

## **Strawberries: Effects of Modifying Irrigation Methods for Transplant Establishment**

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### **ABSTRACT**

In 2009, the Cal Poly Irrigation Training and Research Center began a multi-year analysis of the current irrigation practices of strawberry growers on the Central Coast of California. Specifically, the project examines the impacts of salinity on young strawberry transplants and the current practice of sprinkler use during the establishment of transplants for salinity control in areas where drip irrigation is available. The overall goal of the project is to study current practices and determine any conditions where growers can minimize or eliminate sprinkler use on strawberries, thereby conserving water, saving pumping costs, and reducing runoff. Results from the first year of the study have suggested that, contrary to previous belief, using reduced sprinkler or only drip irrigation results in higher yields than conventional methods.

### **INTRODUCTION**

In recent years, Californian farmers have seen an increase in water and pumping costs. This, coupled with increasing concerns about the environment, has led many in the agricultural industry to seek out ways to use water more efficiently. For the past two growing seasons, the Irrigation Training and Research Center (ITRC) in San Luis Obispo, CA has been conducting research on modified irrigation techniques that will allow strawberry growers in California to reduce their water use and eliminate runoff from their fields without affecting the total yield of the crop.

Commercial strawberries in California are grown on raised, plastic-covered beds (Figure 1). The widths and heights of the beds vary by grower, but the basic layout is the same throughout the state. Typical practice is to place lines of drip tape under the plastic mulch, down the length of each bed and install a grid of sprinklers throughout the field. A tractor implement punches holes along the bed, and the transplants are planted by hand.

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**Figure 1. Typical California strawberry bed with young transplants**

Since the transplants are not well developed and undergo a significant amount of trauma during the transportation to the field and hand planting, the weeks immediately after planting are the most sensitive time for the crop. The major concern during this time is the salinity around the plant. Growers typically utilize overhead sprinklers in the first 4-6 weeks during transplant establishment in order to uniformly leach salts down, away from the root zone. After the strawberry plants are well developed and robust enough to handle increased levels of stress, the drip system is utilized as the sole means of irrigation. The key issue with this technique is the amount of runoff generated during sprinkler irrigation events.

**Irrigation methods evaluated.** Three protocols were established to be used by the growers participating in the project (Figure 2):

1. Conventional Sprinkler Irrigation (SPI) – Sprinkler irrigations were performed for 4-6 weeks during transplant establishment.
2. Partial Sprinkler Irrigation (PSI) – Sprinklers were allowed for special cases such as right after planting, during excessively hot dry wind events, and for frost protection. This was limited to 3-5 events during the season.
3. Drip Only Irrigation (DOI) – No sprinklers use was allowed. The drip system was the only means of irrigation during the season.



**Figure 2. Sammis 2/13/10; left to right: SPI, PSI, DOI**

The level of participation for each protocol varied amongst the growers. Since the test areas were set up on a large demonstration scale, significant amounts of each grower's crop were at stake. Some growers deviated from the protocol in order to

ensure good yields and a profitable season. Deviations from the defined protocol will be discussed later.

**Salinity and strawberries.** Salinity is generally reported in units of electrical conductivity (EC), generally deciSiemens per meter (dS/m). Three common EC measurements are used:

1.  $EC_w$  – salinity of the irrigation water.
2.  $EC_{sw}$  – salinity of the soil water solution. This is the salinity that the plant actually experiences.
3.  $EC_e$  – salinity of the saturated soil extract, which is always somewhat lower than  $EC_{sw}$  due to the way in which it is determined (Burt and Styles 2007).

Strawberries are considered to be extremely sensitive to salts, especially compared to other crops. High salt levels have been reported to cause decreased strawberry size and overall yield (Larson 1994). Bernstein (1965) estimated that an electrical conductivity of saturated soil extract or  $EC_e$  of 1.5 dS/m resulted in a 10% yield loss. Maas and Hoffman (1977) and Maas (1990) report that strawberries have a threshold  $EC_e$  of 1.0 dS/m and 33% loss in yield for every 1 dS/m increase beyond this threshold value. To put this in perspective, one can compare the threshold  $EC_e$  of strawberries to that of tomatoes. Tomatoes have a threshold  $EC_e$  of 2.5 dS/m (1.5 times that of strawberries) and a decrease in yield of only 9.9% for every 1 dS/m past the threshold value (Maas and Hoffman 1977).

The study conducted by ITRC in 2009 found  $EC_{sw}$  values ranging from 3-7 dS/m for the DOI test sites to 7-8 dS/m on the SPI sites. However, the DOI sites generally had a much higher soil moisture content, which may have been the reason for the lower values. Also, the salinity measurements were of the soil water solution, not the saturated soil extract. So, these values cannot be directly compared to the threshold  $EC_e$  values provided above.

It has been shown that the concentrations of specific salts affect the vigor of strawberry plants, and that the specific composition of the soil water solution in addition to the EC is important in the salinity management of strawberries. Ehlig and Bernstein (1958) evaluated several different salt treatments (NaCl, CaCl<sub>2</sub>, and Na<sub>2</sub>SO<sub>4</sub>). Significantly less fresh weight was produced with the NaCl treatment. Maas (1990) reported concentrations of Cl in saturation extracts of 10-15 mmol/L causing yield loss. Suarez and Grieves (2007) reports sodium chloride and mixed salt chloride treatments causing significantly more osmotic stress than sodium sulfate and mixed salt sulfates. Chlorides appear to have more of a negative effect on strawberries than other salts.

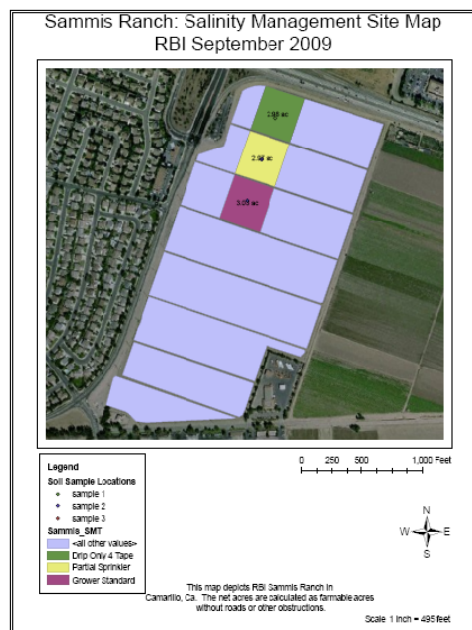
Current salinity management techniques involve heavy sprinkler irrigations just before and after strawberry transplants are put into the beds. This leaches salts away from the young sensitive plants and helps compact soil around the roots. Since the most salt sensitive growth period for most crops is emergence, sprinkler irrigation is often preferred over subsurface drip for leaching salts as it removes the tremendous

uncertainties associated with how evenly water will move upward from buried emitters (Burt and Styles 2007). This also results in a significant amount of runoff due to the plastic bed covers. The bed covers are useful for weed control and reducing evaporation but do not allow good infiltration. Water runoff from strawberry fields has recently been the blame for contaminating local waterways in Oxnard, CA (Krist 2007).

## PROCEDURE AND METHODS

**Test sites.** Test plots were established at three locations:

- The Manzanita Berry Farms test site is located just west of Santa Maria, CA. Four test plots were set up at this location. Two were reduced sprinkler; two were conventional. According to the NRCS soil maps from 2009, the soil in this location is Sorrento sandy loam. This is a well drained soil, ideal for strawberry production.
- The Eclipse Berry Farms test site is located near Oxnard, CA. Six test plots were set up at this location. One was a reduced sprinkler and five were conventional. Soil at this site is a well drained Camarillo sandy loam. The grower at this location deviated significantly from the reduced sprinkler protocol. 15 sprinkler irrigation events occurred on the reduced sprinkler plot. This affected water use numbers significantly.
- The Reiter Brothers Inc. Sammis site is located in Camarillo, CA (Figure 3). Three test plots were set up at this location for each of the defined protocols. The soil type is a well drained Pico loam.



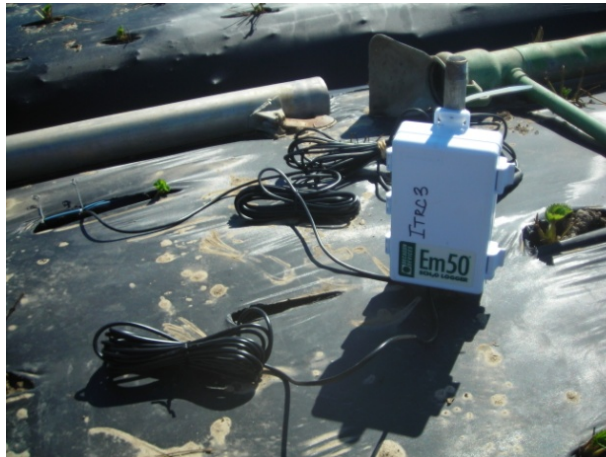
**Figure 3. Sammis site map**

**Flow meters.** Magnetic flow meters were chosen for a flow measurement device due to their high reliability, ease of installation, and accuracy. A magnetic flow meter

(“magmeter”) has no moving parts and does not require the pipe to be full in order to make accurate measurements. It also has the ability to totalize flows and provide an accurate volumetric reading. This was a necessity, as all water use numbers would need to be compared volumetrically. Also, magmeters are much less sensitive to turbulent flows than most other flow measurement devices. This allowed the meter to be installed in close proximity to elbows or valves, which made the installation very convenient. Both types of magnetic flow meters used are made by SeaMetrics and have a rated accuracy of  $\pm 1\%$ .

**Data loggers.** Decagon Em-50 data loggers were installed at every site at the Sammis, Eclipse and Manzanita locations (Figure 4). These small data loggers were placed on the southern end of the fields, near the middle row. Their compact size allowed them to be placed virtually anywhere in the field without the risk of damage from passing equipment. Each data logger was connected to two Decagon 5TE soil moisture/temperature/EC sensors and one Decagon PS1 pressure switch. The 5TE sensors were run down the strawberry bed and placed at a depth of 3” in each of the two middle plant rows. This ended up being essentially in the center of the field. The PS1 pressure switch was connected using a brass T connection to a nearby sprinkler head in order to monitor the duration and frequency of sprinkler irrigations. Generally, the data loggers required little maintenance. Once throughout the season, the batteries had to be changed and occasionally a 5TE sensor would fail.

Later in the growing season, it became of interest to monitor soil conditions at deeper levels at the Sammis location. This was accomplished by adding two additional 5TE sensors at each of the three Sammis sites. These were installed at depths of 6 and 12 inches.



**Figure 4. Decagon Em50 Datalogger Installation at Sammis Block A**

**Data collection.** Data collection consisted of simply visiting each site and downloading the logged data onto a laptop. This was done on a weekly basis during the period of transplant establishment. This allowed for frequent analysis of soil salinity levels during the most sensitive growth period. During the later stages of

growth, data was collected on a bi-weekly basis as the strawberry plants are much more resistant to salinity during this period.

*Soil sample procedure.* Periodically throughout the growing season, soil samples were taken in order to monitor the specific salt concentrations present in the soil. This was done by pulling samples from 0-3", 3-6", and 6-12" from the two middle plant rows. The EC and soil moisture content were also checked at each of the three depths using a handheld Decagon ProCheck device with a 5TE sensor. The samples were taken from near the center of the field close to where the 5TE data logger sensors were located. The locations of the samples vary somewhat between dates but for a given date, each sample was taken from the same spot in each field.

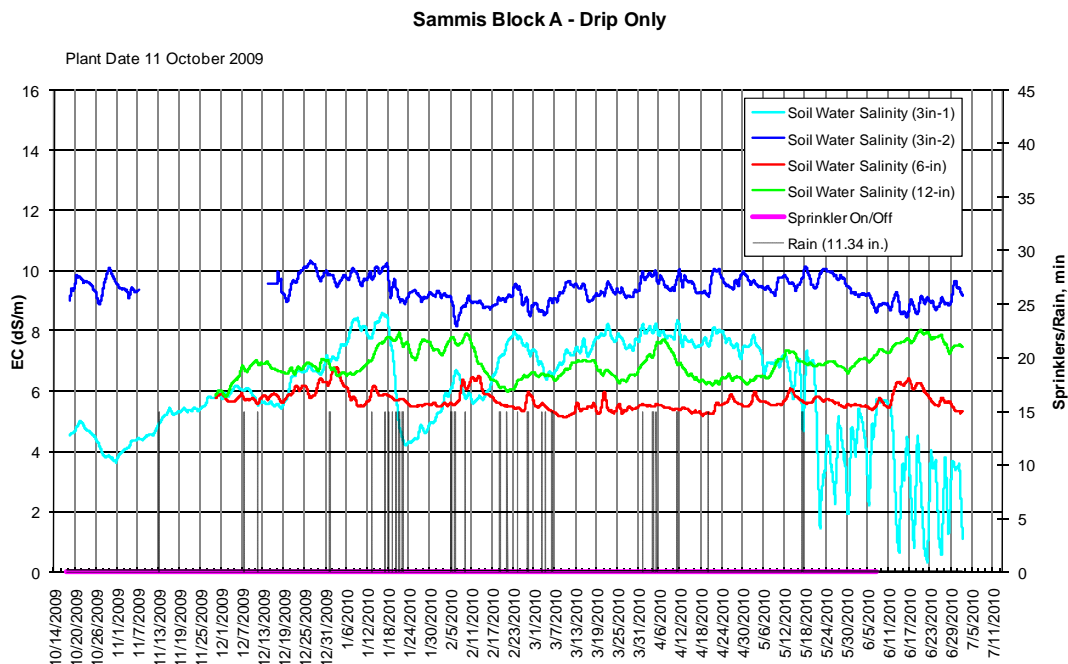
*Salinity snapshot procedure.* In an attempt to track the movement of salts, EC measurements were taken across the top of the strawberry bed at a depth of 3 inches on several occasions throughout the growing season. This was done using a handheld Decagon ProCheck device with a 5TE sensor. These measurements were taken near the middle bed at both the north and south ends of each field. The locations of the measurements vary somewhat between dates, but for a given date, each measurement was taken from the same spot in each field.

## **RESULTS AND ANALYSIS**

### **Data Results**

*Soils data from loggers.* All continuous data was obtained from the Decagon data loggers. The resulting data was highly variable between all of the test plots. This made a statistical analysis of the salinity data infeasible. Clearly, there is a tremendous amount of uncertainty associated with managing salinity. Additionally, the charts clearly show the huge effect that rainfall has on salinity. Heavy rains in mid-January lowered salinity levels by up to 50% while sprinkler irrigation events had a much less apparent impact on the soil salinity.

*Soil lab data.* Much like the continuous data, the soil lab data had no clear trends. An important detail to notice on these charts is that chloride levels are not always directly related to salinity levels. For example, Sammis Block B shows an increase in  $EC_{sw}$  from November 1 to January 1 at the 3-6" and 6-12" depths. During the same time period, the chloride levels drop at these depths. This indicates that the soil salinity is dominated by something other than chlorides, so it is much less harmful to strawberry plants. The salinity levels displayed in Figure 5 showed some common trends. The salinity levels fluctuated daily. There were noticeable drops in the salinity level after periods of rain. This would indicate local leaching had occurred near the sensors. Then the salinity levels would begin to rise after the rain subsided. However, this held true to the sensors only in the 0"-3" range. The sensors deeper than that did not record as prominent of a fluctuation as the 0"-3" range. This would indicate there wasn't a lot of downward movement of the irrigation water.



**Figure 5.** Sample salinity sensor tracking from Sammis Block A

*Picture comparisons.* Due to the large amount of variability in the salinity data, it was impossible to statistically prove that either of the irrigation techniques is better than the other in regards to salinity management. In order to supplement the salinity sensor data, the picture logs were compared side by side in order to observe any visible signs of stress or plant vigor that varied between the irrigation methods. Compared side by side, the SPI, PSI, and DOI plants look virtually identical. Observations from growers at Manzanita and Sammis confirm that there is no visible difference between the plants.

**Impact on yields.** The yields in the first season showed that there was little impact due to the irrigation method. However, there was noticeable damage to plants where the salinity levels were very high due to the placement of the drip irrigation tape. The conclusion was that even though there was some die-off, the other plants seemed to respond better to keep the yields about equal.

Second season yields have shown that the yields are higher with the new irrigation protocol. The yield increase in Manzanita was 13% on the PSI protocol compared to the SIP conventional protocol. The grower also reported the yields on the PSI protocol resulted in early field gains at a time when the market prices were favorable.

The data from Sammis in 2009-2010 (Table 1) has also shown that the yields have improved using the new irrigation methods. The PSI protocol had an 8% increase in yield and the DOI protocol had a 13% increase in yield.

**Table 1.** Yield data from Sammis (2009-2010)

Date	Cartons per Event			Cumulative Totals		
	Reduced Sprinkler	Drip Only	Conventional	Reduced Sprinkler - Cumulative	Drip Only - Cumulative	Conventional - Cumulative
12/26/2009	0	0	0	0	0	0
1/2/2010	0	0	0	0	0	0
1/9/2010	24	31	17	0	0	0
1/16/2010	46	55	35	24	31	17
1/23/2010	40	52	57	70	86	52
1/30/2010	40	21	5	110	138	109
2/6/2010	101	141	93	150	159	114
2/13/2010	7	15	21	251	300	207
2/20/2010	132	85	97	258	315	228
2/27/2010	79	155	63	390	400	325
3/6/2010	102	134	104	469	555	388
3/13/2010	283	219	212	571	689	492
3/20/2010	461	435	515	854	908	704
3/27/2010	313	346	261	1315	1343	1219
4/3/2010	432	467	435	1628	1689	1480
4/10/2010	356	204	319	2060	2156	1915
4/17/2010	215	183	187	2416	2360	2234
4/24/2010	232	341	233	2631	2543	2421
5/1/2010	424	320	390	2863	2884	2654
5/8/2010	299	249	259	3287	3204	3044
5/15/2010	389	392	440	3586	3453	3303
5/22/2010	457	380	327	3975	3845	3743
5/29/2010	472	362	476	4432	4225	4070
6/5/2010	346	329	394	4904	4587	4546
6/12/2010	22	94	66	5250	4916	4940
6/19/2010	118	140	81	5272	5010	5006
<b>Totals</b>	<b>5,390</b>	<b>5,150</b>	<b>5,087</b>	<b>5390</b>	<b>5150</b>	<b>5087</b>

Notes on specific sites include:

- Reported yields from Sammis showed highest yields for the PSI plot followed by the DOI and SPI plots, in that order. However, the percent difference between each of the test plots was less than 5%.
- Yield was reported from Manzanita in a way that broke each of the test plots up in many smaller test plots. The 30 smaller plot yields allowed for a statistical analysis to determine the effect of irrigation method on yield.
- The PSI plots at Manzanita averaged 13.4% less water used than SPI plots. This equates to a savings of 5.4 inches of water per acre.
- For purposes of the water use comparison, only blocks C (PSI) and I (SPI) of the Eclipse site were used. This was due to flow meter failure and deviations from the defined protocol on the other blocks. The partial sprinkler block used 17% less water than the conventional block. This equates to a savings of 5.8 inches of water per acre.
- The blocks at Sammis showed a 15% water savings for the DOI and a 4% water savings for the PSI when compared to the SPI plot. This equates to only a 4-inch and a 1-inch savings per acre, respectively.

## LESSONS LEARNED

The study is still at the beginning stages so the conclusions are based on limited information. The results from the first year (2008-2009) were mixed due to some major die-off issues (up to 30% in one demonstration plot). However, there are some key items that we are seeing as we approach the end of the second year:



1. Salinity is a key determinant in the healthy establishment of the strawberry transplants.
2. Row crop drip tape placement must be done correctly in order to micro-leach salts in the beds. This means that in the Oxnard Plain, growers may need to use four low flow tapes in order to successfully switch to the DOI or PSI protocols. Growers in Santa Maria might be able to use only two tapes per bed but the salinity must be evaluated in order to make sure the salts are not building up at the base of the plant. Using three tapes is not recommended on beds with four plant rows.
3. Monitoring the salinity of the soil and the irrigation water will help growers switch from the conventional irrigation method to a new protocol.
4. The irrigation water is one of the key determinants of whether there may be a problem. If the water quality is 1.0 dS/m or less, the impact is minimal. If the salinity of the irrigation supply water is 1.2 dS/m, the grower could see a 10-25% yield impact. It should be noted that well water, surface water, and reclaimed water sources have changing salinity characteristics during the season.
5. Salts come from various sources. Some sources of salt include the irrigation water, gypsum applications, fertilizers (both pre-plant and liquid), and composting (this seems to be a significant source).
6. Traditional salinity references have used the soil salinity as the key determinant for the salt impact on yields. The traditional approach states that if the soil salinity ( $EC_e$ ) approaches 4.0 dS/m the yield will be 100% impacted (i.e., no yield). However, this research confirmed most growers in the Oxnard Plain routinely work in soils at 4-6 dS/m. with very little impact on yields. The reason is that they have been managing their salts properly.
7. Rain washes salts away from young transplants. The data clearly show that rain water (which is essentially salt-free) can push salts away from the plants. The graphs from all of the fields show rain represented by the black lines on the bottom of the graph. The data shows how dramatically the salinity level dropped after the rain.
8. The new protocols result in a yield increase up to 10%. The new protocols have also decreased the water use by over 10%. This research project has shown that the new approach has resulted in **more crops per drop.**

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