Strawberries Transplants: Modifying Irrigation Methods for Establishment

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Abstract. *The purpose of the project is to develop an analysis of the current irrigation practices of strawberry growers on the Central Coast of California. The primary research evaluation centers on the time period during the establishment of transplants where sprinklers are used even though drip irrigation is available, often due to salinity concerns. The specific objectives of the project are to: (1) Set up research areas and control plots on a demonstration scale, (2) determine the key factors that affect the problems in early growth of transplanted strawberries, (3) determine relationships between the use of irrigation water and the control of salinity, and (4) provide a multi-year analysis to determine long-term salinity impacts on yields. This project examines the motives, methods, and need for sprinklers on strawberries, and is designed to determine the conditions where growers can conserve water by minimizing or eliminating sprinkler use on strawberries. This project targets drought management and aims to reduce runoff as a potential source of contaminants reaching waterways. The results of this study have demonstrated on a block scale that yields can be increased by up to 10%, water use decreased by 10%, and runoff eliminated by heavily reducing or eliminating sprinkler use.*

Keywords. salinity, drip, irrigation, microirrigation, strawberries, runoff, drought management

Introduction

For the past three growing seasons, the Irrigation Training and Research Center (ITRC), has been conducting research on the water use, salinity levels and various other information related to strawberries. This paper is a summary of work that can be found online at the ITRC website (www.itrc.org/projects.htm).

The project started in the fall of 2009 with a capacity issue on the Pumping Trough Pipeline (PTP), which is managed by the United Water Conservation District and supplies growers in the Oxnard area. At the time, strawberries growers would all plant during the same period in October (using sprinklers on the new transplants) and the demand created by sprinkler irrigation exceeded the pipeline's capacity. Faced with complaints of poor service, the district felt the best course of action was to regulate the practice of using sprinklers in October, and threatened to ban sprinkler irrigations for strawberry growers that month. Local growers requested assistance to determine the best method to move away from sprinkler irrigation towards alternate methods. The simplest option was to use the drip irrigation system that is already installed when the transplants are brought to the field, but growers were concerned about the effects of salinity without sprinklers.

The key objectives of the project are to:

- keep the strawberry transplants healthy
- switch to drip irrigation as soon as possible

Specifically, this involves the following steps:

1. Set up research areas and control plots on a demonstration scale
2. Determine the key factors that affect the problems in early growth of transplanted strawberries
3. Determine relationships between the use of irrigation water and the control of salinity
4. Provide a multi-year analysis to determine long-term salinity impacts on yields

Soil salinity, yield data and water use on the strawberry fields during the first three years of the projects will be discussed in this paper.

Figure 1.   California strawberry bed in February, early in the growing season

Irrigation Methods Evaluated
The project continues to use three different irrigation methods. These methods are:

- conventional sprinkler (up to 6 weeks of daily sprinkler application)

- reduced sprinkler

- drip only

In the first two years of the project, the focus was on establishing the project and evaluating initial data. For current and future years, the project focuses on evaluating and applying new techniques that have been discovered through the study. For example, some growers used the method of reduced sprinklers, which allowed the use of sprinklers for special cases such as excessive hot dry wind events (Santa Ana winds), and for frost protection. This was limited to 3-5 events during the season. Growers have noticed an improvement in yields and less water usage with the reduced sprinkler method. The drip only protocol has been successful but may be dependent on other factors such as lighter soils and more rainfall in a given year.

Several blocks of strawberries have been converted from a convenional method (growers performing sprinkler irrigations for 4-6 weeks during transplant establishment) to a reduced sprinkler one. This is partly due to the studies that were conducted on those strawberry fields in the previous years (2008-2011). Once growers have seen the benefits of a new practice, they have opted to change to the new practice. This has caused somewhat of a problem for the study since the control is no longer available. However, it is important to remember that one goal of this project was to demonstrate new techniques.

Salinity
Salinity is a key determinant for the success of the project. Salinity is generally reported in units of electrical conductivity (EC), generally deciSiemens per meter (dS/m). Three common EC measurements are used. EC_w refers to the salinity of the irrigation water. EC_{sw} refers to the salinity of the soil water solution. This is the salinity that the plant actually experiences. EC_e refers to the salinity of the saturated soil extract and is always somewhat lower than EC_{sw} due to the way in which it is determined (Burt and Styles 2007). This project used a new type of sensor that was not widely used prior to 2008 and which allows for the continuous evaluation of the EC_{sw}, allowing for more accurate survey data.

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 (EC_e) of 1.5 dS/m resulted in a 10% yield loss. Mass and Hoffman (1977) and Mass (1990) report that strawberries have a threshold EC_e of 1.0 dS/m and experience a 33% loss in yield for every 1 dS/m increase beyond this threshold value. For comparison, 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 (Mass and Hoffman 1977).   It must be noted that the salts present in these studies are typically chlorides. Soils and water that are high in calcium tend to "buffer" these values and may lead to an adjustment of up to +3 dS/m. Experience from

this project has shown that growers are able to farm on fields with EC_e values of 4-5 dS/m with no reported yield decreases.

Traditional salinity management techniques involve heavy sprinkler irrigations just before and after strawberry transplants are put in to the beds. This leaches salts away from the young sensitive plants and helps compact soil around the roots. 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). The heavy use of sprinklers at this time was to blame for the supply problems in the Pumping Trough Pipeline in 2009. An additional problem is the significant amount of runoff that occurs when sprinkler irrigation is combined with the use of plastic bed covers for weed control and evaporation reduction. Water runoff from strawberry fields has recently been blamed for contaminating local waterways in Oxnard, CA (Krist 2007).

ITRC utilizes two devices for monitoring salinity levels: Decagon Em50 data loggers are used in conjunction with Decagon 5TE soil moisture/EC sensors to constantly monitor salinity and moisture levels at each of the test sites. This setup requires someone to physically go to the onsite data logger to download information. Internet-based systems are available that transmit data from the Decagon 5TE sensor via a radio to a base station where it is posted on a website. These systems allow several 5TE soil moisture sensors, flow meters, and weather station readings to be broadcasted via the internet for real-time monitoring, but have proven to be unreliable (see later discussion).

Procedure and Methods

Test Sites
Table 1 lists the project test sites. One clear conclusion has been that the ease of growing strawberries in Oxnard depends heavily on location. The key differences are that on the east side of the Oxnard plain rainfall is more abundant, water requirements are lower, and the number of wind events is smaller.

Table 1. Strawberry project fields on the Central Coast

Santa Maria	Oxnard	Watsonville

Manzanita 2
   Block I – 2-Tape Drip Only
   Block II – 2-Tape Drip Only
   Block A2 – 2-Tape Conventional
   Block A4 – 2-Tape Conventional
   Block B2 – 2-Tape Conventional
   Block B4 – 4-Tape Conventional
 	
Manzanita 7
   Block A – 2-Tape Conventional
   Block B – 2-Tape Conventional
   Block I – Drip Only
   Block II – Drip Only
 	
Rice
   Block A – 4-Tape Partial Sprinkler
   Block B – 4-Tape Drip Only
 	
Main
   Block B – 4-Tape Reduced Sprinkler
   Block B – 4-Tape Reduced Sprinkler
	Eclipse
	   Block C – 4-Tape Reduced Sprinkler
	   Block I – 4-Tape Conventional
	   Block II – 4-Tape Conventional
	
	Donlon
	   Block A – 4-Tape Partial Sprinkler
	   Block B – 4-Tape Partial Sprinkler
	
	Sammis
	   Block A – 4-Tape Drip Only
	   Block B – 4-Tape Partial Sprinkler
		Redman
		   Block A – 2-Tape Drip Only
		
		Porter
		   Block A – 2-Tape Drip Only
		
		Captainich
		   Block A – 2-Tape Conventional
		
		Shultz
		   Block A – 2-Tape Drip Only

Soil Texture

As mentioned previously, the ease of salinity management in a block depends largely on soil texture. The blocks used for this project are planted in several different types of soil, as shown in the diagram in Figure 2. The large ovals represent general areas of light, medium and heavy soils, from left to right. This diagram is not meant to cover all of the soil types and textures present in the project fields, but rather gives a broad picture of the terms mentioned in this paper.
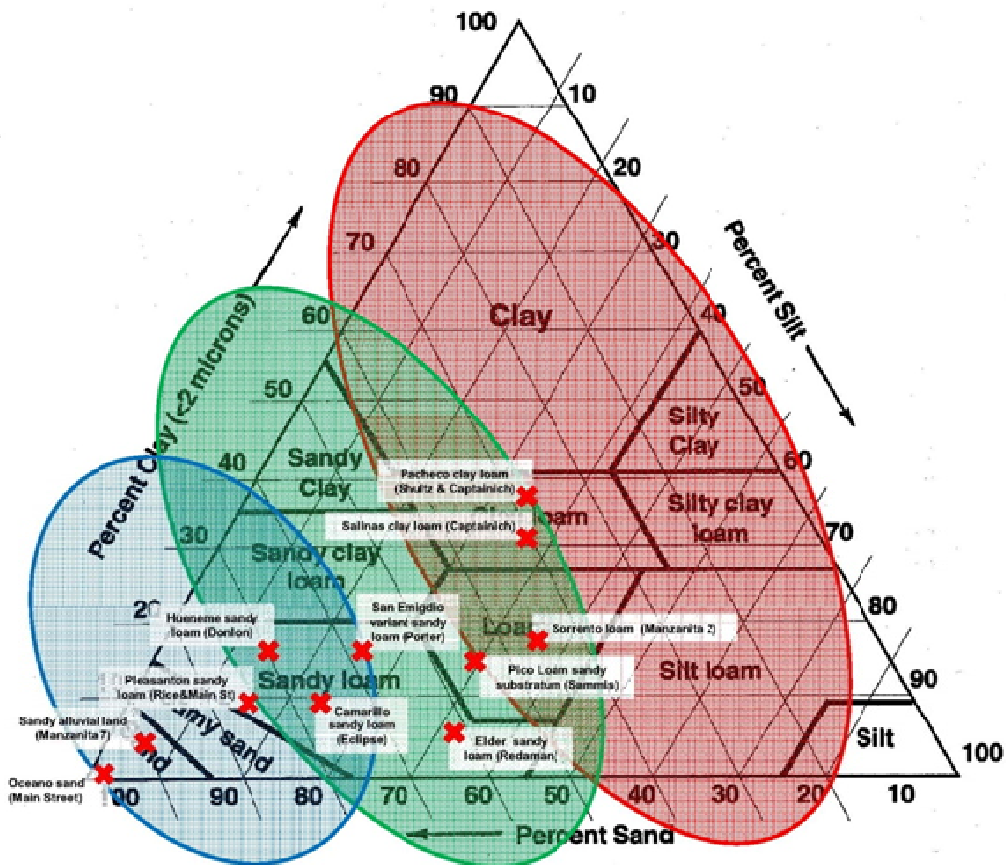
Figure 2.   Soil structure triangle showing soil types on project fields

Flow Meters

Magnetic flow meters were chosen for the project as a flow measurement device due to their high reliability, ease of installation, and accuracy. A magnetic flow meter or "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 ±1%.

Internet Monitoring – Ranch Systems and ClimateMinder

To simplify data acquisition, several growers implemented data monitoring systems from Ranch Systems and ClimateMinder. Ranch Systems offers a variety of products to allow active monitoring of in-field conditions. Generally, this information can be posted on the internet in real-time. The theory was that not only would the data be logged, but valuable irrigation scheduling information would be readily available to the growers.

Base Station. A crucial part of the Ranch Systems setup is a base station that relays all information collected by the nodes to the Ranch Systems network. This allows the information to be presented on the Ranch Systems website and accessed by users.

Nodes. Nodes are the devices that collect field sensor readings and transmit them to the base station. They consist of a solar panel, radio, and in this case soil and pressure sensors. Each node 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. 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.

Figure 3.   Ranch Systems node

Data Collection. Collecting data from the Ranch Systems sensors required simply accessing the Ranch Systems website, logging on and selecting the node of interest. However, the data from Ranch Systems was extremely unreliable and proved to be of little use. The sensors tended to fail and due to the complexity of the system, it was too difficult to repair/replace them.

ClimateMinder. ClimateMinder was also used by several growers. The internet-based real time monitoring systems were provided by the growers.

Data Loggers
A traditional data logger was placed in each site of interest as a method to constantly monitor field conditions. While the manually downloaded loggers do not have the convenience of Ranch Systems' and ClimateMinder's real-time monitoring, they quickly became very useful as Ranch Systems proved unreliable at times especially with the salinity data.

Data Logger Installation. Decagon Em50 data loggers were installed at every site at the Oxnard, Santa Maria, and Watsonville locations. These small data loggers were placed on the end of a block, 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 the middle plant row. To monitor moisture and water movement in the rootzone, additional 5TE sensors were installed at depths of 6 and 12 inches. 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.

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. Generally, the data loggers required little maintenance. About once per season, the batteries had to be changed and occasionally a 5TE sensor would fail. These sensors proved to be much more useful than the Ranch Systems.

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.

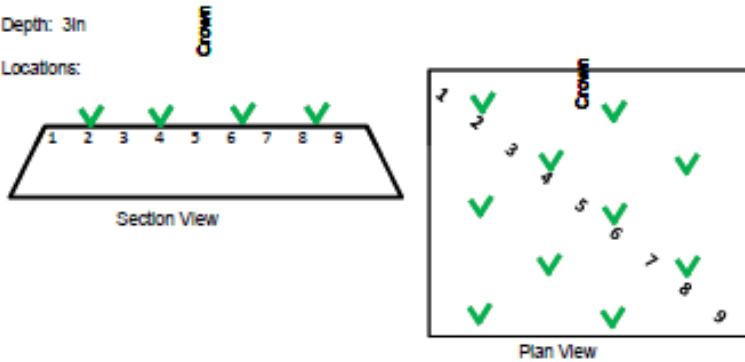**Salinity "Snapshot" Procedure**
In an attempt to track the movement of salts, EC measurements were taken across the top of the strawberry bed at a depth of 3 inches on numerous occasions throughout the growing season. This was done using a handheld Decagon ProCheck device with a 5TE sensor. Measurements were taken at the nine locations shown in Figure 4. These measurements were taken near the middle bed at both ends of each block. 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.

Figure 4.   Salinity snapshot testing locations and data set

Sammis									
Block A	Drip Only								North Side
Location	1	2	3	4	5	6	7	8	9
EC (ds/m)	6.6	0.7	10	6.9	9.7	2	0.5	5.3	3.6
%VWC	26	25	24	23	25	29	21	22	19
									South Side
Location	1	2	3	4	5	6	7	8	9
EC (ds/m)	12.5	3.8	3.8	11.7	13.7	11.1	4	5.4	15.3
%VWC	13	17	28	26	28	24	29	24	15

Water Sample Procedure

Water samples were taken whenever water was on the site. This gave some idea as to the quality of the irrigation water that was being used at each site. A Eutech waterproof total dissolved solids tester was used to test samples.

Photo Log Procedure

Pictures were taken of each test site during each visit. This allowed the growth process of strawberries at each site to be monitored and later compared. All pictures were taken facing north from the location of the data logger in each field. One of the best methods to determine the health of the transplants during establishment has been the evaluation of the photos.

Sammis - Block B
Partial Sprinkler

12/13/2009 – 65 DAP

12/17/2009 – 69 DAP

01/09/2010 – 92 DAP

01/30/2010 – 106 DAP

Figure 5. Sample of plant photos at Sammis at Block B (Note: "DAP" stands for "Days After Planting")

Santa Ana Wind Events
The "Santa Anas" are winds in Southern California that have speeds over 25 knots (28.6 mph) and can range to over twice that speed.   Data for the events are monitored by NOAA. Santa Ana-type conditions are usually associated with hot, low humidity (around 10-20%). These winds typically occur from October to March when there is high pressure in the Great Basin, which adiabatically heats as it travels down to the low pressures at the coast. Such dramatic weather comes at a crucial time for strawberry growers and requires more irrigation in order to prevent crop loss.

PERCENT OF TIME WITH NNE, NE, ENE, OR E WINDS AT 10 KNOTS
OR GREATER, AND RELATIVE HUMIDITIES <30 PERCENT
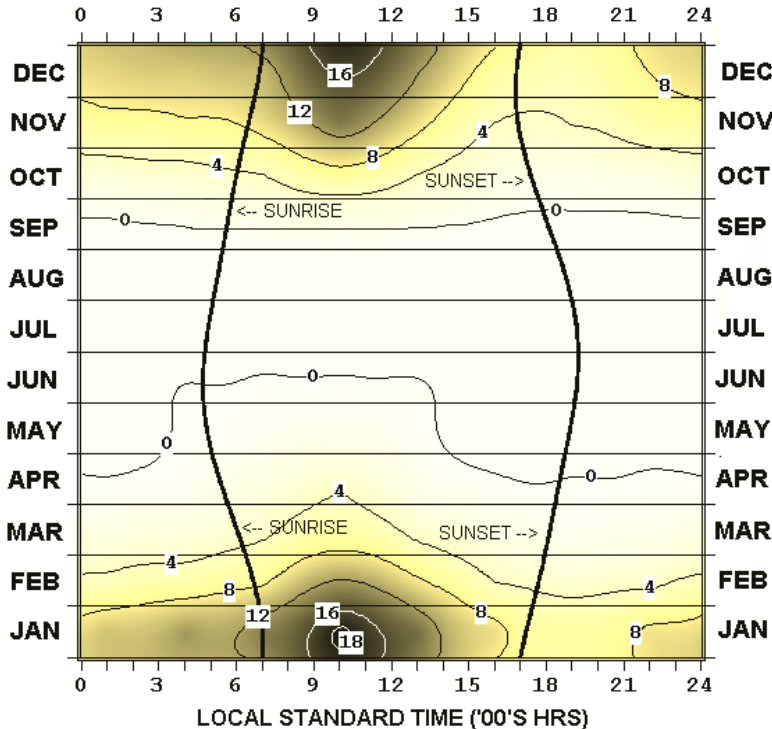- POINT MUGU, CA -

Figure 6.   Graph from NOAA: "Two-way" Climatological Time-Section Plot from
Charles Fisk - Meteorologist with Geophysics Branch - Naval Base
Ventura County (NBVC) 2010

Results and Analysis

Soil Salinity
Continuous Data. All continuous data was obtained from the Decagon data loggers
rather than the Ranch Systems. The Ranch Systems nodes and sensors proved
unreliable early in the season and were quickly abandoned. Similar problems occurred
occasionally with the Decagon data loggers, but were much less frequent.

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. The data showed that a heavy rain in
January lowered salinity levels by up to 50% while sprinkler irrigation events had much
less impact on the soil salinity. This was primarily due to the fact that the rainwater has
a low pH value and no salt content.

From the soil salinity data collected, salinity contours graphs were made. The graphs
display values of salinity (dS/m) in the plant beds. These are useful to the grower for
analyzing where the salt is pushed by applied water. Areas of red signify EC values of
10 dS/m or higher and are considered toxic to the plant if not leached.
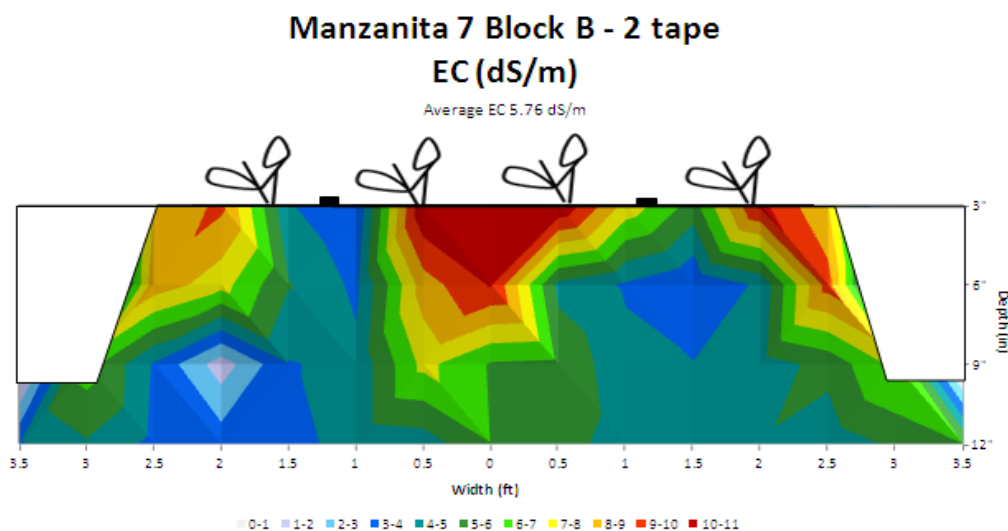
Figure 7.   Contour graph of salinity (dS/m) in Manzanita 7 block

Rainfall Data

The data from the sensors is uploaded to a spreadsheet. This spreadsheet contains data from the entire study, displaying salinity levels in both water and soil. They also contain precipitation data, as well as number of minutes the sprinklers were running. All of the data is collected from the fields except for the precipitation data. The precipitation data is obtained from CIMIS or the Weather Underground website (www.wunderground.com) using the nearest airports as the location. After all of the data is uploaded into the spreadsheet, graphs are made to visually monitor the salinity levels.

The salinity levels displayed in the graph 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 for the sensors only in the 0"-3" range. The sensors deeper than that did not record as prominent of a fluctuation. This would indicate there was not a lot of downward movement of the irrigation water.
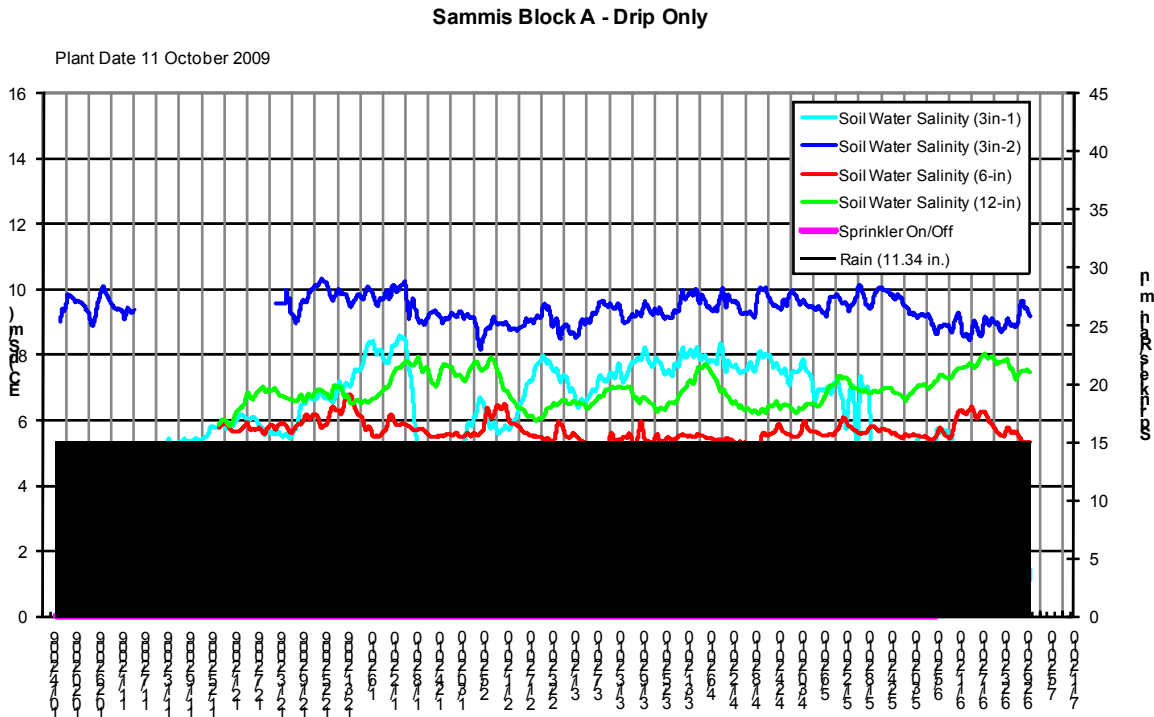
Figure 8.   Sample salinity sensor tracking from Sammis Block A
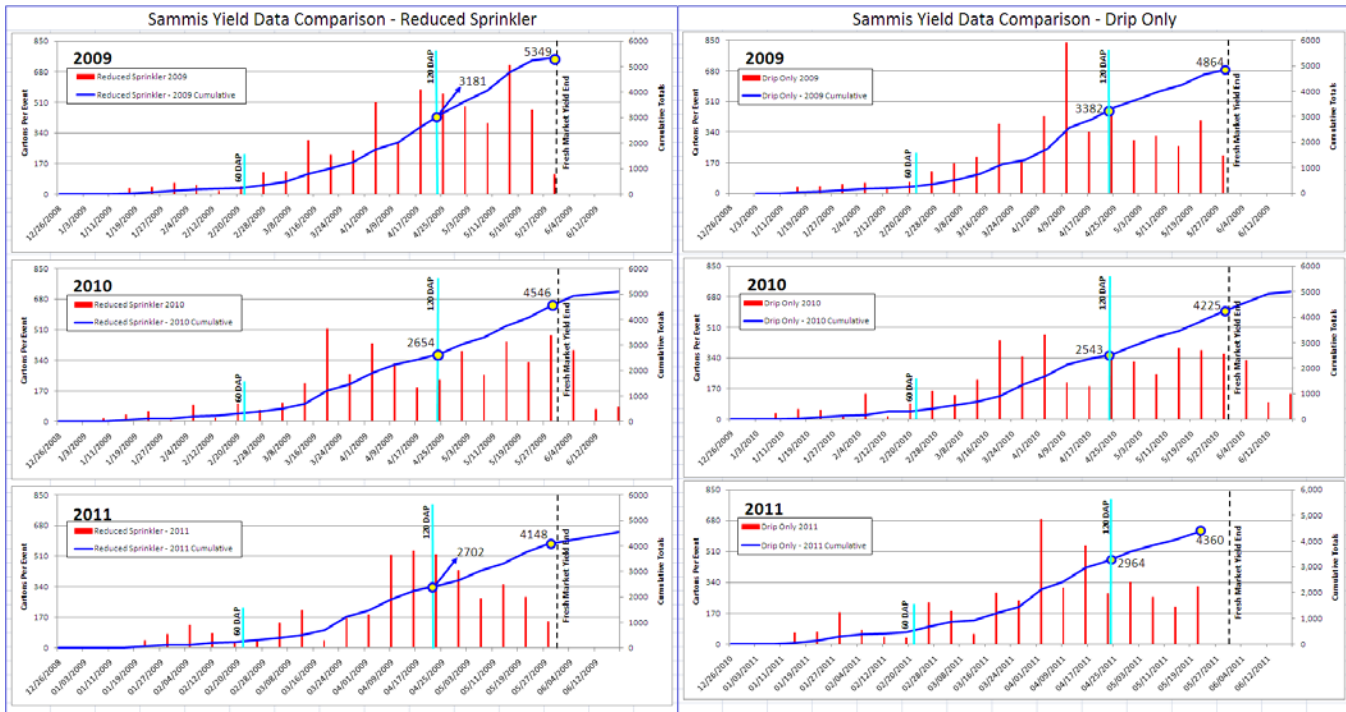
Impact on Yields

The yields in the first season showed little impact due to the irrigation method. However, in the first season 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, which kept the yields about equal to previous years. The other conclusion was that the placement of the drip tape was important.

The second season yields were higher with the new irrigation protocol. The yield increase in Manzanita was 13% on the partial sprinkler protocol compared to the conventional protocol. The grower also reported the yields on the partial sprinkler protocol resulted in early field gains at a time when the market prices were favorable.

The data from Sammis in 2009-2010 also indicated that the yields improved using the new irrigation methods. The partial sprinkler protocol had an 8% increase in yield and the drip only protocol had a 13% increase in yield.

The third year of data has seen a dramatic drop-off in the data collection of yields by the early innovators. These growers have switched their whole fields over to the new protocol and have abandoned the "conventional" irrigation approach. The exception is the Sammis field managed by Reiter Affiliated Companies (RAC). Below is a side-by-side comparison of the partial sprinkler and drip only protocols for 3 years.

Table 2.   Yield data from Sammis for three seasons (2009-2011)

Several preliminary conclusions can be drawn from these graphs:

Yields fluctuate on a year-to-year basis based on numerous factors. The overall weather seems to be a major determinant on yields. The first year of the project the rainfall was less abundant. The third year had three times more rainfall than the first. The hotter, dryer weather may have led to better yields in the first year. Keep in mind that the first year on the drip only saw a 30% die-off due to salinity damage.

For two of the years, the drip only protocol resulted in higher yields at the 120 days after planting mark. This is significant since several of the growers have noticed higher yields early in the season, when prices tend to be higher.

The Sammis grower has abandoned the conventional irrigation protocol. The first year results convinced this early adopter that the new protocol would be beneficial to his operations.

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). The first year seemed to be dominated by low rainfall and numerous Santa Ana wind events. While generally unsuccessful in terms of results, the grower wanted to continue the study since the potential seemed promising, and there were numerous key lessons learned.

The second year had some incredible results for increases in yield and decreases in water use. There were decreases in water use of up to 10% and a surprising increase in yields was reported.

The third year has been one where the focus has shifted to more of the details. For example, is 4-tape better than 2-tape? If 2-tape will work, what are the soil texture characteristics that will allow that to happen? There are some key items that we are seeing as we approach the end of the third year:

- Salinity is a key determinant in the healthy establishment of the strawberry transplants. The young plants will not tolerate high levels of salts. The damage in the plants will appear similar to a plant that lacks sufficient water.
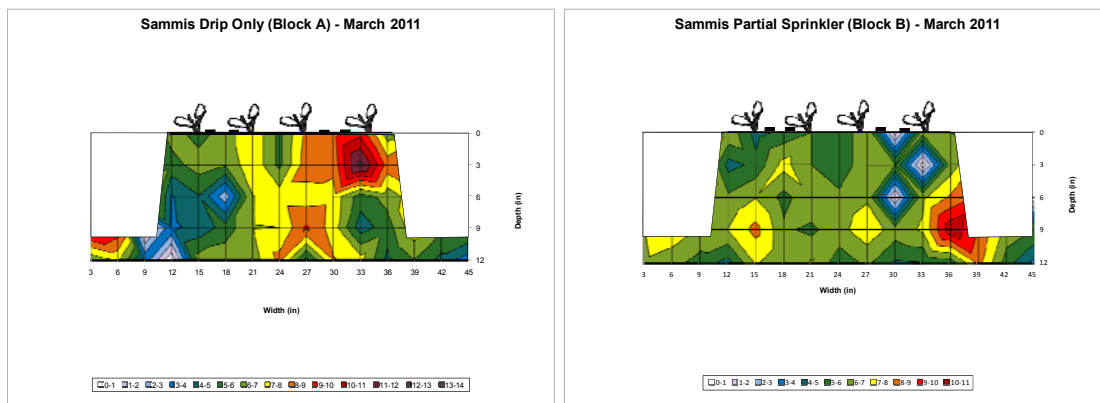

Figure 9.   Sample salinity contours from Sammis Block A and B

- 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 drip only or partial sprinkler protocols. Growers in Santa Maria might be able to use only two tapes per bed (on lighter soils) 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.

Figure 10.   New 4-tape machine

- Monitoring the salinity of the soil and the irrigation water will help growers switch from the conventional irrigation method to a new protocol. The soil salinity should be less than 7 dS/m (EC_e) and the water salinity should be less than 1.0 dS/m (EC_w). Monitoring can be done with portable measurement equipment but should be verified using professional soil labs.

- 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.

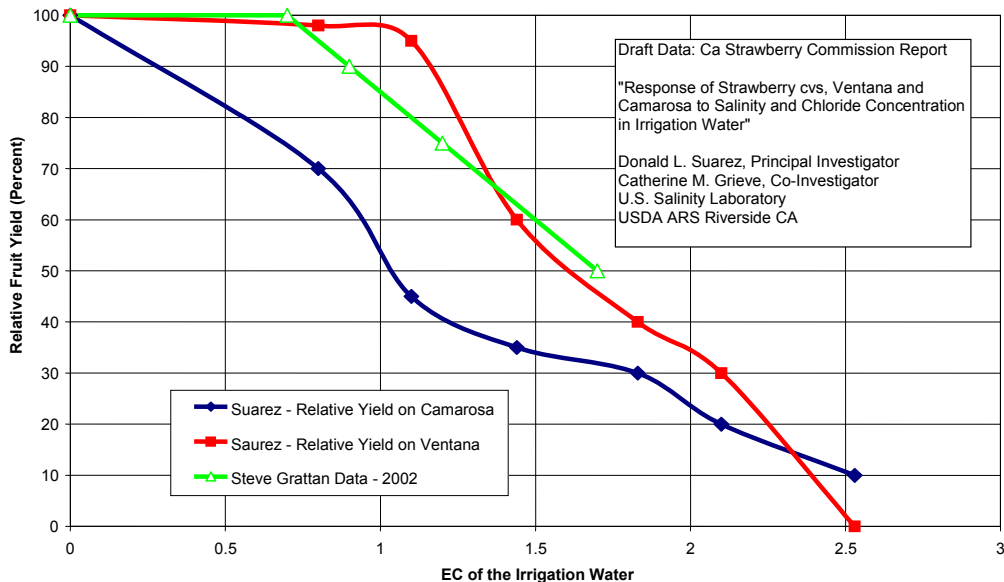**Salinity of Irrigation Water - Impact on Strawberry Yield**

Figure 11.   Impact of supply water quality on yield

- Salts come from various sources. Some sources of salt include the irrigation water, gypsum applications, fertilizers (both pre-plant and liquid), and composting (which can be a significant source).

- Traditional salinity references have used 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. <u>The reason is that they have been managing their salts properly near the roots of the young plants.</u>

- Soils that are lighter will be easier to irrigate and manage than soils that are heavy. This has been observed in the various plots as part of this research.

- Rain washes salts away from young strawberry transplants. The data clearly show that rainwater (which is essentially salt-free and acidic) can push harmful salts away from the plants. The data show how dramatically the salinity level dropped after the rain.

- 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***.

Figure 12.   View of strawberries at 120 days after planting (DAP)

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