Getting the Most out of Your Irrigation System in Strawberry

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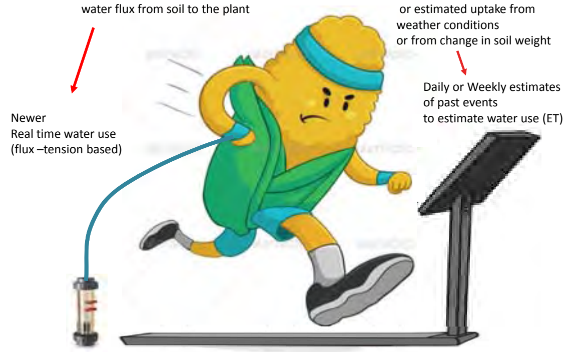
Two commonly used approaches to run irrigation:



Introduction

- 86% of the strawberry of North America grown in California, along with Florida (7%) and Québec (3.5%) and Ontario (3.5%)
- Water is becoming increasingly scarce in California, and under increasing controlled use elsewhere.

Evapotranspiration (ETo):

- ETo is the loss of water by evaporation (from soil and plant surfaces) and transpiration (from plant tissues)
- Estimates of Et for a specific crop and area are used for irrigation scheduling:

Crop Et = ETo x Kc

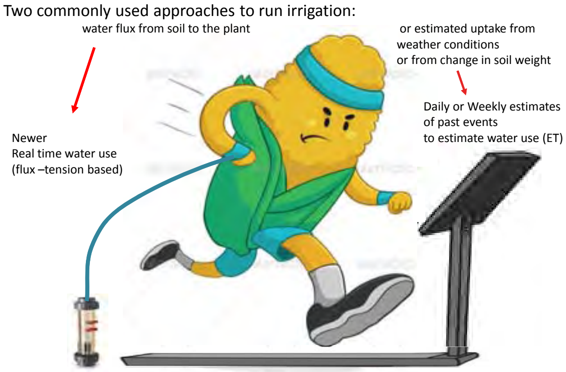
Introduction

Cuts may be imposed to strawberry growers to save water, with limited information on the impact on crop yield.

This also increases pressure to get more crop per drop

A new approach was recently proposed to manage irrigation and offers the opportunity to maximize yield and generate water savings without affecting yield, getting the most of your irrigation system

Two commonly used approaches to run irrigation:



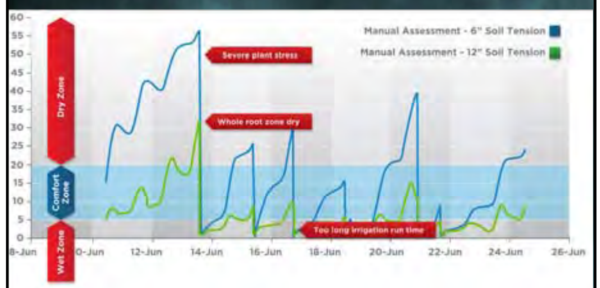
Complementing ET in managing irrigation

- ET: For a runner, adjusting your diet based on your weekly weight basis or your past calorie consumption: risk of reducing your efforts due to underfeeding if rate of feeding does not feed enough
- Tension real time: heart and calorie monitor: you will adjust your food uptake based on your real time consumption and your feeding rate hence optimizing your efforts. Irrigation initiated at a tension threshold h_c to provide adequate soil water flux to the plant. It considers actual ET ($s_0 + q_0$) to make sure the plant is properly supplied during peak activity (in real time)

$$h_c = -\frac{1}{\alpha^*}\ln\left(-\frac{1}{\alpha^* K_{sG}}\left|\begin{matrix} q_0\alpha^* e^{-\alpha^* L} - q_0\alpha^* \\ +S_0 e^{-\alpha^* L}\alpha^* L \\ +S_0 e^{-\alpha^* L} - S_0 \end{matrix}\right|\right) + L$$

L=rooting depth
K_s and α = soil hydraulic properties
s_0: is plant transpiration
h_c= tension irrigation threshold

Observed tension fluctuations at two depths under manual assessment



Part 1: Comparing grower managed (Crop ET and visual assessment) with a real time tensiometer approach

Saving water

- Stay within the blue: initiate irrigation before being out of the blue zone with the top tensiometer: likely avoid prewetting and risk of slaking
- Stop it before the lower tensiometer hits low values: avoid water logging and leaching

Using tension or suction forces to drive irrigation decisions

Stopping irrigation: tension drops

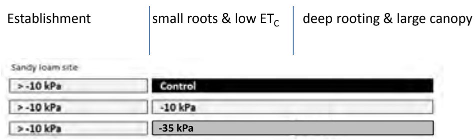
Initiating irrigation: threshold reached

Newer approach to maintain the crop in a non limiting flux situation (below h_c) with two tensiometers

Comparing irrigation threshold to initiate irrigation (top of the blue band)

Determine h_c to get top yield irrespective of water use (2011-2014)

Irrigation treatments applied though the growth cycle (CRBD with 5 replicates)



Results for 2012 to 2015 in California and Québec

Plant performance and water used (Weekly measurements from January to June)

15 minute real time soil water potential at 15 cm and 30 cm(3 reps) using wireless Hortau tensiometers

Irrigation initiated by the irrigator (2012,13, 14) or automated (2015)

Parameters Measured

Plant performance and hydric stress measurements (Weekly measurements from January to June)

- Yield in sub-sampling sites
- Size of the fruits (caliber)
- Fruit quality using Brix index
- Plant size (canopy area)
- Leaf Water Potential (SWP) using pressure chamber
- Leaf temperature with infrared thermometer

Effects of real time irrigation management on strawberry production:

	Watsonville	Salinas	Oxnard
Soil series	Clear Lake clay	Salinas Clay and Mocho silty loam	Hueneme sandy loam
Yield difference from optimum thresholds	16% (8,000 pounds per acre)	17%	14%
Optimum tension cbars (top of blue band)	10	13	8
Acre foot/Acre difference between treatments	0.30	0.15	0.15
Percentage of crop ET for top yield	75	49	114

Parameters Measured

Soil sampling and soil analysis (3 soil samples/plot)

Initial properties

- **Texture**
- **Saturated Hydraulic Conductivity (Ksat)**
- **Soil Water Retention Curves**
- **Salinity (Electrical Conductivity (EC)) and pH**

Weekly determination

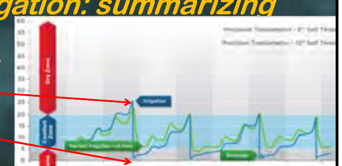
- **Soil salinity from SSE method (1: 1 suspension)**
- **Soil salinity (EC) using suction lysimeter**
- **Amount of water/ha using flowmeters (non replicated though)**

Real-time irrigation: summarizing

Real time management:

Irrigation triggered

Irrigation stopped before leaching
Fast leaching = 0 kPa



Etc management:

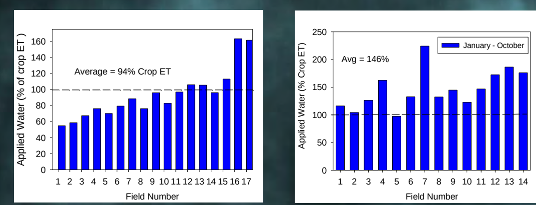
Irrigation triggered too late

Too long irrigation = leaching and waterlogging

Flux is important to be maintained non limiting through irrigation

				Water Used % of crop ET		Yield Increase Relative to Grower
	Year	Soil Type	Region	Grower	-10 kPa	(%)
Wastonville	2011	Clay	CA	100	93	0
	2013	Clay	CA	144	84	0
	2014	Clay	CA	83	83	26
Salinas	2012	Silty Clay Loam	CA	163	68	17
	2012	Silty Clay Loam	CA	100	114	14
Oxnard	2013	Sandy Loam	CA	93	128	6
	2014	Sandy Loam	CA	100	154	7
Île d'Orléans	2012	Gravelly Clay Loam	QC	35	42	20
	2013	Gravelly Clay Loam	QC	49	42	18
	2014	Gravelly Clay Loam	QC	52	63	0
Average Water Use in Percentage of Crop ET (CA only):				112	103	10

CA: California; QC: Québec



Percentage of crop ET applied by growers in 2010 and 2011 in the Watsonville area (drawn from Cahn, 2012)

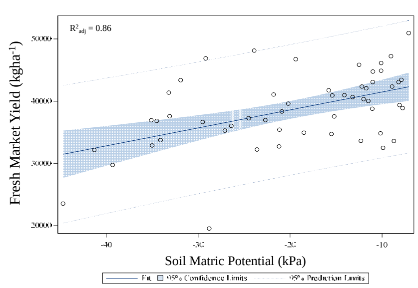


Fig. 2. Predicted total fresh market yield (1 kgha^{-1} = 0.89 lbac^{-1}) from average soil matric potential reached before irrigations using data from seven experimental sites (centered regression line).

Cost-benefit Analysis – *Case study of a 50-acre farm*

Assumption: conventional management triggers irrigation at -15 kPa, on average.

We are looking at the gains and losses associated with the management based on tension at -10 kPa compared to conventional management at -15 kPa, for a 50 acre-farm.

LOSSES

REDUCED INCOMES

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INCREASED COSTS

Increased Variable Costs

	$lb^{-1}	($)
Operating Costs	0.50	**32 250**

Increased Fixed Costs

Wireless Tensiometer Technology	**($)**
○ Depreciation (0% intesrest) 24 480 $ / 5 years	**4 896**
○ Annual Service Fees	**3 000**
○ Initial Costs (Shipping & Installation) 975 $ / 5 years	**195**
Total	**($) 40 341**

GAINS

INCREASED INCOMES

	lbac^{-1}	lb supp.	$lb^{-1}	($)
Yield Gain	1 290	64 500	1.00	**64 500**

REDUCED COSTS

Reduced Variable Costs

	acftac^{-1}	Tot. Water	$acft^{-1}	($)
Water Savings	0.20	10	150	**1 500**

Reduced Fixed Costs

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Total ($) **66 000**

Net Change in Profit : 25 659 $ → *Payback Period: 0.8 year*

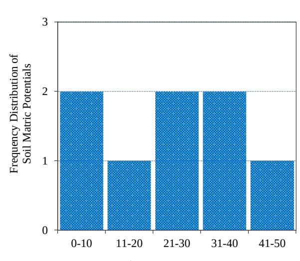


Fig. 3. Frequency distribution of average soil matric potentials reached before irrigations considering eight treatments under conventional irrigation management. Treatments consisted of the grower standard procedure, which aimed at applying 100% of crop ET, and of the treatment based on 100% of crop ET.

Part 2: Using a real time tensiometer approach to manage deficit irrigation

Adjusting critical irrigation threshold

- h_c is expected to vary during the season because rooting depth (L) and crop ET (S_o) vary

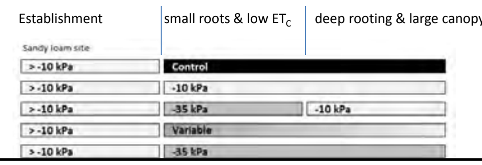
$$h_c = \frac{1}{\alpha^*}\ln\left[-\frac{1}{\alpha^* K_{sc}}\left(\begin{array}{l} q_0\alpha^* e^{-\alpha^* L} - q_0\alpha^* \\ +S_0 e^{-\alpha^* L}\alpha^* L \\ +S_0 e^{-\alpha^* L} - S_0 \end{array}\right)\right] + L$$

- Software and controllers could allow adjustment for increasing root and increasing ET and implement them for managing irrigation
- Alternatively, a simpler approach could maintain a lower (-35 kPa) threshold when the roots and the plants are small and move to a higher (-10 kPa threshold) when the plants gets bigger to save water

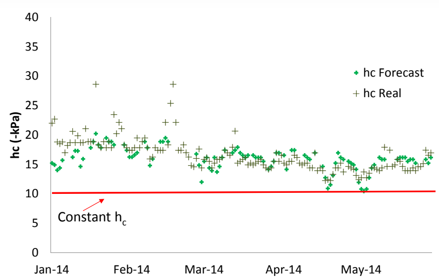
Main objective

Determine if adjusting the irrigation threshold h_c could increase water productivity without affecting yield

Irrigation treatments applied though the growth cycle (CRBD with 5 replicates)

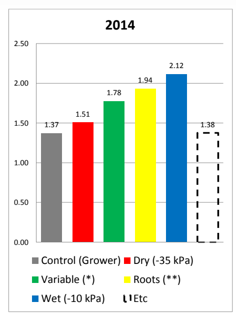


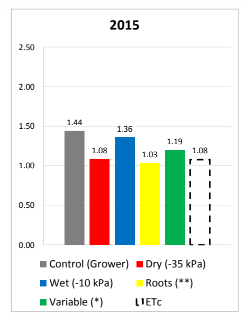
Daily critical threshold (h_c) calculated with Forecast of ET and with actual threshold using monitoring data of ET (Oxnard 2014)



Cumulative total water use for the 2 seasons of experiment in ac-ft/ac

a) Year 2015: from January 9th to June 11th 2015
b) Year 2014: from November 26th 2013 to June 12th 2014





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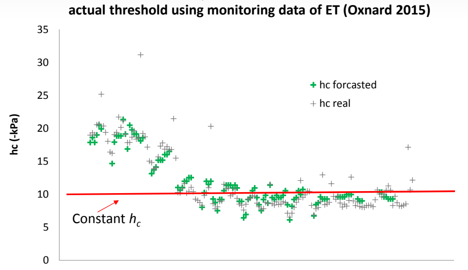
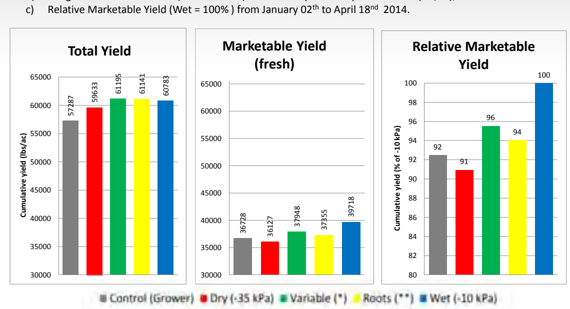


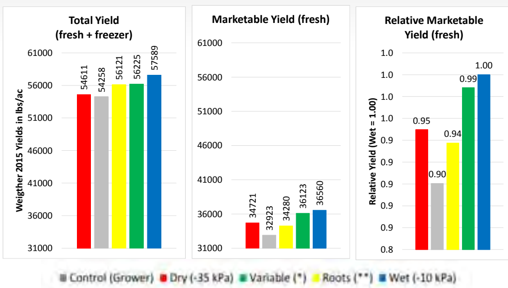
Weighted Yields for 2014

a) Weighted Total Yield during the whole season from January 02th to June 05th 2014 (lbs/ac);
b) Weighted Marketable Yield (Fresh Market) from January 02th to April 18nd 2014 (lbs/ac);
c) Relative Marketable Yield (Wet = 100%) from January 02th to April 18nd 2014.



Weighted Yields for 2015

a) Weighted Total Yield (Fresh Market + Freezer) during the whole season (January 9th to June 11th 2015);
b) Weighted Marketable Yield (Fresh Market) from January 9th to April 2nd 2015;
c) Relative Marketable Yield (Wet = 1.00) from January 9th to April 2nd .



Treatments

Implantation phase	Low ETc period	High ETc period
Sandy loam site		
>-10 kPa	Control	
>-10 kPa	-10 kPa	
>-10 kPa	-35 kPa	-10 kPa
>-10 kPa	Variable	
>-10 kPa	-35 kPa	
Clay loam site		
>-10 kPa	Control	
>-10 kPa	-10 kPa	
>-10 kPa	-35 kPa	-10 kPa
>-10 kPa	100% ET	
>-10 kPa	75% ET	
>-10 kPa	50% ET	

Summary of the performances for both years

Irrigation treatments	Relative yield[1]	Water used
	%	acre-foot per acre
Grower	91	1.41
-10 kPa	100	1.74
-35 kPa	93	1.30
Partial deficit		
Roots	94	1.51
Variable	98	1.49
Reference ET	-	1.23

[1]Main effects significant at p=0.05

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Water use efficiency and relative yield

Sandy loam

	Step	Dry	Variable	Wet	Grower
Yield (% of Grower)	104 a	105 a	110 a	111 a	100 a
Water use efficiency (kg/ha.cm)	1229 a	1187 a	1118 a	996 b	846 c

Statistical analyses were performed using proc mixed and proc GLM in SAS (p<0,05).

Clay loam

	Step	Wet	50% ET	100% ET	Grower
Yield (% of 100% ET)	95 ab	105 a	76 c	100 a	83 bc
Water use efficiency (kg/ha.cm)	1539 a	1407 a	1531 a	1109 b	1208 b

Statistical analyses were performed using proc mixed and proc GLM in SAS (p<0,05).

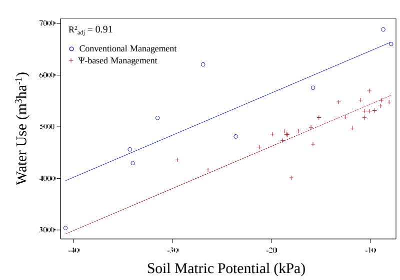

Fig. 1. Effect of (1) average soil matric potential reached before irrigations and (2) irrigation management method on predicted total WU (1 acft.ac^{-1} = 3047 m^{3}ha^{-1}) using data from eight experimental sites (centered regression line).

Deficit Irrigation – using wireless tensiometers

Impact on profit of a deficit irrigation (-15, -20, -30 kPa) relative to a wet management based on tension (-10 kPa)

					Operation Costs ($\$kg^{-1}$) (*$\$lb^{-1}$*)				
					1.10 *(0.50)*				
					Annual Fresh Strawberry Price ($\$kg^{-1}$) (*$\$lb^{-1}$*)				
					2.20 *(1.00)*				
					Water Price ($\$m^{-3}$) (*$\$acpi^{-1}$*)				
					0.12	0.28	0.41	0.81	4.05
					150	*350*	*500*	*1000*	*5000*
Deficit ψ-based management	Yield decrease (relative to -10 kPa)		Water savings (relative to -10 kPa)		Net Gain (Loss) ($\$ac^{-1}$)				
-kPa	***lbac***$^{-1}$	*%*	***acftac***$^{-1}$	*%*					
-15	-1290	*-4*	-0.13	*-7*	(625)	(598)	(578)	(511)	25
-20	-2580	*-7*	-0.27	*-11*	(1 250)	(1 196)	(1 156)	(1 022)	50
-30	-5150	*-16*	-0.54	*-23*	(2 495)	(2 387)	(2 307)	(2 039)	105

Conclusions

- **Real time management at -10 kPa is important for more crop per drop and higher revenues**
- **Target is -10 kpa to initiate irrigation, any stress even early in the season has generated yield decreases and revenue losses.**
- **Water savings do not compensate for yield losses but at a cost of 1000-5000$ per acre-foot**

- - - Thank you - - -

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Driscoll's

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