ESTABLISHING A MODEL FOR IRRIGATION TERMINATION IN COTTON

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Abstract

A management model for predicting optimum timing for irrigation termination in San Joaquin Valley Acala cotton is proposed. This model incorporates crop maturity and late-season plant available water determinations as primary model inputs. Plant available water is calculated by a combination of root depth determination and available water estimates based on soil textural type, to arrive at a specific value. A palmtop computer system has been developed to accept these inputs and provide water termination estimates. Thus far, two years of field trials have helped validate the assumptions of the model and provide yield test results to confirm model predictions.

Introduction

Persistent pressure has been placed on California irrigated farmlands to reduce total water use. This is especially true for the west side San Joaquin Valley water districts which consistently received reduced water deliveries with much of this water re-directed to the Sacramento-San Joaquin River Delta to improve water quality and enhance andromodous fish populations. Cotton is the primary field crop grown in many of these impacted irrigation districts and producers are, therefore, under considerable pressure to reduce acreage planted, reduce total seasonal applied water, or use a combination of these two to maintain a profitable farm system. Since the cotton crop has relatively high late season water use rates, a logical and commonly asked question is: What is the ideal time to terminate irrigations on a current cotton crop? Better defining this time has been the subject of past and current research activities (Grimes 1970, Munk 1994) and has been observed to be an important key in minimizing irrigation water losses during the season.

Earlier research conducted in California has attempted to answer this question from a soil-based approach. That is, soil type determines soil water availability to a specific crop and, therefore, is the parameter used to identify irrigation termination dates (Grimes 1974). This method has shown considerable promise and many growers recognize and use this method to approach to the irrigation termination question.

Three major obstacles remain with this approach, however, and hamper the accurate decision-making process that enables the grower to make the most efficient use of applied water. The first obstacle that remains is that late-season crop evapotranspiration (ET) rates are variable and depend on climatic conditions that are somewhat unpredictable. The amount of soil water required by the crop following the final irrigation will, therefore depend upon late-season weather conditions. Secondly, although we may have significant knowledge of soil water retention characteristics, it is often difficult to define the rooting depth that needs to be defined to obtain a sound estimate of crop water availability following the final irrigation. This requires some knowledge of soil moisture changes with depth over some late-season time interval. Thirdly, crop maturity varies from season to season and field to field. Late-season boll maturity can be related to the number of heat units accumulated late season. Following crop cut-out, a finite number of heat units and water are required to finish the crop and successfully mature these late-season bolls.

It appears that for the near and distant future, late-season climatic predictions will continue to be difficult at best and have an unpredictable component. However, we currently do have the means to minimize the risk of late-season crop loss by better evaluating late-season soil moisture availability and incorporating crop maturity evaluations into an irrigation termination model. The focus of this paper will be to discuss these later two methods and propose a method that will allow growers to better define irrigation termination dates that are reasonably low risk and provide for the conservation of late-season applied water.

Materials and Methods

Irrigation studies were conducted on three sites in 1995 and on four sites in 1996. Sites were selected based on soil textural characteristics in order to achieve a range of plant available moisture levels, Table 1. The California Cotton Manager (CCM) Final Irrigation Module (Young 1995) was used to estimate the optimum timing for irrigation termination. Selected sites were mapped using CCM plant mapping module (Munier, 1996) prior to crop cutout and again near harvest.

Applied water was monitored by metering the turnout to the study field and obtaining a field wide application total and factoring the area of land water was applied. Each individual irrigation event was monitored and total applied water determined, similar to applied water measured for the WSREC site found in Table 2. Neutron probe access tubes were installed in two of the four replications for each irrigation treatment. Neutron probe readings were made at 7 to 12-day intervals depending largely on irrigation scheduals. Irrigation termination dates varied depending on site soil characteristics and CCM module estimates, ranging from three to four individual irrigation termination dates across the season. A randomized complete block design was used at each site with four replications.

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Mid-day leaf water potential readings (LWP) were monitored at each soil moisture reading using the pressure chamber (Scholander, 1965). A minimum of three LWP measurements were made for two of the four replicates at each site. Readings were made at seven to ten-day intervals beginning just prior to the initiation of the differential crop water regime establishment.

Seed cotton yields were obtained from four or five field-length rows for each plot at the end of the season with gin turnouts obtained from a six-pound subsample from two of the four replicates to obtain lint yield estimates. The number of unharvested bolls was estimated using two 13.1 foot strips from each plot and later reported as unharvested bolls per acre.

Late Season Crop Model

Using long-term average reference ET data and established crop coefficients suitable to regional growing conditions, long-term crop water use figures are developed. This data is then used to establish crop water needs following cutout for the desired period of time.

The number of days needed to finish the last pickable bolls can also be estimated using long-term heat unit accumulation data. Average daily heat unit accumulation decreases over time and is our best estimate of establishing boll maturity following cutout. Bolls set early in the season typically require about 1100 heat units (HU), while those produced near cutout require 900 HU to fully mature. A boll maturity date can thus be established with date of cut-out estimate.

A date for plant cutout is approximated using the California Cotton Manager Irrigation Termination module. As the crop approaches cutout, defined as 5 nodes above white flower, a plant mapping evaluation is inserted into the module and a date of cutout established, based on long-term NAWF decline for SJV conditions (Kerby and Hake, 1996). With a cutout date determined, long-term heat unit data is used to calculate the date of maturity for the last harvestable boll. Cummulative crop water use values can now be determined and the total crop water requirement defined from cutout to full maturity of the last harvestable boll.

Plant available soil moisture must be carefully determined to develop an accurate estimate of a proper irrigation termination date. Soil moisture monitoring conducted just prior to cutout can be used for this estimate. Because the rooting profile of cotton is largely developed two weeks prior to cutout, soil moisture extraction in the root zone is relatively constant through season’s end. Because water extraction patterns decline in a nonlinear manner, the root zone is sometimes difficult to define from soil moisture uptake data. In an effort to simplify this dynamic parameter, we used 90 percent of total soil profile water extraction to establish the rooting depth, Figure 1.

Soil water retention characteristics were derived from field data collected from earlier studies. Soils were grouped into textural types including sand, loam, sandy loam, clay loam, and clay. Estimates of crop water availability are now available by using the product of rooting depth and soil type.

Model Validation

The present model denotes a wide range of plant available water figures following the final irrigation. In the case of sandy loam soils, often noted for their low soil intake rates and crusting problems, 3 inches of plant available water is predicted for a 4-foot root zone established on the Tulare County location. In contrast, WSREC site, having a 6-foot root zone in clay loam soil, 11.3 inches of water is the predicted crop available water following the final irrigation. As expected, these results project a vastly different date for final irrigation. The model predicts an August 1 irrigation termination for the WSREC site while an August 25 termination date was anticipated for the Tulare site, Table 3.

Leaf water potential readings can also be used to help assess the degree of plant water stress and late-season yield impact. Generally, sustained late-season water stress levels above -20 bars have been found to decrease yields and impact maturity of late-season bolls (Munk, 1994). This appears to be consistent with the 1996 observations at most sites, Figure 2.

Actual yields showed peak yield increases corresponding to irrigation cutoff treatments near the predicted optimum date. The WSREC site yields, for example, peaked with an irrigation termination date of August 15. Additional irrigations made after this point resulted in less effective defoliation (observations by author), more unharvested bolls, and slightly lower yields. Terminations earlier than August first resulted in high crop water stress levels, severe soil moisture depletion, and lower crop yield, Figure 3.

The peak yield obtained at the Tulare County site occurred with an August 20 irrigation termination. The model predicted an August 25 termination, very close to this higher yielding treatment. Because no severe stress was allowed to develop on this plot, yield reductions from earlier terminations were not readily apparent and yield differences not statistically significant using LSD=0.05.

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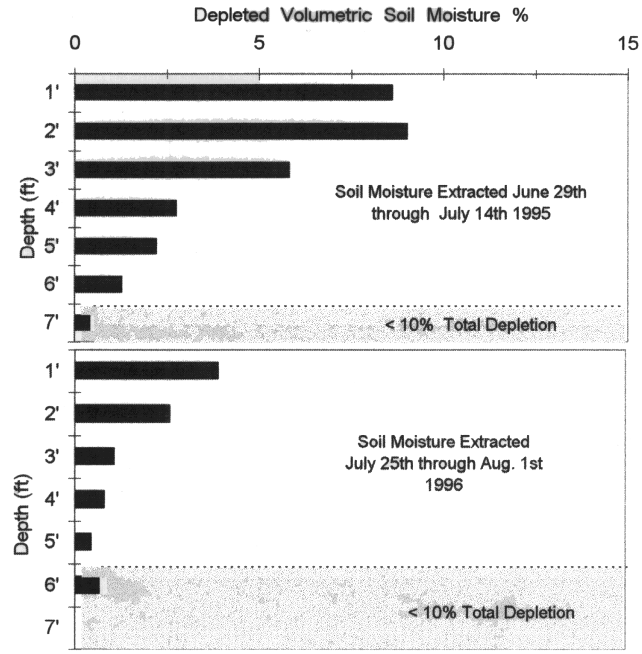

Figure 1. Late-season water depletion with depth.

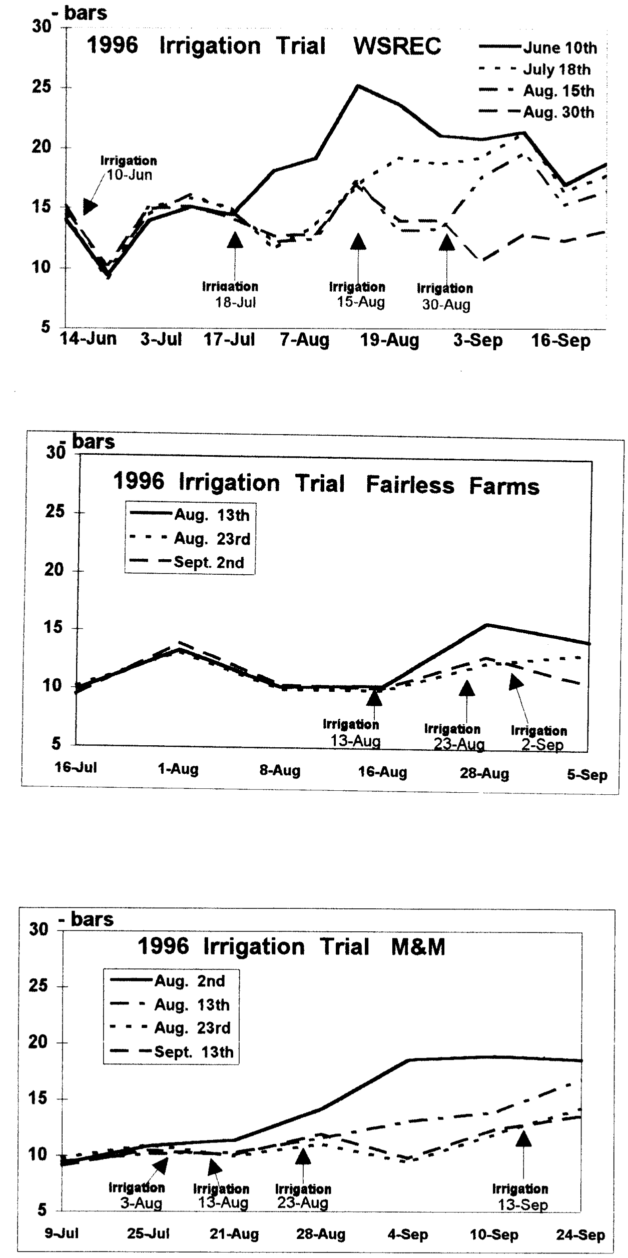

Figure 2. Mid-day leaf water potential during late-season following three or four irrigation termination dates at three sites in 1996.

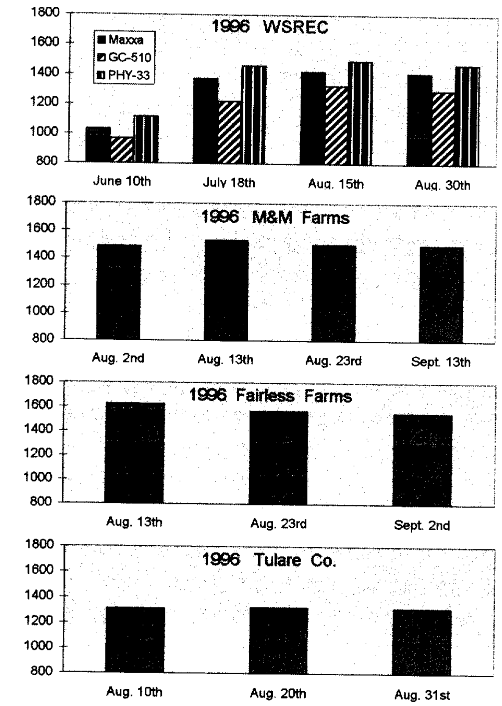

Figure 3. Lint yield in pounds per acre for the four 1996 study sites having three or four irrigation termination dates.

Table 1. Soil textural characteristics for four of the 1996 irrigation termination study sites.

Soil Depth	Sand %	Silt %	Clay %
		WREC	
1'	24	48	28
2'	32	45	23
3'	22	56	22
4'	25	44	31
		Fresno M&M	
1'	43	39	18
2'	42	45	13
3'	48	45	7
4'	40	53	7
		Fresno Fairless	
1'	22	44	34
2'	22	43	35
3'	22	44	34
4'	35	42	23
		Tulare Co.	
1'	61	26	13
2'	70	20	10
3'	84	12	4
4'	60	30	10

Table 2. Irrigation water applied at the West Side Research and Extension Center site for four separate irrigation termination dates.

Date of Last Irrigation	Total Applied with Pre-Irrigation	Total Applied In-Season
June 10	19.95"	7.30"
July 18th	25.40"	12.75"
August 15th	30.46"	17.81"
August 30th	33.57"	20.92"

Table 3. Estimated cutout date, estimated plant water availability and predicted date of irrigation termination. *=termination date with highest yield.

	Cutout Date	Soil Texture	Irrigation Depth	Plant Available Water	Date of Final Irrigation
WSREC	Aug. 1	Clay Loam	6'	11.3"	Aug. 1 **Aug. 15*
M&M Farms	Aug. 21	Loam	6'	9.0"	Aug. 17 **Aug. 13*
Fairless Farms	July 26	Clay Loam	5'	9.4"	Aug. 2 **Aug. 13*
Tulare Co.	July 28	Sandy Loam	4'	3.0"	Aug. 25 **Aug. 20*