Special considerations must be given when injecting phosphorus
  - Irrigation water quality – Ca, Mg, Fe, pH
  - Most dry phosphorus fertilizers cannot be injected (too insoluble)
  - Phosphoric acid can be injected only if the pH of the fertigation remains very low (>3.0)

Florida – P applied pre-plant (high calcium carbonate levels in the irrigation water)
Potassium – fallow the recommended rates from soil testing

Pre-plant fertilizer vs Fertigation

Table 2.8. Fertigation[1] and supplemental fertilizer[1] recommendations on mineral soils testing low in potassium (K_2O) based on the **MEHLICH 3 SOIL EXTRACTION METHOD.**

	Preplant[2] (lb/A)	Injected[3] (lb/A/day)					Low plant content[4,5]	Extended season[4,6] (lb/A/day)
Eggplant								
Wk after transplanting[7]		1-2	3-4	5-10	11-13			
N	0-70	1.5	2.0	2.5	2.0		1.5-2.0	1.5-2.0
K_2O	0-55	1.0	1.5	2.5	1.5		1.5-2.0	1.5-2.0
Okra								
Wk after transplanting		1-2	3-4	5-12	13			
N	0-40	1.0	1.5	2.0	1.5		1.5-2.0	1.5-2.0
K_2O	0-50	1.0	1.5	2.0	1.5		1.5-2.0	1.5-2.0
Pepper								
Wk after transplanting		1-2	3-4	5-11	12	13		
N	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0
K_2O	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0
Strawberry								
Wk after transplanting		1-2	Sept.-Jan.	Feb.-Mar.	Apr.			
N	0-40	0.3	0.6	0.75	0.6		0.6-0.75	0.6-0.75
K_2O	0-40	0.3	0.5	0.75	0.6		0.6-0.75	0.6-0.75
Tomato[8]								
Wk after transplanting		1-2	3-4	5-11	12	13		
N	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0
K_2O	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0

[1] A=7,260 linear feet per acre (6-ft. bed spacing); for soils testing "low in Mehlich 3 potassium (K2O), seeds and transplants may benefit from applications of a starter solution at a rate no greater than 10 to 15 lb/A for N and P2O5 and applied through the plant hole or near the seeds.

[2] Applied using the modified broadcast method (fertilizer is broadcast where the beds will be formed only, and not over the entire field). Preplant fertilizer cannot be applied to double/triple crops because of the plastic mulch; hence, in these cases, all the fertilizer has to be injected.

[3] This fertigation schedule is applicable when no N and K20 are applied preplant. Reduce schedule proportionally to the amount of N and K20 applied preplant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.

[4] Plant nutritional status may be determined with tissue analysis or fresh petiole-sap testing, or any other calibrated method. The "low' diagnosis needs to be based on UF/IFAS interpretative thresholds.

[5] Plant nutritional status must be diagnosed every week to repeat supplemental fertilizer application.

[6] Supplemental fertilizer applications are allowed when irrigation is scheduled following a recommended method (see "Evapotranspiration-based Irrigation Scheduling for Agriculture at <http://edis.ifas.ufl.edu/ae457>). Supplemental fertilizations is to be applied in addition to base fertilization when appropriate. Supplemental fertilization is not to be applied 'in advance' with the preplant fertilizer.

[7] For standard 13 week-long, transplanted tomato crop.

[8] Some of the fertilizer may be applied with a fertilizer wheel through the plastic mulch during the tomato crop when only part of the recommended base rate is applied preplant. Rate may be reduced when a controlled-release fertilizer source is used.

Zucchini daily N uptake

N: 125 lb/ac via fertigation
N: 25 lb/ac pre-plant
Total: 150 lbN/ac

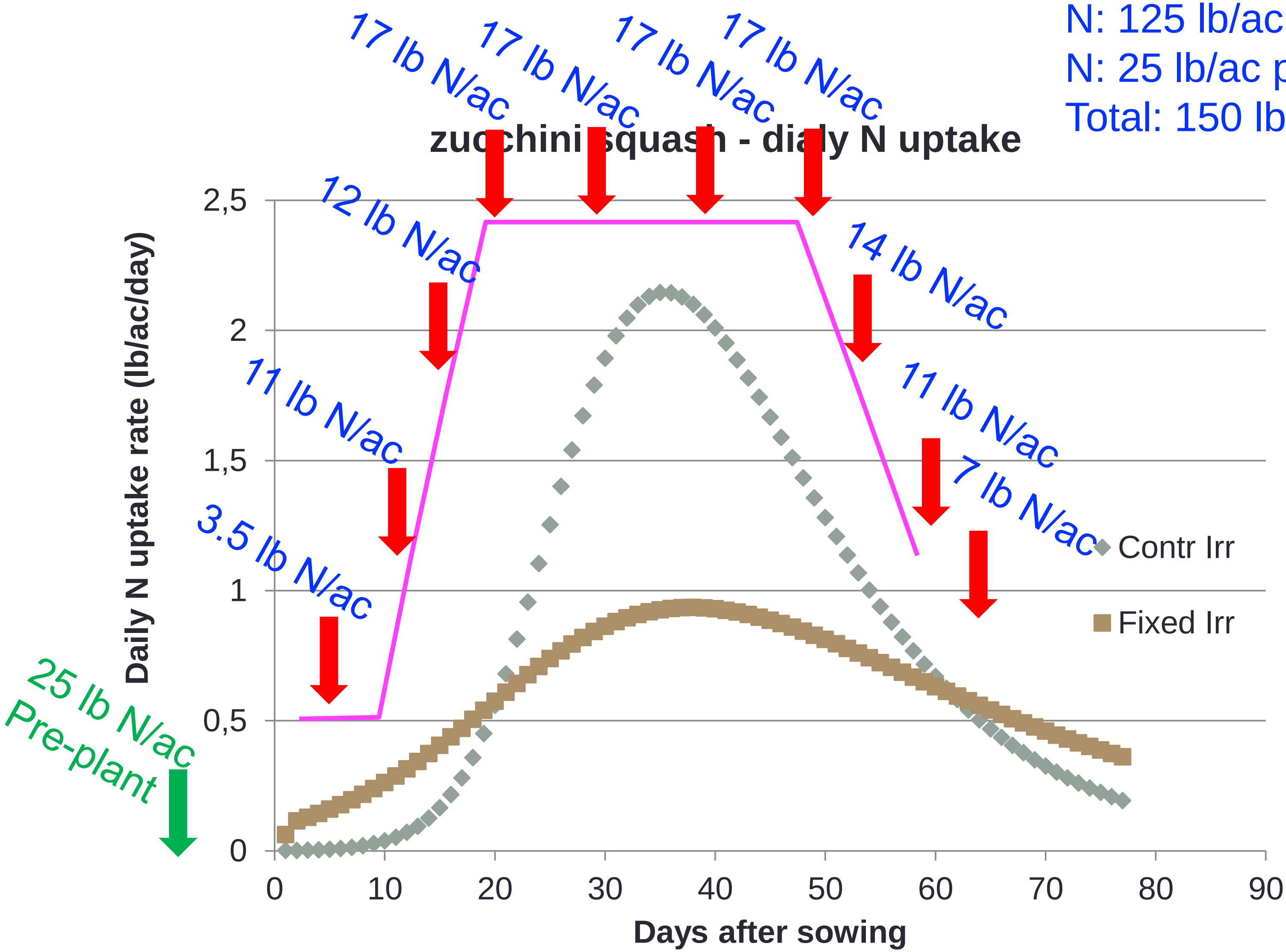


Table 33. Weekly nitrogen fertigation estimate of (gross) requirements of vegetable crops under California conditions. (Hartz et al., 1994)

Crop	Growth Stage	Approximate nitrogen fertilizer requirement (pounds N/ac/day)	(pounds N/ac/wk)
Broccoli	Early growth	0.71 – 2.14	5 – 15
	Midseason	1.42 – 2.86	10 – 20
	Button formation	2.14 – 4.29	15 – 30
	Head development	1.42 – 2.86	10 – 20
Cucumber	Vegetative growth	0.71 – 1.42	5 – 10
	Early flowering/fruit set	1.42 – 2.86	10 – 20
	Fruit bulking	1.42 – 2.14	10 – 15
	First harvest	0.71 – 1.42	5 – 10
Lettuce	Early growth	0.71 – 1.42	5 – 10
	Cupping	1.42 – 2.86	10 – 20
	Head filling	2.14 – 4.29	15 – 30
Melon	Vegetative growth	0.71 – 1.42	5 – 10
	Early flowering/fruit set	1.42 – 2.86	10 – 20
	Fruit bulking	1.42 – 2.14	10 – 15
	First harvest	0.71 – 1.42	5 – 10
Pepper	Vegetative growth	0.71 – 1.42	5 – 10
	Early flowering/fruit set	2.14 – 4.29	15 – 30
	Fruit bulking	2.14 – 2.86	15 – 20
	First harvest	0.71 – 1.42	5 – 10
Squash	Vegetative growth	0.71 – 1.42	5 – 10
	Early flowering	1.42 – 2.86	10 – 20
	First harvest	0.71 – 1.42	5 – 10
Tomato	Vegetative growth	0.71 – 1.42	5 – 10
	Early flowering/fruit set	2.14 – 2.86	15 – 20
	Fruit bulking	1.42 – 2.14	10 – 15
	First harvest	0.71 – 1.42	5 – 10

Note: Upper threshold values represent fertigation needs in low residual N soils and/or under high temperature (rapid growth) conditions. Higher values are for soils with low residual nitrogen or conditions of rapid growth under favorable environmental conditions.

Should I fertigate everyday or once a week?

- Little difference has been found between fertigation frequencies of once per day and once per week (Locascio and Smajstrla, 1995)
- No difference in bell pepper yield between 6 and 12 applications (Neary et al., 1995)
- Little effect on broccoli yield and quality on sandy loam between N applied daily, weekly, monthly (Thompson et al. 2003)

- **Our preference**:
- Once a week
- Fertilizer injection during the middle one-third to one half of the irrigation set time

Take home message

- **Importance of <u>irrigation management</u>:**
  - reduction of irrigation water application
  - maintenance/increase of vegetable yields
  - potential reduction of N-leaching

- **Clear soil moisture targets for irrigation;**

- **Combination of water and fertilizer application: timing and rate**

Thank you

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