A Comparison of Irrigation Scheduling Methods on Durum Wheat, Safford Agricultural Center, 1988-90

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Abstract

Four irrigation scheduling methods are compared over a three year period on the Safford Agricultural Center. A computerized checkbook method based on the consumptive water use curves of Erie, et al, updated with near real time evapotranspiration data from the AZMET system and utilizing empirical crop coefficients, produced the highest yields and with the highest water use efficiency. Scheduling irrigations with the IR thermometer produced yields higher than the Check when a Stress Index threshold of 2 (similar to a CWSI of 0.2) was used, but not with a threshold value of 3 nor 4. A method of irrigation scheduling using Erie's curves, but not updated for current weather values, yielded less than the check in all years of the study, and was not considered an acceptable method.

Irrigation inputs from the 1990 season were plugged into new near real time irrigation scheduling software which utilizes AZMET data to determine both evapotranspiration and crop coefficients. This method was found to track the field data quite well and will be utilized in future research.

Introduction

This paper reports this years work, summarizes the work of the past three years and leads into the research for the coming year. The work of the past has been scheduling irrigations using infrared thermometry, computerized checkbooks using modified data from Erie, et al (1) and then modifying the consumptive use values from Erie further using AZMET data and empirically derived crop coefficients. The latter method was effective in scheduling irrigations in a manner to maximize yields and increase efficiencies, but was laborious in that reference evapotranspirations and crop coefficients had to be found for each day and resultant number added to or subtracted from the value in the computer spreadsheet to determine the water needs of the crop. Our research for the future will be based on an irrigation scheduling program described by Scherer, et al (2) which calculates reference evapotranspiration (ET_o) from the AZMET data and multiplies it by a crop coefficient (K_c) to produce the actual crop evapotranspiration (ET_a). We shall refer to this method in this paper as the Near Real Time (NRT) method. Soil data are needed as in the previous computerized checkbooks, as plants extract available water from the soil profile. In this paper, the 1990 study is discussed first and then its data interfaced with the new software.

Methods and Materials

Four irrigation scheduling methods were used in this study, they are as follows:

Check Availability of ditch water and the farm manager's knowledge of crop needs determines when and how much water to apply.

Erie This is the computer method described by Clark and Biggs (3) using historical consumptive use information adapted to this area.

Erie + This method was identical to the previous method except one additional irrigation was added at the end of the season.

IR The infrared thermometer was used to determine a Stress Index on the crop. The crop was to be irrigated when the SI exceeded the value of 3 (similar to a CWSI value of 0.3). Since this method does not indicate the amount of water to be added, water was pushed through the furrows until they were full and then the flow was stopped.

Crop History

Cultivar: Aldura wheat
Elevation: 2950 feet above sea level
Soil type: Pima clay loam
Available Water: 4.5" in the top 2 feet
7.6" in the top 4 feet
Planting date: 21 December 1989
Planting rate: 150 pounds of seed per acre
Fertilizer: 83 lbs/ac urea pre-plant
300 lbs/ac 16-20-0 at planting
73 lbs/ac side dressed on 12 February
Herbicide: 1.75 pints/ac 2,4-D on 15 March
Insecticide: 1 pint/ac Malathion on 10 April
Rainfall: 2.08 inches
Harvest date: 21 June
Number of replicates: 4

Plant heights were measured just prior to harvest, plots were combined with a Massey Harris Clipper small plot harvester. Bushel weights and moisture were determined in the field.

Discussion

The results of this year's study are found in Table 1, with the applied irrigations shown in Figure 1. It can be seen that the Erie plus and Check plots yielded significantly higher than the other two treatments but used larger quantities of water. The two higher yielding plots received 5 irrigation applications compared with 4 for the lower yielding plots. It is interesting to note, however, that the timing and amounts of water applied made large differences in the water use efficiency. The closer the irrigations were to supplying but not exceeding the crop's needs, the more efficient was the cropping system. In addition to using the infrared thermometer to schedule irrigations, it was also used as a tool to follow the stress levels of plants in all treatments. Stress indices by treatment across time are seen in Figure 2. It should be noted, however, that IR readings were taken principally when the IR plots were getting near time for an irrigation and were under their maximum stress. For this reason the stress levels of the IR plots were generally higher than the other plots. One can note from Figure 2 that the stress level of 3, the threshold level for the IR scheduled plots, was exceeded twice during the season. This brings out on of the weaknesses of this system, at times the sky is cloudy during the time of the day when IR readings should be taken, several days can pass before a reading can be taken. Stress levels can shoot up rapidly in a few days, even much more than would be predicted by extrapolating data. This difficulty could be minimized by use of an installed infrared sensor system described by Fangmeier, et al (4).

The highest yielding treatment, Erie plus, was scheduled using historical consumptive use data up to the 16th of May, Day 146. On Figure 3, the pluses (+) show the percent water depletion through the irrigation season using the historically driven software. This software was managed so that irrigations were applied when 67% of the water was depleted from the top 2 feet of soil, with the exception of the irrigation applied on Day 58. On Day 146, it was felt that the historical data was underestimating the consumptive water use so an irrigation was arbitrarily added. This irrigation did not affect plant height nor bushel weight, but dramatically affected the yield and efficiency.

The irrigation inputs from the Erie treatment were plugged into the new software described by Scherer, et al (2) along with AZMET data for the crop growing season and a water depletion curve was calculated, based on water uptake from a 4 foot profile of the same soil. The curve plotted from this data is found in Figure 3 labeled as "NEAR REAL TIME". It can be seen from the comparison between the two curves that the curve generated by the historical data rose earlier in the spring but then slowed down and was passed by the curve generated by AZMET driven data. The NRT irrigation schedule would have called for the additional irrigation that was given to the Erie plus plots, even though it would have scheduled it 16 days earlier.

The irrigation data from each of the treatments in the 1990 season was then plugged into the NRT software and water depletion curves were calculated plotted in Figure 4. All lines ran together up to Day 92, when the check treatment was irrigated. The Check treatment received the most water during the season and this is corroborated by the frequency of dips in its curve and the low maximum and minimum values. This also corresponds well with the Stress Index data shown in Figure 2. The Erie plus and Erie treatments ran together up to Day 146, when the Erie plus treatment received its additional irrigation. The IR treatment ran its curves up nearly to 100% depletion before irrigations were applied. These same peaks were seen in Figure 2 with the Stress Indices, and give reason for the reduction in yield for this treatment.

The NRT model seems to be tracking what was happening in the field and we are looking forward to finding what percent water depletion threshold that will bring optimal yields in the 1991 season.

The summary of three year's data, from 1988 to 1990 are found in Table 2. The Comp(AZMET) treatment, which works very much like the NRT but with empirical crop coefficients, produced the best yields and had the highest water use efficiency. These software models using near real time weather data from the AZMET system are very encouraging. This methodology requires at least weekly updates on weather. The infrared thermometry stress index method produces yields inversely proportional to the threshold level selected for irrigation. With a threshold level of 2, the yields fell between the yield of the Check and the Comp(AZMET), even though the yield increased at the expense of water use efficiency. The higher threshold levels yielded less than the Check and also had lower efficiencies. It is our opinion that infrared thermometry provides stress index values that are of value in irrigation scheduling on wheat, in practice, however, we have not had the success that we feel it is capable of. Our IR readings were made on approximately a weekly basis during the irrigation season and we now feel that two or three times that frequency would be needed to get the desired results. The Erie method, using historical weather data, requires the least attention of the methods, the spreadsheet need only be updated in case of rainfall and irrigations. The seasons irrigations can almost be scheduled a year in advance, but the Farm Manager's Check method always out-yielded this method. Thus, it cannot be recommended as a stand-alone method.

References

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2. Scherer, T.F, F. Fox, Jr., D.C. Slack and L. Clark. 1990. Near Real Time Irrigation Scheduling Using Heat Unit Based Crop Coefficients. Irrigation and Drainage, Proceedings of the 1990 National Conference, Irrigation and Drainage Division of the American Society of Civil Engineers. pp.544-53.

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4. Fangmeier, D.D., S.H. Husman, D.J. Garrot, Jr., and M. Yitayew. 1990. A Sensor System for Monitoring Cotton Water Status. Cotton, A College of Agriculture Report, The University of Arizona, Tucson, AZ. Series P-81, pp.104-6.

Table 1. Yield, Bushel Weight, Plant Height, Water Applied and Water Use Efficiency by Treatment on the Safford Agricultural Center, 1990.

Treatment	Yield[1] (lbs/ac)	Bushel Wt (lbs)	Plant Ht (in)	Irrigation (in)	Efficiency (lbs/ac in)
Erie plus	4717 a[2]	55.5 a	22.0 b	35.3	133.6
Check (Farm mgr)	4531 a	57.0 a	26.0 a	37.8	119.9
Erie (Historical)	3883 b	54.3 a	23.0 ab	29.9	129.9
Infrared	3858 b	57.8 a	23.3 ab	30.9	124.8
Average	4247	56.2	23.6	33.3	127.1
LSD (05)	475	3.9	3.2		

1. Yields are converted to a 10% moisture basis.
2. Values followed by the same letter, in the same column, are not significantly different at the 5% level using the Duncan multiple range test.

Table 2. Yields and Water Use Efficiencies for Irrigation Scheduling Experiments at the Safford Agricultural Center from 1988 to 1990.

Treatment	1988 Yield (lbs/ac)	1988 Effic (lbs/ac in)	1989 Yield (lbs/ac)	1989 Effic (lbs/ac in)	1990 Yield (lbs/ac)	1990 Effic (lbs/ac in)	Weighted Avg Yield (lbs/ac)	Weighted Avg Effic (lbs/ac in)
Comp (AZMET)	4593 a	156.8	4081 a	114.3	-	-	4498.3	136.4
Erie plus	-	-	-	-	4717 a	133.6	4426.2	131.3
IR (SI = 2)	4538 a	154.9	3795 a	95.1	-	-	4309.4	124.3
Check (Farm mgr)	4283 ab	139.5	3503 ab	117.6	4531 a	119.9	4098.8	130.7
IR (SI = 3)	-	-	3664 ab	105.3	3858 b	124.8	3897.2	122.9
Erie (Historical)	3999 ab	130.3	3018 b	100.9	3883 b	129.9	3622.3	120.4
IR (SI =4)	3641 b	125.6	2929 b	107.3	-	-	3391.6	118.5
Average	4210.8	140.8	3498.3	106.8	4247.3	127.1	3985.5	124.9

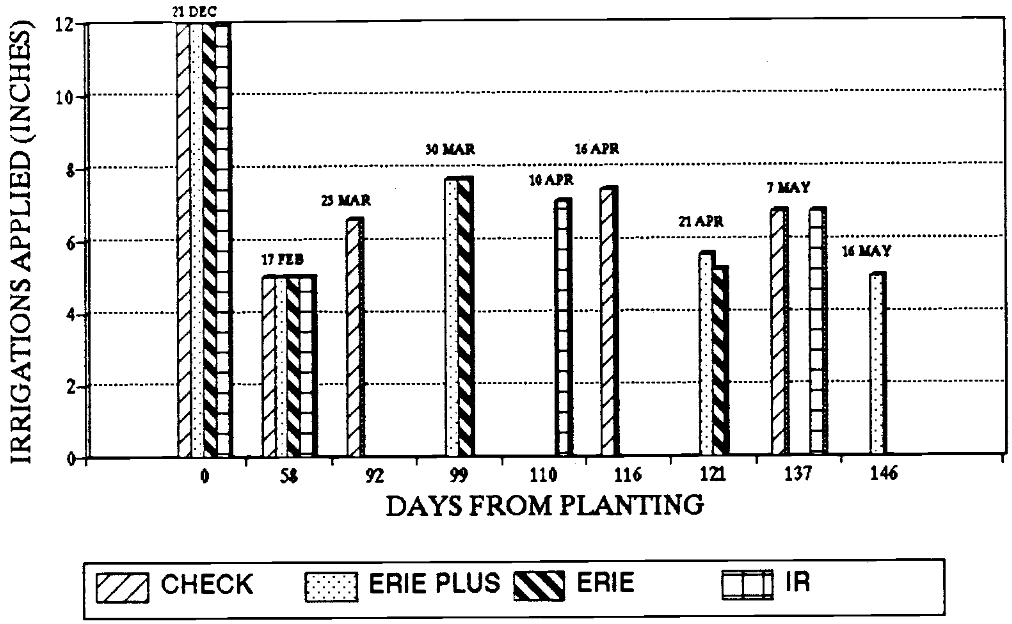

Figure 1. Irrigation quantities applied by treatment and date at the Safford Agricultural Center, 1990.

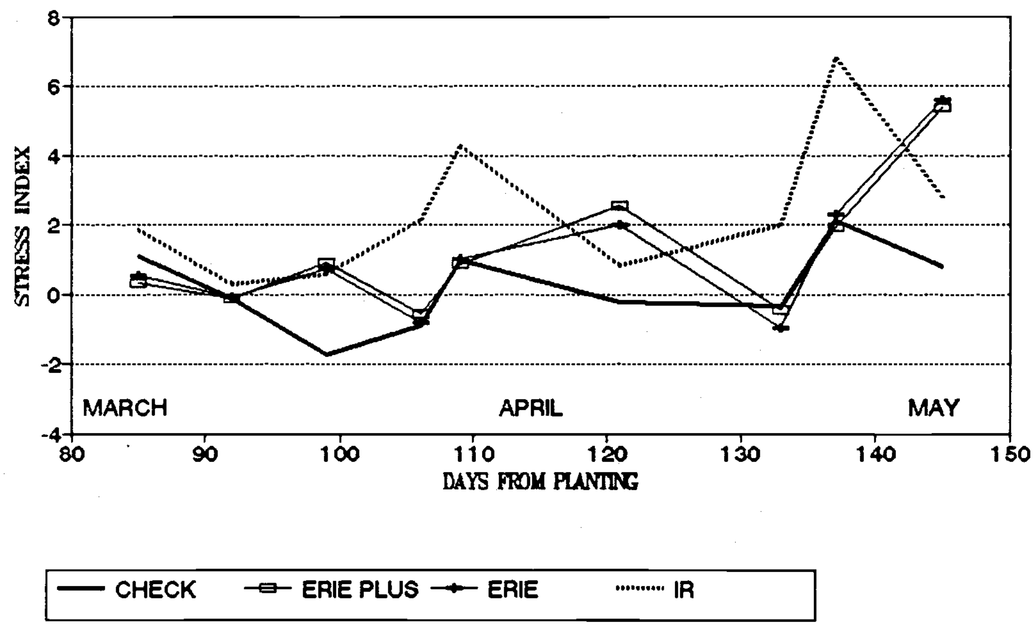

Figure 2. Stress indices on durum wheat by treatment at the Safford Agricultural Center, 1990.

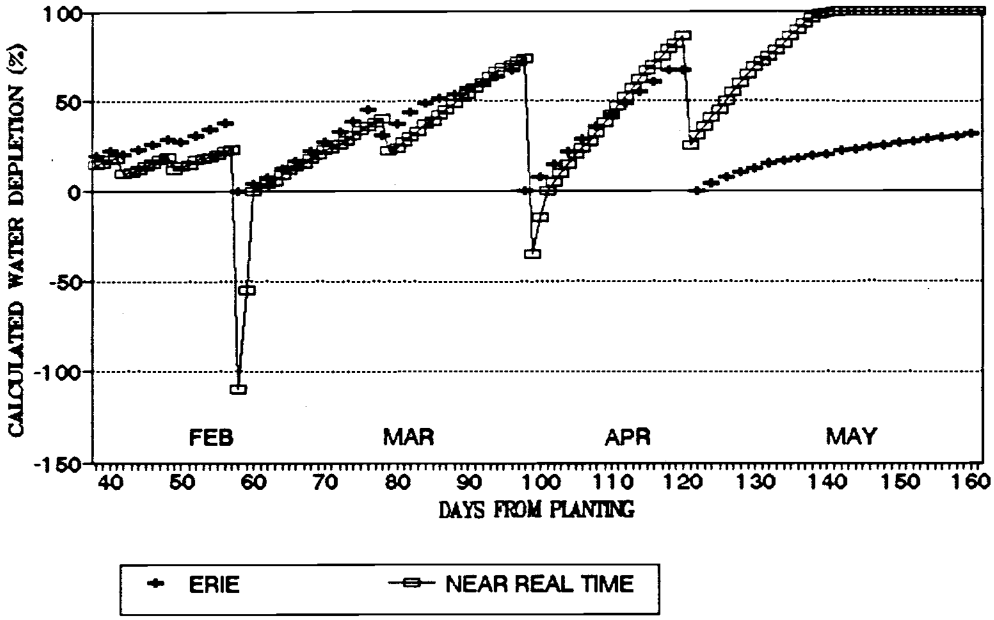

Figure 3. A comparison of calculated percent water depletion curves between the Erie method using historical consumptive water use and the new Near Real Time (NRT) method on the Safford Agricultural Center, 1990.

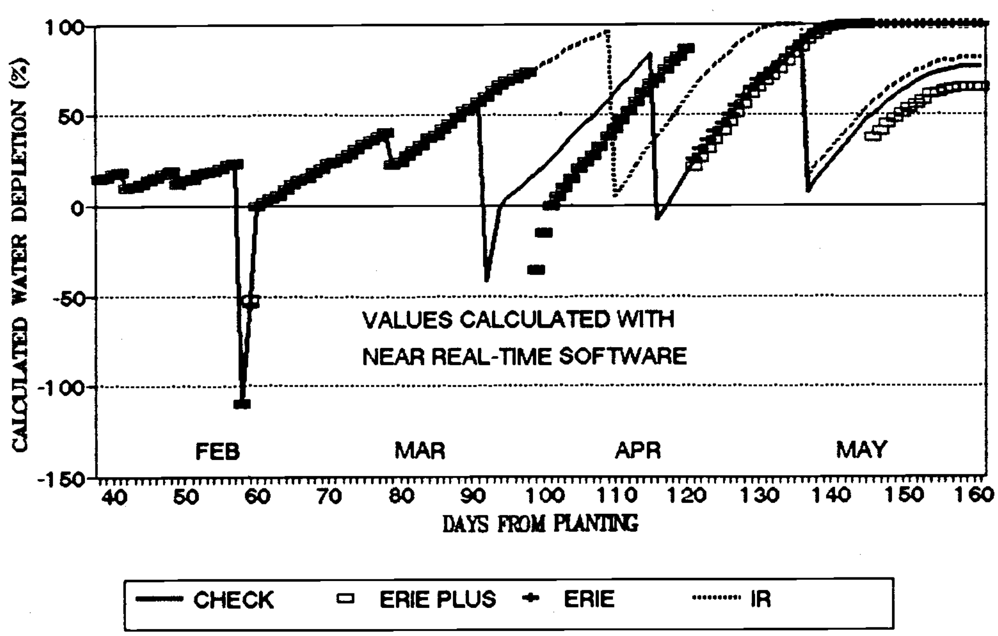

Figure 4. Percent water depletion curves generated by plugging irrigation data from the four treatments into the Near Real Time (NRT) software using 1990 AZMET data from the Safford Agricultural Center.