Project Title: **Extending Efficient Drip Irrigation Management Approaches to San Joaquin Valley Pima Cotton Growers**

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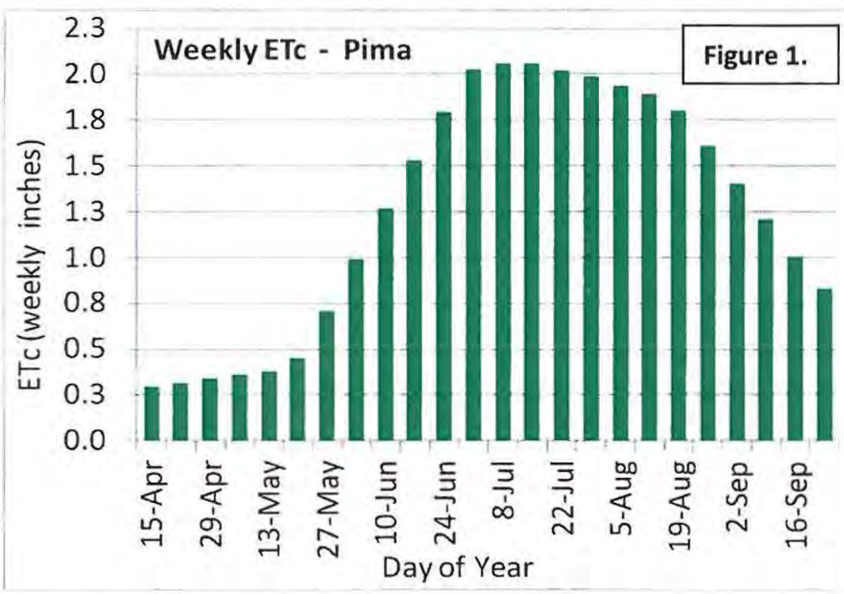
Various growers

Starting Date and Project Duration: 3/1/2013 - 12/31/2013

Introduction

Irrigation scheduling methods in the irrigated far west are not uniformly accepted and depend on irrigation system, production economics and the management investment the grower is committed to. Most current and successful methods use soil and/or plant-based measurements that are combined with regional estimates of ETo and Kc to calculate best irrigation timing. Growers that make use of the available technology find that the time and financial costs invested in making careful field evaluations improve farm economics.

Seasonal cotton water use for optimum yields can exceed 750 mm (30 inches) with typical rainfall contributions less than 15 percent of total season water requirements. Crop water requirements are distributed unevenly across the season with very low ET observed in the 60 days following planting and peak ET observed 100 to 115 days after planting. The highest cotton water use period is from late June to mid August during peak-bloom with daily water use of slightly over 2.0 inches per week (**Figure 1.**)



Cotton's long maturity period and high water requirement during the effective flowering period make it particularly vulnerable to yield decline caused by improper irrigation scheduling. Irrigation management that allows periodic but modest levels of plant stress is appropriate for achieving high yields in cotton. While no single irrigation scheduling method suits all growers and conditions, there are 2 to 3 basic approaches that have been successful at minimizing the risk to the producer. Soil and plant-based measurements have each been successful and can be enhanced with direct and indirect estimates of Evapotranspiration (ET) using energy balance methods. The most successful of western U.S. cotton farmers use soil- or plant-based methods combined with input obtained from area ET networks such as CIMIS, which provide real time and long-term ETo estimates.

Objectives

To test the predictive capacity of the new University of California irrigation guidelines which provide growing season estimates of water application timing and amount while remaining flexible to alter water schedules as needed. The new guidelines use crop coefficient estimates (Kc curves) which were developed by UC on irrigated cotton using the surface renewal method. The crop coefficients reflect the various stages of crop development during the growing season. (**Figure 2.**)

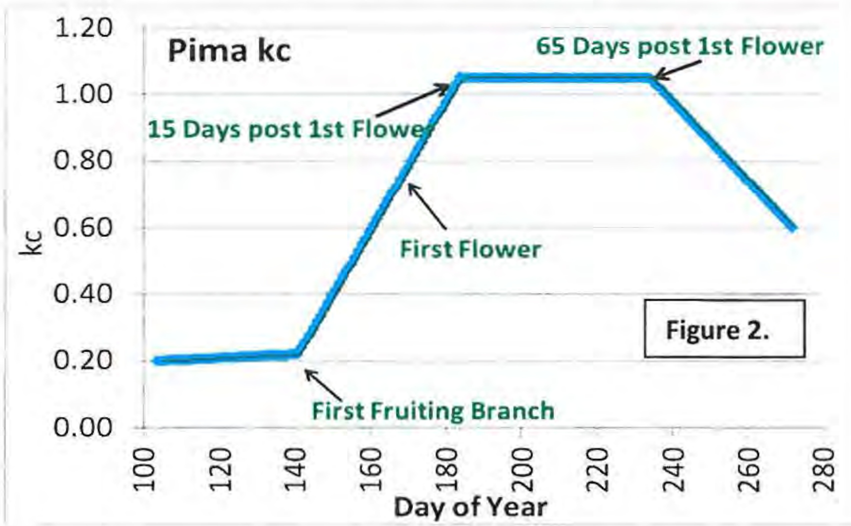


Figure 2.

Incorporating the use of plant monitoring parameters such as plant height, height to node ratio index, top and bottom-5 retention, and 4^{th} to 5^{th} internode distance to evaluate in real-time how the plant is responding morphologically. Mid-day pressure chamber readings have been found to be useful in the evaluation of plant water stress by integrating atmospheric water demand with plant water availability. Previous work has shown that both leaf water potential (LWP) thresholds as well cumulative stress measures of LWP are highly correlated with yield loss in water stressed systems. Frequent measurement of volumetric soil moisture (neutron probe) with depth can help identify root zone water availability as it expands early in the growing season and can greatly assist in determining late season water availability useful in estimating irrigation termination dates late in the season. While elements of these methods have been used in the past to guide irrigation scheduling and water management decisions, applying these specific approaches to multiple large scale grower fields allows us to further test the application of research and experimental principles to whole farm systems.

Materials and Methods

A set of seven trials were established in Fresno, Madera, and Kings counties located in California's San Joaquin Valley to evaluate newly developed guidelines for in-season water applications in sub-surface drip(SDI) Pima cotton. The 7 trial sites we evaluated ranged in soil type as well as the presence of a water table that was observed in four of the locations ranging from 18" to 84", **table 1**. A questionnaire was sent to cooperators regarding specific information of water application, field history, plant date, acreage, and drip system. Water content was measured down to 8 feet with the neutron probe to measure the actual water storage within the soil. By estimating a rooting depth and water content at both field capacity and wilting point, a determination of crop available water was developed.

Grower:	Morningstar	Morningstar	Morningstar	J&M Farms	Sheely	Esagian	Newton
Location:	Ave.9 & Rd. 40 Madera Co.	Nees Ave. & I-5	Nees Ave. & I-5	Nees and Washoe Ave.	NW of Avenal Cutoff & Gale Ave.	Avenal Cutoff & Gale Ave.	Tulare Lake Bed
Bed Width:	60"	60" (No Till)	60"	36"	33"	33"	38"
Field Acreage:	145	223	223	-	155	190	160
Pre-irrigation (if any):	1.5"	2.0"	2.0"	-	24 hr spr.	24 hr spr.	6.0"
How long in drip:	4 years	4 years	4 years	-	7 years	4 years	1st year
Previous crop in field:	Corn	Cotton	Cotton	-	Cotton	Tomato	Grain
Cotton Variety:	805 Pima	805 Pima	805 Pima	-	802 Pima	802 Pima	800 Pima
Date Planted:	8-Apr	13-Apr	13-Apr	-	27-Mar	1-Apr	10-Apr

Table 1. Summary site and cropping system characteristics for each of the 7 study fields.

The crop Kc was adjusted down from 100%, taking into account the stored soil moisture estimate for each of the sites with Kc values ranging from 50% to 90% of the full Kc curve, depending on the estimated stored soil moisture. Pre-Irrigation amounts as well as water table levels at some of the sites were factored in. Crop ETc was estimated on a weekly basis using a long term average (projected) CIMIS ETo - the CIMIS historical and 2013 season ETo data were obtained from the CIMIS station located closest to the individual trial locations.

The irrigation amounts (ETc) for the projected week as well as the past week was sent via e-mail to our cooperators for their use.

Results

Example Field 1 started the season with moderate levels of stored soil water intended to be available to the crop throughout the season. However as the season progressed beyond first flower, plant available water rapidly declined in the 1 to 4 foot depths until water was nearly depleted when water extraction deepened to the 5 to 6 foot zones, **Figure 3**. Due to an issue with the drip system failure, water applications were restricted until mid-July when a full complement of water was applied to the field. Plant stress levels (LWP) peaked out at -22 bars in early July and were found to be highly sensitive to the irrigation deficits. Eventually the internode distance responses followed, **figure 4,** as did plant height and height to node ratio index**, figure 6.** During the season, we also observed a reduction in Top and Bottom 5 fruiting branch retention attributed to insect pest pressures, **Figure 5**. Late season was deficits resumed at this site when the grower's surface water supplies were reduced creating a late season deficits. However, our plant growth and stress indicators suggest there was little or no yield impact in response to these deficits. Stored soil water reserves played a key role in maintaining adequate plant water status levels during the season limiting yield loss potential.

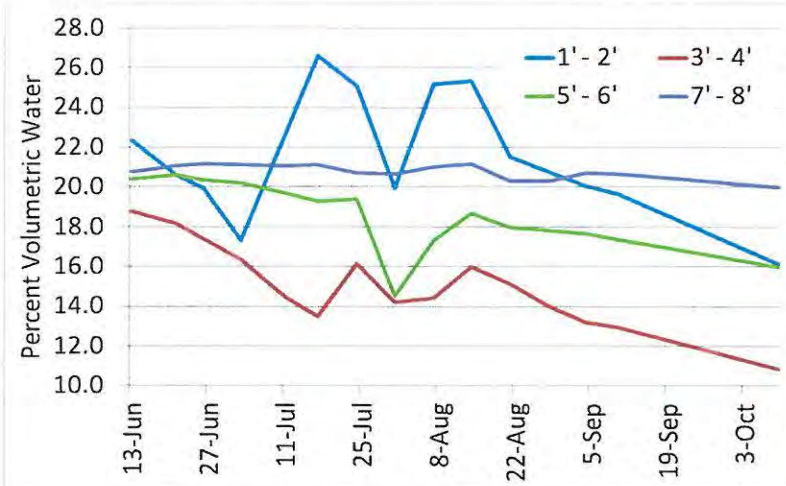
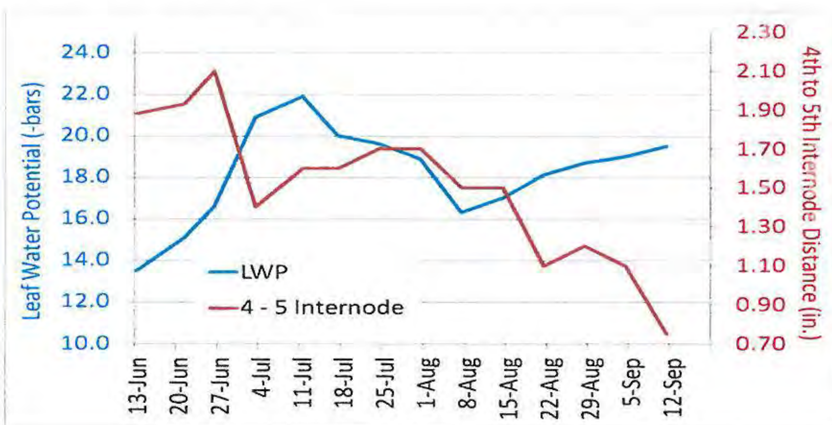
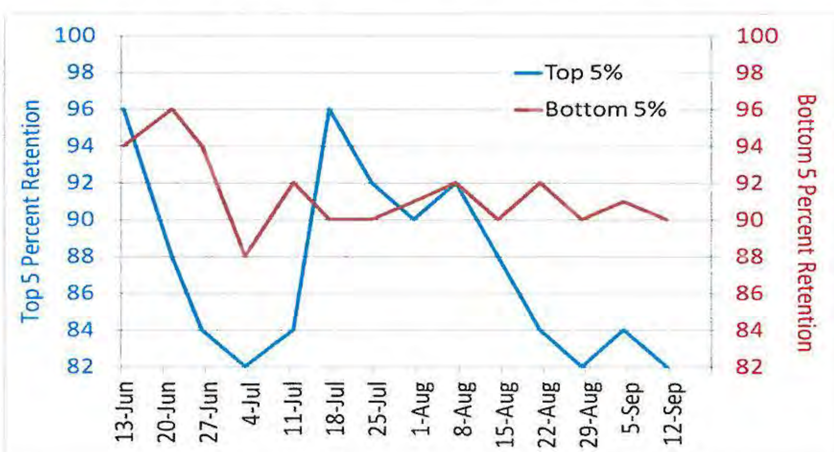
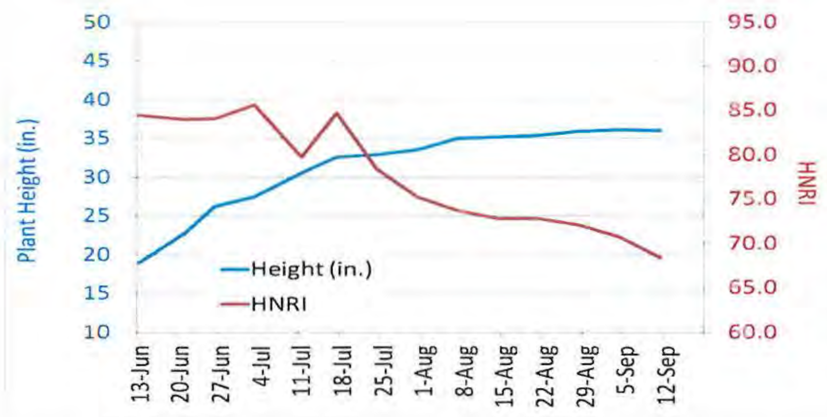


Figure 3. Volumetric soil moisture with depth collected at 1-foot intervals and grouped into 2 foot zones for comparison.







Figures 4-6. In-season plant monitoring information used to assess irrigation adequacy.

Example Field 2 had a soil moisture content of about 17% in the top 2 feet in mid-June and later depleted to about 11% by the first week of July, **Figure 7**. However increased water application amounts were recommended and soil moisture levels were restored to 20% in the top 4 feet during peak bloom and early cutout. The sandy loam soils in this field contained less available plant water with most of the soil moisture extraction taking place in the top 4 feet. However some late season moisture extraction did take place in the 5 to 8 foot zones. Plant stress levels (LWP) reached a high of -18 bars in early July right after a precipitous early season drop in surface soil moisture, **Figure 8.** However low sustained LWP levels were not observed at this site indicating stress levels were contained at this site. All plant vigor indices further supported the conclusion that water stress levels were not substantial enough to cause yield loss, **Figure 10.** As a result of early season Lygus pressure, Bottom 5 fruiting branch retention ranged from 55 to 60% in mid June and fell to near 50% by mid July, **Figure 9**. Due to this loss in retention, we concluded that yield losses at this site were related to insect pest pressures and not plant water status.

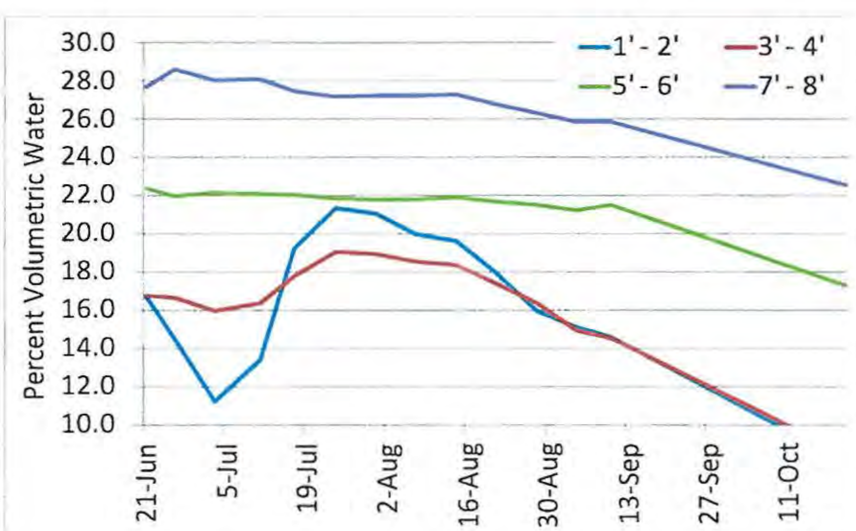
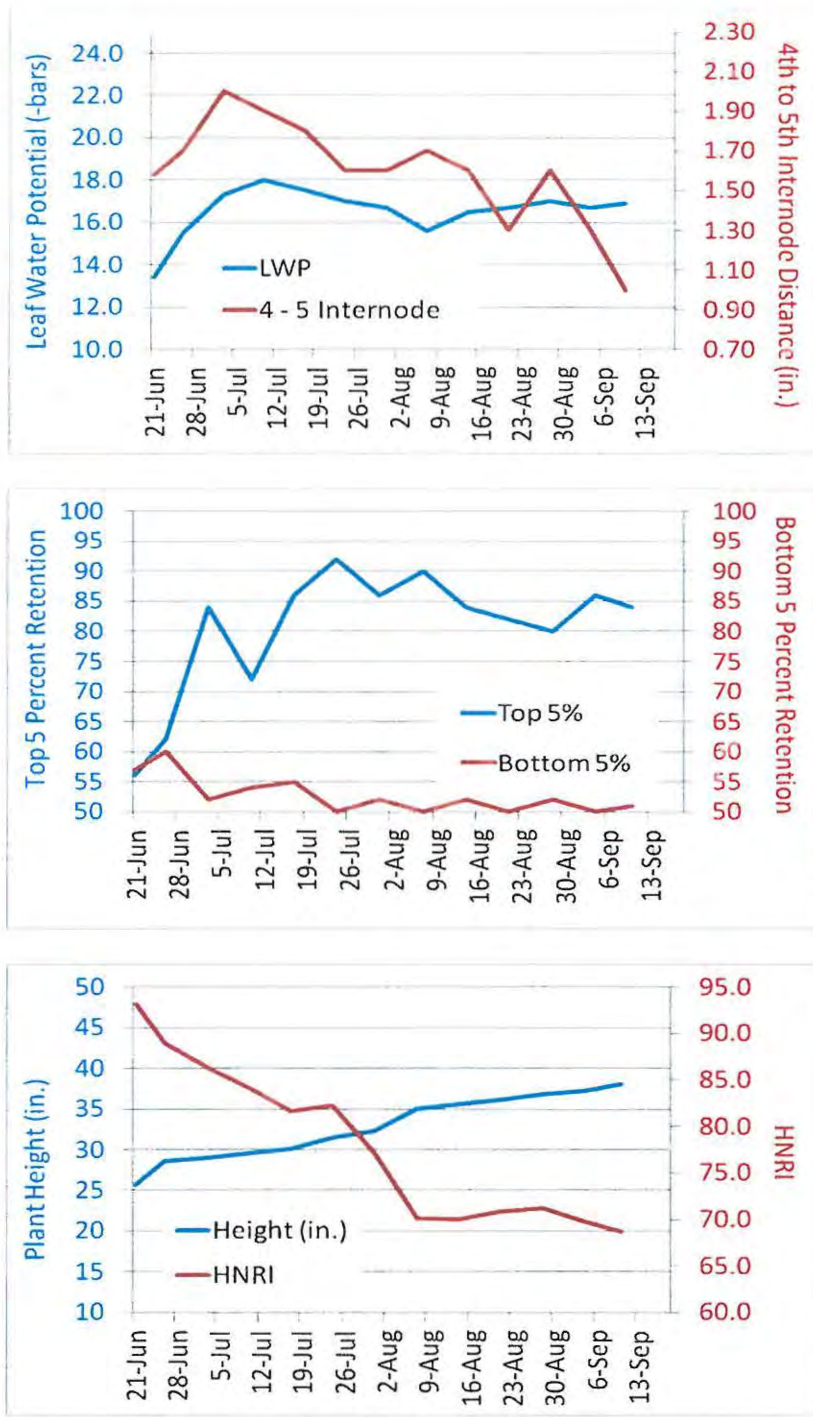


Figure 7. Volumetric soil moisture with depth collected at 1-foot intervals and grouped into 2 foot zones for comparison.



Figures 8-10. In-season plant monitoring information used to assess irrigation adequacy.

Summary and Conclusions

Various methods of irrigation scheduling continue to be used for a variety of agricultural crops with no single method used as a standard. Some of those methods include approaches that are largely soil based and make use of soil water content or soil capacitance as an indicator of plant water availability. Soil based approaches can be used successfully but require a knowledge of the individual field soil behavior including water retention characteristics as well as a good sense for where plant roots are exploiting soil water at any point in time. Atmospheric or climate based approaches use information collected from meteorological stations that estimate potential water demand by plant systems. To adopt this approach successfully, users must adopt an appropriate crop coefficient (Kc) that is based on the stage of crop growth. This method is very useful for long term planning and can provide reasonable in-season water use estimates but does not provide a way to make modifications in water management when climatic estimates deviate or when irrigation schedules are changed as a result of changing water availability. Plant based irrigation scheduling approaches on the other hand can use a variety of plant indicators to help assess plant stress levels and monitor how growth and development are being impacted as water and pest pressures change. In the large scale fields evaluated, we adopted a management approach that integrates the use of tools that are easily available to the grower and are consistent with other information useful in cotton crop management.

Monitoring plant height, terminal node growth, and fruit retention was shown to be useful in evaluating the plants access to available water. Of these measures, the distance between the 4^{th} and 5^{th} node from the terminal is the most sensitive plant growth measurement to recent changes in plant water status while plant height or height to node ratio help project more long-term cumulative impacts caused by improper water management practices. Under some of the field systems we evaluated, fruit retention information assisted in irrigation management decisions by identifying fields and periods that are expected to deviate from normal crop growth. This information can result in modified water management practices that are more consistent with improved yields or more efficient water application practices. Finally, we continue to find that the most responsive plant-based tool in the irrigation manager's box is the pressure chamber. Properly used, this method integrates the effects of atmospheric water demand with the plants access to available soil moisture at the time of the measurement.

The development and use of multiple tools was especially useful from the perspective of whole field and farm water management. Soil water monitoring provided useful information on the early season storage capacity and potential to supplement crop water when in-season water deficits are unavoidable. Crop ET estimates were readily obtained from local CIMIS stations coupled with our estimates of early season crop cover. The ET information developed assisted the growers with better water management planning. Crop growth and square monitoring provided additional tools to assess crop vigor in relation to water deficits and surpluses as well as identify non-irrigation management issues controlling crop growth. We found that the monitoring of leaf water potential to measure relatively small changes in plant water status continues to be the most sensitive of plant based measures and an early indicator plant stress. Pressure chamber guidelines developed for surface irrigated cotton appear to be roughly transferable to drip irrigated cotton which has the advantage of being an irrigation system that is more responsive to changing plant water needs.