PLANNED SOIL WATER DEPLETION OF IRRIGATEDCOTTON ON THE SOUTHERN HIGH PLAINS

James P. Bordovsky and William M. Lyle
Texas Agricultural Experiment Station
Lubbock/Halfway, TX

Abstract

Limited irrigation capacities, short growing seasons, and irregular rainfall on the southern Texas High Plains require good irrigation management of cotton for optimum yields. Irrigation technologies are now available that can efficiently apply very limited quantities of irrigation water at intervals of less than 3 days. A simple soil water balance model driven by estimated daily evapotranspiration, crop coefficients, and infiltrated rainfall was used to determine irrigation timing and quantities with limits set by optimum available soil water, minimum irrigation interval, and maximum irrigation capacity. The protocol established the first irrigation date and determined daily irrigation quantities and start up dates following significant rainfall events. It also provided controlled depletion of soil water beginning at the time of crop maturity, which, on the Texas High Plains, corresponds with a time of significant seasonal rainfall. The protocol was configured as a computer spreadsheet and used to determine daily irrigation amounts of 9 cotton treatments irrigated with a LEPA system during the 1995 and 1996 growing seasons. Irrigation intervals were 1d, 2d, and 3d with irrigation capacities limited to 0.1, 0.2, and 0.3 in./d. The three irrigation capacity treatments (0.1, 0.2, and 0.3 in./d) resulted in average lint yields of 719, 1042, and 1079 lb/A in 1995 and 1109, 1315, and 1363 lb/A in 1996. Water use efficiency and seasonal irrigation water use efficiency ranged form 46 to 58 lb/A-in. and 69 to 79 lb/A-in., respectively, in 1995; and from 60 to 71 lb/A-in. and 67 to 97 lb/A-in. , respectively, in 1996 for the nine irrigation treatments. The soil water depletion protocol resulted in high cotton lint yields and water use efficiencies while utilizing available rainfall and irrigation water during two growing seasons.

Introduction

Maximum use of seasonal rainfall as well as efficient use of irrigation water is critical in the southern Texas High Plains where ground water is rapidly diminishing and the growing season length is limited. Of the 18 to 20 inches of average annual precipitation, over 75% occurs during the months of May through October. Unfortunately, the year-to-year occurrence and magnitude of rainfall is highly irregular as illustrated by monthly rainfall totals shown in Fig. 1. Good water resource management requires seasonal rainfall be stored in the soil profile for future use by a crop.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1403-1406 (1997)
National Cotton Council, Memphis TN

Light, frequent irrigations provide room for rainfall storage while maintaining crop growth. Prior research has shown that high frequency (3d interval) irrigations also produce significantly higher cotton lint yields and earlier crop maturity than longer irrigation intervals. Yields from deficit irrigated experiments (0.4 and 0.6 BI, where BI = evapotranspiration minus infiltrated rainfall) have been significantly greater than those obtained with larger irrigation quantities in the northern cotton producing area of the Texas High Plains (Bordovsky, et al., 1992).

High frequency cotton irrigation with limited supplemental water requires accurate control of irrigation quantities. Both Low Energy Precision Application (LEPA) and drip systems have the potential to provide the control and efficiency needed for high frequency irrigation. The prospect of sustaining the High Plains irrigated economy depends on the proper management of cotton with these systems.

A successful High Plains cotton crop requires efficiently wetting a majority of the root zone prior to planting with rainfall and preplant irrigations, initiating seasonal irrigations early with quantities that do not produce excessive vegetation, and utilizing most seasonal rainfall. Water management should also provide a controlled reduction in profile soil water late in the season to discourage non-productive plant growth and create soil water storage capacity for off-season rainfall. Use of a simple soil water balance model, daily evapotranspiration (ET), and rainfall data provides timely, easily attainable information on both irrigation timing as well as quantity. This paper summarizes a management protocol for maximizing cotton lint yield with variable water resources and gives yield and water use efficiencies for the 1995 and 1996 growing seasons.

Procedure

Timing and amount of in-season irrigations were determined by using a protocol described by Bordovsky and Lyle (1996). Irrigation timing and amounts were limited by the difference between a target soil water content (SW_T) and the calculated daily available soil water content (SW_N); the desired irrigation interval (Inv); and the daily irrigation capacity (I_{CAP}).

Irrigations were restricted to days when SW_N was below SW_T. SW_N was determined by reducing the previous day's calculated soil water content (SW_{N-1}) by the previous day's evapotranspiration (ET_{N-1}) and adding the previous day's irrigation (IR_{N-1}) and effective rainfall (R_{N-1}). Daily ET was a function of a locally developed crop coefficient, effective rainfall, and potential evapotranspiration derived from a modified Penman equation using local weather data.

Fig. 2 illustrates the relationship between crop development and the planned decline in SW_T at peak bloom prior to

September and October rainfall at Halfway, TX. SW_T on any given day was a function of cotton crop development described by heat units (HU, Fig. 2A) and was based on previous production experiences, plant rooting depth, and water holding capacity of the soil (Stapleton, 1970). SW_T is illustrated in Fig. 2B. SW_{HI} (field capacity) is the upper limit of plant available soil water in the root zone. Early season rainfall storage was allowed by establishing SW_T below SW_{HI}. In most situations, available soil water content can be well below SW_T early in the growing season and increased by frequent light irrigations to reach SW_T prior to peak bloom without causing detrimental effects to the crop. With limited irrigation capacities, it is critical that actual soil water be at or near SW_T by peak bloom. A planned decline and leveling off of SW_T after peak bloom prevents excess vegetative growth, promotes cotton maturity, and provides storage for late season rainfall.

Research has shown optimum irrigation intervals exist that maximize crop yields and/or water use efficiencies for particular irrigation systems, irrigation capacities, and crops (Lyle and Bordovsky, 1995). For example, water delivery through a subsurface drip system may result in peak cotton lint yield when small irrigations occur daily compared to spray systems where daily irrigations of small amounts may result in proportionally high evaporative losses. The protocol dictates that irrigations cannot occur more frequently than at a preset interval (Inv). The upper limit of IR_N was equal to the daily irrigation capacity (I_{CAP}) times the irrigation interval (Inv).

The irrigation protocol was used to irrigate cotton in 1995 and 1996 with a LEPA system. Cotton lint yields and water use efficiencies at three irrigation intervals and three irrigation capacities were determined. The intervals were one, two, and three days (Inv = 1d, 2d, and 3d) and the daily pumping limits were 0.1, 0.2, and 0.3 in./d representing the wide range in irrigation capacities available on the Texas High Plains. The nine irrigation treatments, therefore, resulted in irrigation quantities of up to 0.1, 0.2, or 0.3 inches applied up to every day; 0.2, 0.4, or 0.6 inches applied up to every two days; 0.3, 0.6, or 0.9 inches applied up to every three days.

The experiment was conducted at the Texas Agricultural Experiment Station at Halfway, TX on moderately permeable (0.1 in./h) Olton loam (fine, mixed, thermic Aridic Paleustolls) soil with a slope of less than 0.2%. Cotton had been grown on the test area in 1993 and 1994. Five replications of the 9 treatments plus a preplant only irrigated check were randomly placed in a 6.2-A area irrigated by a 5-span lateral irrigation system. Each span was subdivided into two sections with each section delivering water to 16 40-inch rows through a manifold system similar to that described by Bordovsky et al. (1992). Water was delivered to every other diked furrow from the manifold system through a drop tube into a wide, flat sock which minimized dike erosion. Furrow dikes were maintained in all furrows to capture rainfall and retain applied irrigation water. No runoff or surface redistribution of water occurred throughout the testing period. Nitrogen and phosphorus were banded on each side of the crop bed based on soil analysis. Preplant irrigations with LEPA elevated profile water to approximately 85% of field capacity prior to planting. Paymaster HS26 cotton variety was planted on 13 May 1995 and 10 May 1996. Normal cultural practices were used to control weed and insect pests.

Each day following plant emergence, a computer model with the irrigation decision protocol was used to determine irrigation amounts for each treatment on that day. On days that one or more treatments required irrigation, the linear irrigation system controller was programmed to dispense the appropriate quantity of water on the correct plots as the irrigation system transversed the field. Recorded flow rates, water pressures and time were used to calculate water applied on each plot. Cotton lint yield samples were hand harvested in November from a 26.1 row-ft area in the center of each plot. The cotton samples were ginned with a small gin stand to determine lint yields, and water use efficiencies were calculated from water inputs, soil water depletion, and yield.

Results

An example of the daily calculated soil water contents (SW_N) for the 0.1, 0.2, and 0.3 in./d irrigation limit treatments for the 2 d interval during 1995 is shown in Fig. 3. Also shown is the target soil water content (SW_T) used during the 1995 and 1996 crop years. The three irrigation capacities plus rainfall were able to hold SW_N of all three treatments near SW_T through mid July (HU=1100 dd60). However, as ET increased with crop development, the 0.1 in./d irrigation capacity treatment was unable to meet evaporative demand resulting in SW_N falling well below SW_T. The 0.2 in./d capacity maintained SW_N at the SW_T level until HU=1200 dd60, SW_N then declined at the approximate rate of the planned decline of SW_T until rains occurred in mid September (HU=1700 dd60). At the initiation of SW_T decline (peak bloom), however, SW_N of 0.2 in./d treatment was only one inch below SW_T. The SW_N of the 0.3 in./d treatment was maintained at or above SW_T during the growing season. An early frost terminated the crop in late September (HU=1750 dd60). The planned decline in profile soil water during the short 1995 growing season provided storage for September rains which reduced preplant irrigations in 1996.

Cotton lint yield response to identical irrigation treatments will change drastically from year to year due to the variable weather in this region of Texas. The 1995 crop year was short (HU=1780 dd60 vs 2150 dd60, long term average) with only 3.03 inches of rainfall during July and August. Heat units and seasonal rainfall were near average in 1996 at 2100 dd60 and 11.18 inches, respectively, from planting to harvest and rainfall of 5.66 in during July and August.

Timely rainfall and higher heat unit accumulation in 1996 contributed to lower seasonal irrigations with higher yields than in 1995 (Table 1). The highest seasonal irrigation quantity for the two year period was 10.30 inches for the 0.3 in./d capacity in 1995 (average yield = 1079 lb lint/A) and the lowest quantity at 4.06 inches for the 0.1 in./d capacity in 1996 (1109 lb/A). In both 1995 and 1996, total seasonal irrigation quantity increased much more between the 0.1 and 0.2 in./d irrigation capacities (60% average increase) than between 0.2 and 0.3 in./d capacity (8% average increase) indicating the irrigation capacity above the 0.2 in./d was not fully utilized in 1995 or 1996.

At a given irrigation capacity, irrigation intervals of 3 days or less had no significant affect ($P<0.05$) on yield. This differs from the trend seen in earlier research which showed significant yield decreases when irrigation intervals exceeded 3 days. Surprisingly, there was no response to irrigation interval even at the 0.1 in./d capacity. The daily quantity applied at 0.1 in./d was extremely small with irrigation water in the center of alternate diked furrows ponded to depths of less than 1 inch immediately after irrigation. Although not consistently significant, the 0.1 in./d capacity at the 2 d interval consistently resulting in higher average yield and WUE's than the 1 or 3 d treatments.

In 1995, seasonal water use ranged from 15.45 to 19.12 inches resulting in average yields of 719 to 1079 lb/A and, in 1996, 17.42 to 19.78 inches resulting in average yields of 1109 to 1363 1b/A. Seasonal water use included infiltrated rainfall, the change in seasonal profile soil water, and irrigation. Both water use efficiency (WUE) and seasonal irrigation water use efficiency (IWUE) tended to increase with increase of irrigation capacity. WUE was significantly higher when irrigation capacity was at or exceeded 0.2 in./d (47 lb/A-in. at 0.1 in./d verses 56 lb/A-in. at 0.2 and 0.3 in./d) in 1995. In 1996, WUE was significantly higher when irrigation capacity was 0.2 in./d at the 1 d interval (71 lb/A-in.) or 0.3 in./d (69 lb/A-in.). Seasonal IWUE was not significantly different for either year except at the 2 d interval, 0.1 in./d capacity in 1996 where seasonal IWUE was very high at 96 lb/A-in. The cotton lint yields for all treatments in both years were generally high compared to normal production in the area.

Summary

A procedure was described that utilizes available water resources for irrigation of cotton on the southern Texas High Plains. The protocol, which was tailored to the cotton physiology and rainfall of the area, determines irrigation quantities and timing for LEPA and drip irrigation systems. Irrigation decisions were based on a soil water balance and daily ET model and were used to irrigate nine treatments with limitations of daily soil water status, irrigation capacity, and irrigation interval in 1995 and 1996. Cotton lint yields and water use efficiencies tended to increase with increased irrigation capacity up to 0.2 in./d. Irrigation intervals of 1, 2, and 3 days had no significant effect on yield or WUE's except the seasonal IWUE of the 2 d, 0.1 in./d capacity treatment in 1996. The described protocol was easy to use while utilizing available water resources.

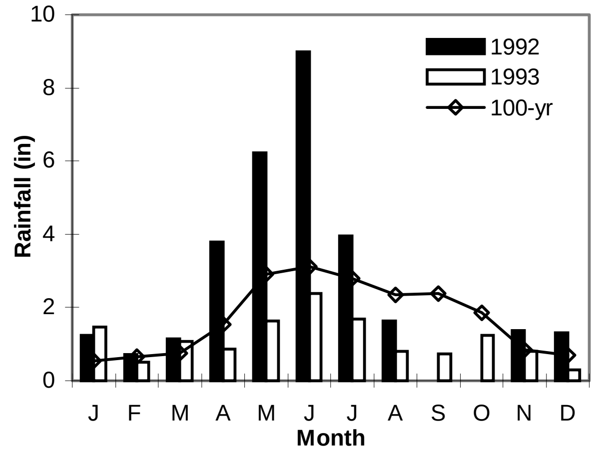
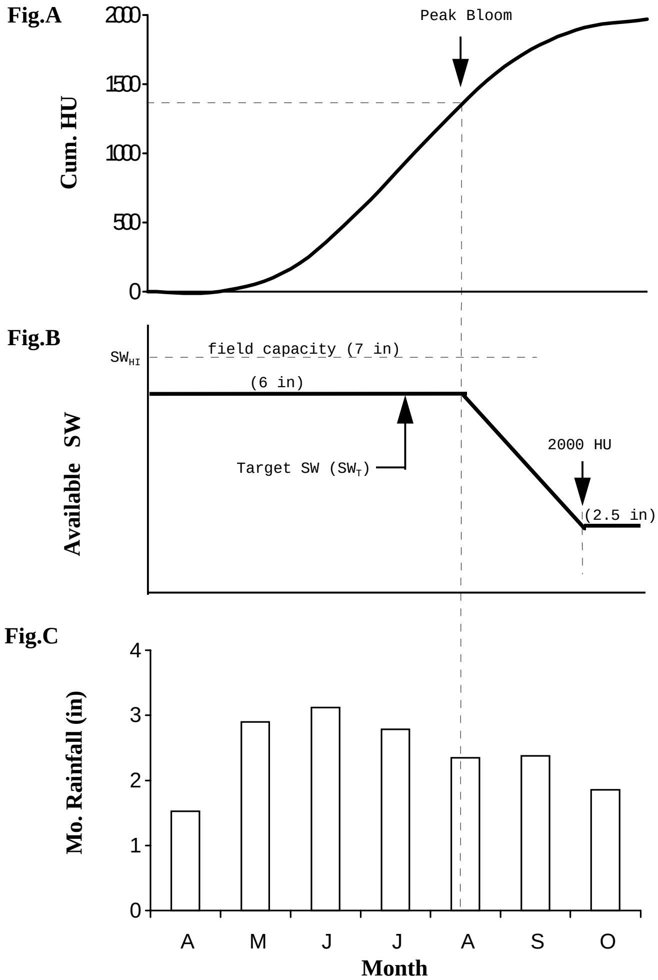


Figure 1. Variation in monthly rainfall illustrated by a "wet" year (1992, TAES, Halfway), a "dry" year (1993, TAES, Halfway), and 100-yr average



(1890-1990, Plainview).Figure 2. Relationship between 10-yr average heat units from 10 May at Halfway, target soil water content, and 100-yr average monthly rainfall at Plainview (14 miles W. of Halfway).

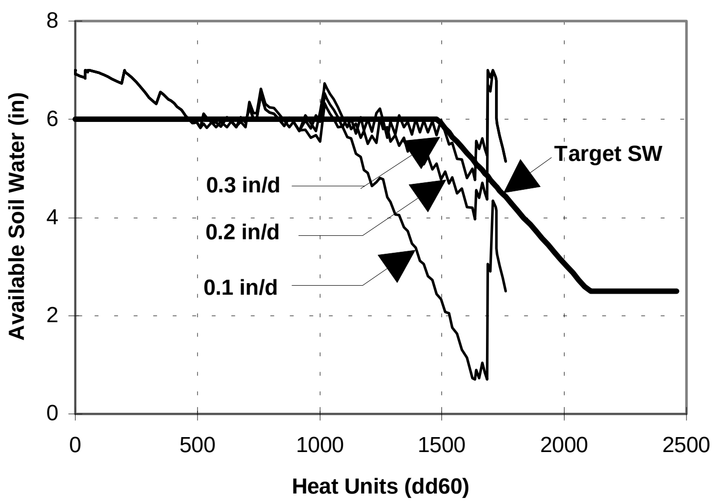


Figure 3. Calculated soil water content (SW_N) resulting from the 0.1, 0.2, and 0.3 in./d irrigation capacities for the 2d irrigation interval in 1995.

Table 1. Lint yield and water use efficiencies resulting from planned soil water depletion treatments in 1995 and 1996 at the Texas Agricultural Experiment Station at Halfway, TX.

Year	Irr. Cap.(in/d)	Irr. Int. (d)	Sea. Irr. Amt. (in.)	Sea. Water Use (in.) 1/	Cotton Lint Yield (lb/A) 2/	WUE (lb/A-in.) 3/	Sea. IWUE (lb/A-in.) 4/
1995	P.P.Only 5/		0.00	10.30	311a	30a	-
	0.1	1	5.75	15.55	708 b	46 b	69a
		2	5.71	15.47	740 b	48 b	75a
		3	5.82	15.34	710 b	46 b	69a
		Avg.	5.76	15.45	719	47	71
	0.2	1	9.21	18.66	1030 c	55 c	78a
		2	9.41	18.70	1049 c	56 c	78a
		3	9.33	18.35	1047 c	57 c	79a
		Avg.	9.32	18.57	1042	56	78
	0.3	1	10.23	19.06	1075 c	56 c	75a
		2	10.27	19.02	1042 c	55 c	71a
		3	10.39	19.29	1120 c	58 c	78a
		Avg.	10.30	19.12	1079	56	75
1996	P.P.Only 5/		0	13.92	790a	57	-
	0.1	1	4.21	17.72	1070 b	60a	67a
		2	4.20	17.58	1175 bc	67abc	96 b
		3	3.95	16.95	1083 b	64ab	74ab
		Avg.	4.06	17.42	1109	64	79
	0.2	1	6.78	19.34	1368 d	71 bc	85ab
		2	6.78	19.40	1304 d	67abc	76ab
		3	6.05	19.01	1272 cd	67abc	80ab
		Avg.	6.53	19.25	1315	68abc	80ab
	0.3	1	6.86	19.53	1348 d	69 bc	81ab
		2	6.85	19.99	1370 d	69 bc	85ab
		3	6.69	19.82	1369 d	69 bc	87ab
		Avg.	6.80	19.78	1363	69	84

1/ Seasonal water use includes seasonal infiltrated rainfall of 8.90 and 9.23 inches in 1995 and 1996, seasonal change in profile SW, and seasonal irrigation.
2/ Values in a column for a given year followed by the same letter are not significant at $P<0.05$.
3/ WUE = cotton lint yield / seasonal water used.
4/ Seasonal IWUE = (lint yield - P.P.Only yield) / seasonal irrigation.
5/ P.P. Only = preplant irrigation only.

Acknowledgments

This research was funded in part by Cotton Incorporated through the Texas State Support Committee. Their support is gratefully acknowledged.

References

1. Bordovsky, W. M. Lyle, R. J. Lascano, D. R. Upchurch. 1992. Cotton irrigation management with LEPA systems. Trans. of the ASAE 35(3):879-884.
2. Bordovsky, J.P. and W. M. Lyle. 1996. Protocol for Planned Soil Water Depletion of Irrigated Cotton. Proceedings of the International Conference on Evapotranspiration and Irrigation Scheduling. Nov. 3-6, San Antonio, TX., pp. 201-206.
3, Lyle, W.M. and J.P. Bordovsky. 1995. LEPA corn irrigation with limited water supplies. Trans. of the ASAE 38(2):455-462.

4. Stapleton, H.N. 1970. Crop production system simulations. Trans. of the ASAE 13(1):110-113.