CROP RESPONSES UNDER VARIOUS IRRIGATION SCHEDULING CRITERIA

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INTRODUCTION

Irrigation scheduling research conducted in recent years at the KSU Northwest Research-Extension Center has concentrated on methods which use the water budget approach. The water budget approach to irrigation scheduling is similar to balancing a checkbook. The withdrawal is the evapotranspiration amount (ET) which is a term that is used to describe the water use of growing crops. Deposits are rainfall and/or irrigation amounts. The balance is the amount of water remaining in the soil. The crop is irrigated when the balance reaches a pre-determined amount.

The amount of ET that occurs is influenced by climatic factors, farming practices, stage of crop growth, and other factors. The amount of ET that occurs based on climatic conditions is referred to as reference evapotranspiration. Growing season reference evapotranspiration in western Kansas can range from 30 inches to 40 inches due to yearly climatic differences, a value which would represent the total water needs of a well-watered crop of alfalfa. Summer precipitation is also erratic in the Central Great Plains, much of it coming in the form of scattered thunderstorms. These variations in ET and precipitation emphasizes the need to schedule irrigation based on crop needs. The amount of crop water use that occurs for a given crop is obtained by multiplying a crop coefficient value and the reference ET.

The reference evapotranspiration (ETr) has been calculated on a daily basis during the growing season for Northwest Kansas since 1978. These daily values are reported on the local radio stations, and weekly summaries are included in the area papers. Daily inputs for the modified Penman equation for ETr are solar radiation, maximum and minimum temperatures, drybulb and wetbulb temperature at the 8:00 a.m. observation, and wind run. Precipitation values are also needed to update the water budget. Research conducted since 1982 at the KSU Northwest Research-Extension Center has shown the validity of using daily ET values in a simple water budget to schedule irrigation of summer crops.

BASELINE STUDIES

Studies conducted between 1982 and 1984 have been termed as the baseline studies. These studies had the following objectives: to validate the use of calculated ET in irrigation scheduling for northwest Kansas; to determine the average water requirement for the principal summer crops--corn, grain sorghum and soybeans; and to determine the effects of limited irrigation on these crops. The water stress levels were imposed by multiplying the daily calculated ET value by one of the following factors: 0.4, 0.6, 0.8, 1.0, 1.2, 1.4. The 0.4 ET treatment would essentially be receiving only 40% of its water needs, whereas the 1.4 ET treatment would be overirrigated by 40%. Of course, the 1.0 ET treatment is the control or standard treatment, where the ET value is not modified.

Corn

Corn responds well to irrigation, with yields increasing sharply with total water use (Figure 1). The average irrigation water requirement for the standard (1.0 ET) treatment during the three-year study was 14.9 inches, with an average total water use of 27.7 inches (Table 1).

Irrigation for the standard treatment (1.0 ET) varied from 10.9 inches in the wet, cool year 1982, to 18.2 inches in the hot, dry year 1983. This once again emphasizes the need to use irrigation scheduling based on crop needs rather than average conditions. There was no additional response to increased irrigation above the standard amount (1.0 ET) except in 1983, a hot, dry year. However, the amounts applied for the heavy irrigated treatments, 22.6 and 27.0 inches, would not be feasible from a practical standpoint for most systems in northwest Kansas. It is interesting to note that, even for the severely limited irrigation (0.4 ET) treatment, yields were above 130 bushels/acre on less than 4 inches of net applied irrigation. The water use efficiency (WUE), the amount of grain produced with an inch of total water use, was also highest for the 0.4 ET treatment.

Soybeans

The response of soybeans to total water use was fairly flat (Figure 1). In 1983 and 1984, there was a moderate yield increase with irrigation until the standard treatment (1.0 ET) was surpassed (Table 1). However, in 1982, a wet year, soybean yields decreased with irrigation. This emphasizes the fact that care should be taken not to overwater soybeans. There was some yield depression, even for the standard treatment, which may indicate the calculated ET values were too high during portions of the season. Some research has indicated soybeans may respond better with moderate water stress applied during the vegetative stage.

Overall, irrigation amounts were similar to the amounts required for corn. This is in contrast to commonly held beliefs that soybeans are inappropriate to the Central Great Plains due to high water use.

Grain Sorghum

The response of grain sorghum to total water use was relatively flat (Figure 1). Overall, yields were low in two of the three years due to bird damage (Table 1). The yield for the standard treatment (1.0 ET) was highest, averaging 103.2 bushels/acre with 11.7 inches of irrigation.

On the deep silt loam soils of the Central Great Plains, grain sorghum can tolerate periods of water stress and still yield well. Of the three crops studied, grain sorghum is probably the most suited to flexibility in scheduling irrigation. The water budget is still useful in tracking the water needs of grain sorghum, but the ability to tolerate periods of water stress allows the irrigator to shift water to other more sensitive crops when necessary.

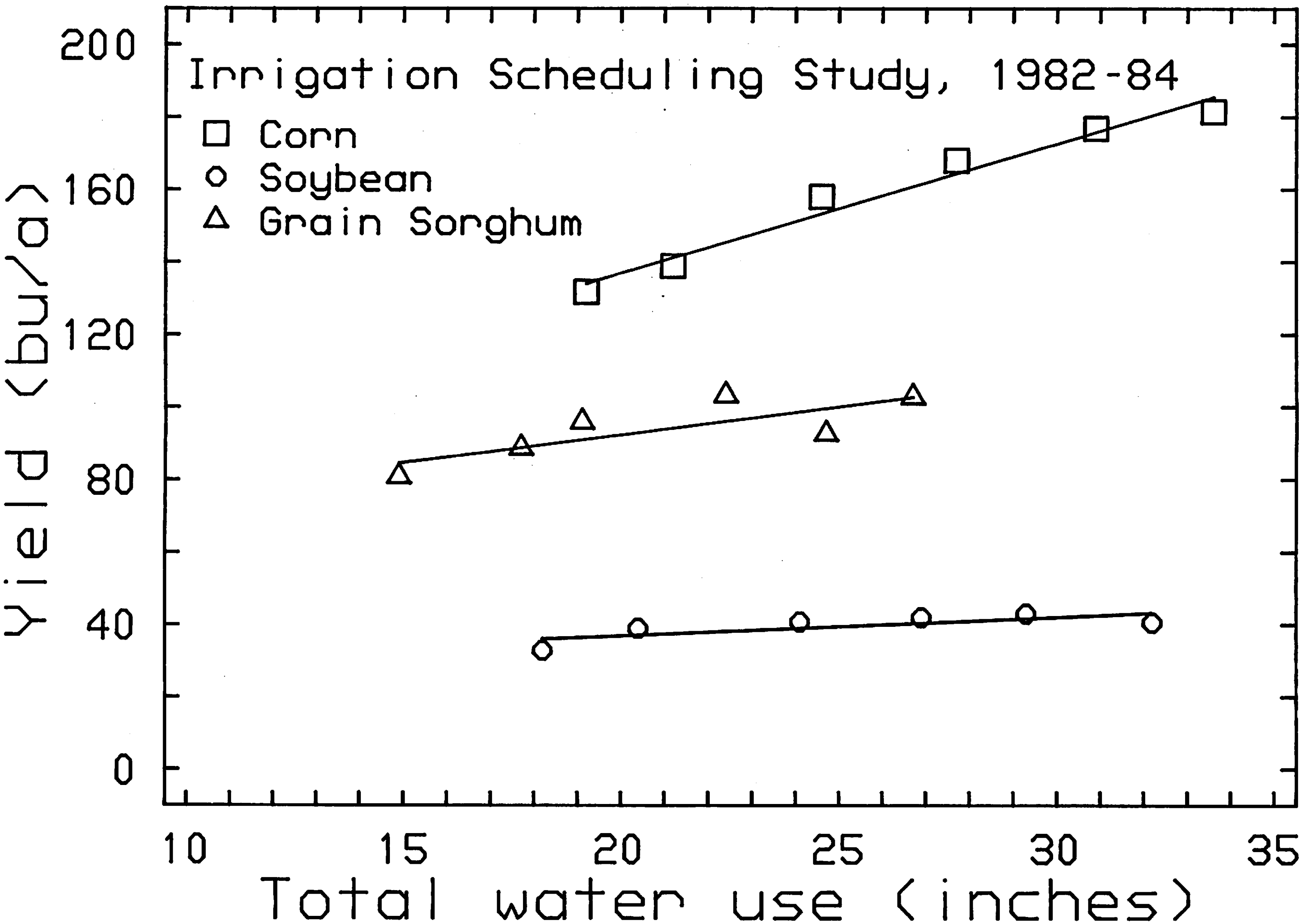
Irrigation Scheduling Study, 1982-84
Corn
Soybean
Grain Sorghum
Yield (bu/a)
200
160
120
80
40
0
10
15
20
25
30
35
Total water use (inches)

Table 1. Summary of Yields and Water Use Data from an Irrigation Scheduling Study
KSU Northwest Research-Extension Center. 1982-1984

CROP	ET Factor	IRRIGATION, in.				WATER USE, in.				YIELD, bu/a.				WUE, lbs/acre-in.			
		1982	1983	1984	MEAN	1982	1983	1984	MEAN	1982	1983	1984	MEAN	1982	1983	1984	MEAN
Corn	1.4	13.3	27.0	25.1	21.8	30.1	36.2	34.6	33.6	190.2	181.0	172.9	181.4	355	280	280	305
	1.2	11.1	22.6	21.2	18.3	28.4	32.8	31.5	30.9	190.0	169.2	171.3	176.8	375	289	305	323
	1.0	10.9	18.2	15.7	14.9	27.6	27.9	27.7	27.7	191.9	139.8	171.9	167.9	391	280	347	339
	0.8	8.3	12.0	11.2	10.5	27.2	23.9	22.7	24.6	165.7	136.6	171.5	157.9	343	321	423	362
	0.6	3.3	10.0	6.6	6.6	23.5	21.0	19.0	21.2	172.5	130.7	113.2	138.8	411	352	334	366
	0.4	3.0	5.3	3.1	3.8	23.2	18.0	16.4	19.2	155.6	111.5	116.5	127.9	403	348	398	383
LSD .05=						2.4	1.7	1.7		NS	25.6	23.1		NS	NS	51	
Soybeans	1.4	10.1	27.5	24.9	20.8	26.2	35.0	35.3	32.2	34.3	43.5	43.8	40.5	79	75	75	76
	1.2	8.5	22.7	21.1	17.4	24.4	31.6	31.8	29.3	39.3	44.1	45.2	42.9	97	84	85	89
	1.0	7.0	18.3	17.6	14.3	22.8	28.7	29.1	26.9	38.2	42.0	45.4	41.9	100	88	94	94
	0.8	6.5	13.8	11.2	10.5	23.1	24.4	24.7	24.1	40.6	39.7	41.7	40.7	106	98	102	102
	0.6	4.1	9.5	5.8	6.5	20.5	21.3	19.5	20.4	41.5	31.5	43.6	38.9	122	89	135	115
	0.4	3.1	3.6	3.1	3.3	20.1	16.6	17.8	18.2	41.0	21.3	36.2	32.8	123	77	122	107
LSD .05=						1.6	1.4	1.6		NS	8.8	4.0		17	NS	19	
G.Sorghum	1.4	8.1	20.9	23.1	17.4	20.7	28.8	30.7	26.7	98.2	79.2	131.1	102.8	267	154	239	220
	1.2	6.8	17.5	19.6	14.6	20.1	25.9	28.0	24.7	93.8	60.4	123.2	92.5	262	131	247	213
	1.0	6.8	14.1	14.3	11.7	20.5	22.8	23.9	22.4	95.4	84.4	129.7	103.2	260	207	304	257
	0.8	4.4	8.4	10.0	7.6	17.7	19.4	20.2	19.1	91.5	70.2	125.6	95.8	290	203	347	280
	0.6	3.2	5.6	7.1	5.3	16.9	17.8	18.3	17.7	84.3	68.4	113.0	88.6	280	215	345	280
	0.4	0.0	3.1	3.2	2.1	14.1	15.2	15.3	14.9	85.0	54.9	102.0	80.6	341	202	375	306
LSD .05=						1.7	0.9	1.0		NS	NS	NS		39	NS	69	

ADVANCED STUDIES

Soybeans

Results from the baseline study and the literature suggested that there might be an opportunity to increase soybean yields by imposing a moderate degree of stress during the vegetative period.

The water budgets for the six treatments were modified to give the following range of irrigation levels:

1. 100% of reported ET (Standard)
2. 75% of reported ET
3. 50% of reported ET
4. No Irrigation
5. 75/100% of reported ET
6. 50/100% of reported ET

Treatments 5 and 6 received only 75 and 50% of the ET requirements during the vegetative period and 100% during the reproductive stage, respectively. Treatments 5 and 6 were shifted to the higher irrigation level on approximately July 25 of each year. The range of treatments allows for examining the effects of full-season and vegetative-period stress on yields as compared to a 100% of ET (standard) treatment and to a nonirrigated control.

Yields were equal or better for the treatments receiving vegetative-period stress as compared to the standard treatment in both 1986 and 1987 (Table 2). Significant savings in irrigation were made by the 0.50/1.00 ET treatment. However, in 1988, yields were depressed for both the full-season and vegetative-period water stress treatments. This is probably due to the severity of the early-season water stress which occurred in June. The cumulative ET for June was the highest on record for the seventeen-year period in which we have calculated values. This, coupled with less than an inch of precipitation, resulted in severe water stress.

The results show that imposing a moderate amount of water stress on soybeans during the vegetative period can reduce irrigation requirements while maintaining yields. In extreme years such as 1988, the irrigator should alter his schedules to alleviate severe water stress during the vegetative period.

Corn

The irrigator is primarily concerned with the net return from an acre rather than the maximum grain yield. A new corn study was initiated in 1986 to examine the effects of three management practices on net return. The three inputs were irrigation amount, fertilizer rate, and seeding rate. The irrigation amounts selected were 18, 12, and 6 inches, and superimposed on these three amounts were three management strategies. The 18-inch net irrigation constraint isn't reached in most years. The 12-inch constraint represents a moderate constraint, and the 6-inch constraint would be a severe limitation.

Table 2. Summary of soybean yield and water use data from a climate-based irrigation scheduling study, KSU Northwest Research-Extension Center, 1986-1988, Colby, Kansas.

Irrigation Trt. (ET Factor)	Net Irrigation 1986	1987	1988	Mean	Water Use 1986	1987	1988	Mean	Grain yield 1986	1987	1988	Mean	WUE[1] 1986	1987	1988	Mean
	inches				inches				bushels/acre				lbs/acre-inch			
1.00 (Standard)	15.5	11.1	12.7	13.1	25.6	23.7	26.0	25.1	57.7	49.7	64.4	57.3	135	126	149	137
0.75	10.2	7.2	9.8	9.1	22.1	20.1	24.5	22.2	56.4	48.2	54.3	53.0	152	145	133	143
0.50	3.6	3.5	3.2	3.4	16.9	17.0	18.7	17.5	39.9	40.3	32.2	37.5	142	142	103	129
No Irrigation	0.0	0.0	0.0	0.0	14.0	14.7	14.7	14.5	26.3	29.0	21.7	25.7	113	120	88	107
0.75/1.00	10.8	11.4	12.5	11.6	21.5	24.0	24.8	23.4	59.7	48.5	55.6	54.6	166	121	135	141
0.50/1.00	10.4	9.9	10.3	10.2	21.4	22.2	20.2	21.3	59.5	51.7	42.9	51.4	167	139	127	144
Mean	8.4	7.2	8.1	7.9	20.3	20.3	21.5	20.7	49.9	44.6	45.2	46.6	146	132	123	134
LSD.05	----	----	----	----	1.0	0.9	1.4	----	10.7	5.3	9.9	----	29	23	23	----

1 Water use efficiency is defined as yield in lbs/acre divided by total water use in inches.

The schemes were as follows:

Water allowance not to exceed 18 inches.

1. 100% of reported ET
2. 75% of reported ET
3. 50% of reported ET

Water allowance not to exceed 12 inches.

4. 100% of reported ET
5. 75% during vegetative stage, 100% thereafter,
6. 50% during vegetative stage, 100% thereafter.

Water allowance not to exceed 6 inches.

7. 100% of reported ET
8. 75% during vegetative stage, 100% thereafter,
9. 50% during vegetative stage, 100% thereafter.

The three irrigation treatments within each major irrigation constraint level were matched up with appropriate fertilizer and seeding rates (Table 3). Though the study design does not allow the absolute determination of the best management practice for irrigated corn, it does allow us to compare nine different possibilities.

For treatments 7 through 9, the irrigation constraint was always reached (Table 3). Analysis of the yields and net returns show that if water is limited to 6 inches, best results can be obtained by reducing fertilizer and seeding rates and by saving the water as long as possible to try to reach the critical reproductive stage. Net returns were highest for treatment 9, which also had less year-to-year variability.

For treatments 4 through 6, best results could be obtained by reducing fertilizer and seeding rates to the medium level and by imposing a moderate amount of stress during the vegetative period (treatment 5). It should be noted that in both 1986 and 1987, treatment 5 was essentially equal or better than treatment 1 in terms of net return.

For treatments 1 through 3, best results were obtained by full irrigation, full fertilization and with the higher seeding rate. Net returns decreased drastically when the alternative conservation treatments 2 and 3 were employed.

The study shows there are reasonable alternatives to full irrigation. However, best results can only be obtained by proper matching of inputs with irrigation constraints. This study does not examine the aspects of spreading the irrigation amount over a larger land base, but some of the results are be readily applicable.

Table 3. Economic analysis of management practices and their effects on corn yields in an irrigation scheduling study, KSU Northwest Research-Extension Center, 1986-88, Colby, Kansas.

ET Factor	Irrigation Constraint	Fertilizer Rate	Plant Population	Irrigation 1986	Irrigation 1987	Irrigation 1988	Irrigation Mean	Yield 1986	Yield 1987	Yield 1988	Yield Mean	Net Returns* 1986	Net Returns* 1987	Net Returns* 1988	Net Returns* Mean
		lb N/a	p/a	inches				bu/a							
1.00ET	18	210	23000	15	12	18	15	159	161	157	159	$186	$202	$171	$186
0.75ET	18	180	20900	9	9	12	10	154	121	125	133	$200	$116	$116	$144
0.50ET	18	150	17100	3	3	6	4	125	102	63	97	$154	$96	($14)	$79
1.00ET	12	210	23000	12	12	12	12	169	147	120	145	$222	$166	$97	$162
0.75/1.00ET	12	180	20900	12	9	12	11	162	152	127	147	$210	$195	$121	$175
0.50/1.00ET	12	150	17100	9	9	12	10	147	143	125	138	$189	$179	$123	$164
1.00ET	6	210	23000	6	6	6	6	123	112	63	99	$126	$98	($27)	$66
0.75/1.00ET	6	180	20900	6	6	6	6	139	136	74	116	$172	$165	$7	$115
0.50/1.00ET	6	150	17100	6	6	6	6	139	120	102	120	$179	$131	$85	$132

* Budget analysis based on different costs of fertilizer, seed and irrigation for the various treatments. Prices assumed were nitrogen fertilizer at $0.12/lb, seed at $70/bag with 75000 seeds/bag, irrigation pumping costs of $3.50/acre-in, other fixed and variable costs of $120, and corn at $2.55/bu.