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CORN AND GRAIN SORGHUM PRODUCTION WITH LIMITED IRRIGATION

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INTRODUCTION

Soil water management during the growing and non-growing season can be enhanced with crop residues. Capture and retention of soil water plus irrigation at critical growth stages can maximize limited irrigation resources. This research quantified the water use and irrigation requirements of corn and grain sorghum grown with optimum water management using water conservation techniques. Corn grain and forage yields declined with less than full irrigation, but sorghum grain and forage yields remained nearly constant. Net economic returns increased as more irrigation was applied to corn, but decreased with additional irrigation on sorghum. When irrigation was reduced in corn and sorghum production, there was less impact on grain and forage yield from the same proportional decrease in irrigation. For example, a 50% reduction in full irrigation caused a 20% reduction in corn grain yields. Sorghum grain yields were reduced by 8% with a 72% reduction in irrigation. However, net economic return from corn production increased at the same rate with additional irrigation. Additional irrigation decreased annual net returns from sorghum production. Irrigators, responding to economic returns form their irrigation practices, would tend to fully irrigate corn and reduce irrigation for sorghum.

OBJECTIVES

The overall goal of the project was to conduct cropping systems field research with the emphasis on crop yield response to full and limited irrigation. The objectives were to:

1. Measure grain and forage production of corn and grain sorghum with deficit irrigation and no-till management.
2. Measure grain yield and irrigation to develop production functions for corn and grain sorghum in no-till management with irrigation inputs from 2 to 3 inches to full irrigation.
3. Determine soil water during the growing-season and non-growing season to assess the impacts irrigation on soil water storage and use.
4. Find the net economic returns of corn and grain sorghum receiving irrigation from deficit to fully irrigated management.

METHODS

The cropping systems project was located at the Kansas State University's Southwest Research-Extension Center near Garden City, KS. Deficit irrigation strategies and no-till management strategies were used to test crop responses to limited water supplies. The experimental field was subdivided into strips, oriented east to west, that were irrigated by a 4-span linear move sprinkler irrigation system. Six irrigation treatments, replicated four times, ranged from 3 to 12 inches for corn and 2 to 8 inches for sorghum. If rainfall was sufficient to fill the soil profile to field capacity, irrigation was not applied. Irrigation treatments were the same for each plot from year to year so the antecedent soil water carried over to the next year. The days between irrigation events increased as irrigation decreased (table 1). The same net irrigation (1 inch) was applied for each irrigation event. Soil water was measured once every two weeks with the neutron attenuation method in increments of 12 inches to a depth of 8 feet. These measurements along with effective precipitation (no runoff), net irrigation, and soil water use were used to calculate evapotranspiration for each two-week period during the season. Ending season and beginning season soil water measurements were used to calculate soil water accumulations during the non-growing season and soil water use during the growing season. The soil was a Ulysses silt loam with an available water capacity of 2 inches/ft and volumetric water contents of 33% at field capacity and 17% at permanent wilting. Cultural practices, including hybrid selection, no-till planting techniques, fertilizer applications, weed control, were the same across irrigation treatments. Yield-irrigation relationships were used with current commodity price and crop production costs to determine net economic returns from corn and sorghum crops across irrigation treatments.

Table 1. Days between irrigation events for irrigation treatments.

Irrigation Treatment	Corn Days	Sorghum Days
1 High	4.5	4.9
2	5.5	5.6
3	6.0	6.3
4	8.3	11.1
5	10.8	13.2
Low 6	13.8	15.7

RESULTS AND DISCUSSION

Relative yields were calculated as the ratio of irrigation treatment yields and fully irrigated yields for corn and sorghum (table 2). Relative yield results were expressed as percentages of yields for the fully irrigated treatment. In the same fashion, relative irrigation was calculated as the ratio of irrigation amount of each treatment and the fully irrigated treatment. For example, the corn treatment that received 9 inches of water produced 92% of the yield of fully irrigated treatment with 74% of the irrigation. Corn grain yields decreased at a decreasing rate as irrigation was reduced. Sorghum yields from the driest irrigation treatment produced only 5 bu/acre less that the fully irrigated treatment. The driest irrigation treatment produced 96% of full yield with 28% of the water.

Table 2. Average grain yields, relative grain yields, irrigation, and relative irrigation for corn after corn and sorghum after wheat for 2004-2007.

Corn after corn 2004-2007				Sorghum after Wheat 2004-07			
Average Yield	Relative Yield	Annual Irrigation	Relative Irrigation	Average Yield	Relative Yield	Average Irrigation	Relative Irrigation
bu/ac	%	inches	%	bu/ac	%	inches	
205	100	12	100	122	100	7	100
199	99	10	85	125	100	6	86
185	92	9	74	124	100	5	72
163	81	6	52	117	100	4	48
141	70	5	39	117	96	3	34
119	59	3	29	117	96	2	28

Results for forage yields from corn and sorghum mimicked grain yields (table 3). Corn was planted at rates for predicted yield potential from each irrigation treatment, which were 19,500 plants/ac for the driest treatment to 32,000 plants/ac for the driest treatment. Sorghum was planted with 107,000 plants/ac for all irrigation treatments.

Table 3. Average forage yields (dry matter) and relative forage yields for corn after corn and sorghum after wheat for 2004-2007.

Corn after corn 2004-2007				Sorghum after Wheat 2004-07			
Average Yield	Relative Yield	Annual Irrigation	Relative Irrigation	Average Yield	Relative Yield	Average Irrigation	Relative Irrigation
T/ac	%	inches	%	T/ac	%	inches	
9.6	100	12	100	7.6	100	7	100
8.2	85	10	85	7.2	98	6	86
7.9	82	9	74	7.5	96	5	72
5.7	59	6	52	6.8	90	4	48
6.2	64	5	39	7.5	92	3	34
5.7	61	3	29	6.7	92	2	28

Results in tables 2 and 3 are four-year averages for each irrigation treatment. Variation in crop yields from year-to-year is important to evaluate income risk. Data for each irrigation treatment each year of the study are in figures 1 & 2. Regression of corn relative yields (the line in figure 1) show decreasing yields as irrigation decreased, but sorghum relative yields remained constant. The distance of the data points from the trend line indicates the variation in yields from year-to-year. Corn yield variation increased for less than 10 inches of irrigation. Variation in sorghum yields remained constant from the most to least irrigation. Yield variation can influence crop rotation choices.

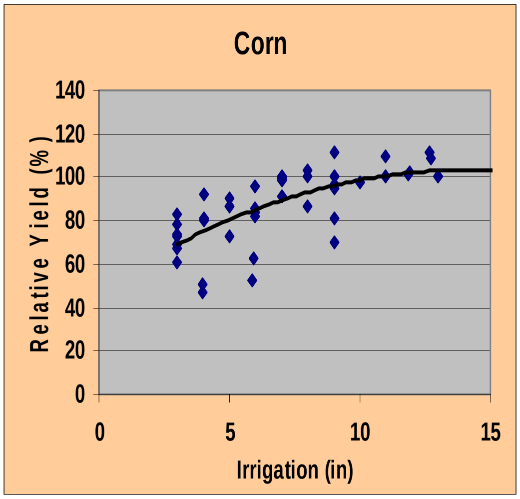

Fig. 1. Trend and variation in relative yields for corn.

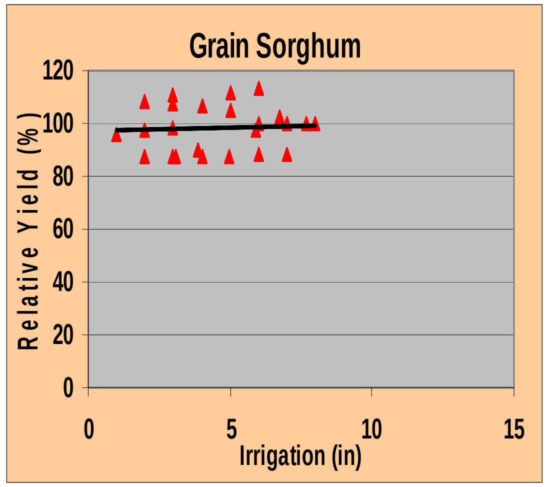

Fig. 2 Trend and variation in relative yields for sorghum.

Cropping season evapotranspiration (ETc) was calculated from the summation of net irrigation (water that infiltrated) effective precipitation (no observed runoff), and the stored soil water used during the growing season. Corn ETc (table 4) was from 25.5 the wettest irrigation treatment to 19 inches for the driest treatment for a difference of 6.5 inches. Productivity was calculated as the ratio of grain yields and ETc. Corn yields decreased relatively more than ET causing productivity to decrease with less irrigation. Plant population may have decreased potential yields for the drier treatment in 2004, which had above normal growing season precipitation. Sorghum ET (table 5) was 24.2 to 20.8 inches. Field observation and forage yields showed that the wetter treatments developed more dry matter, but the uniform plant populations did not restrict yield potential in the drier plots. Sorghum productivity increased with less irrigation causing better use of available water for grain production.

Table 4. Cropping season ETc, yield, and productivity for corn.

Irrigation	SW Use	Rainfall	ET	Yield	Productivity
Inches	inches	inches	inches	bu/ac	bu/ac-in
12	1.8	11.7	25.5	205	8.0
10	2.3	11.7	24.0	199	8.3
8	3.2	11.7	22.9	185	8.1
6	2.9	11.7	20.6	163	7.9
4.5	3.9	11.7	20.1	141	7.0
3	4.3	11.7	19.0	119	6.3

Soil water accumulated during the non-growing season and some of this water was used as component of ETc during the following growing season (table 6). As irrigation decreased, the crop developed roots deeper into the soil and extracted more soil water creating more room to store water during the following non-growing season (data not shown). There was a correspondence between

Table 5. Cropping season ETc, yield, and productivity for sorghum.

Irrigation inches	SW Use inches	Rainfall Inches	ET inches	Yield bu/ac	Productivity bu/ac-in
8	4.3	11.9	24.2	122	5.0
6.7	4.7	11.9	23.3	125	5.4
5.3	5.5	11.9	22.7	124	5.4
4	5.8	11.9	21.7	117	5.4
3	6.3	11.9	21.2	117	5.5
2	6.9	11.9	20.8	117	5.6

water stored and water used during the following season. More water soil water use followed more water storage. More water accumulated prior to sorghum than corn because soil water extraction was deeper into the soil in the sorghum crop.

Table 6. Stored soil water (SW) gains during the previous non-growing season and stored soil water use during the growing season for corn following corn and sorghum following wheat.

Irrigation Corn inches	SW Gain Corn inches		SW Use Corn inches		Irrigation Sorghum inches	SW Gain Sorghum inches		SW Use Sorghum inches	
12	3.3	b	1.8	d	8	6.8	bc	4.3	d
10	4.9	ab	2.3	cd	6.7	6.4	c	4.7	d
8	4.9	ab	3.2	ab	5.3	7.5	ab	5.5	c
6	5.9	a	2.9	abc	4	7.8	ab	5.8	bc
4.5	5.7	a	3.9	ab	3	8.0	a	6.3	b
3	6.0	a	4.3	a	2	7.9	a	6.9	a
$LSD_{0.05}$	1.7		1.1			1.1		0.5	

Fallow efficiency was calculated as the ratio of stored soil water and precipitation during the non-growing season (table 7). The time between wheat harvest and sorghum emergence was almost 11 months, but 7 months elapsed between corn harvest and emergence of the next corn crop. Soil water accumulations nearer to the time of use were more effective than early water storage. There was more time to store water in the wheat stubble that preceded sorghum planting, which refilled more of the soil profile, but there was more time for drainage. The small difference in stored soil water between the wettest irrigation treatment and the driest treatment was 1.1 inches, probably contributed to smaller differences in sorghum grain yields.

Yield results from the field study and crop prices were used to calculate gross income for corn sorghum (tables 8 & 9). Net income was calculated as the difference in gross income and production costs including irrigation costs. These commodity prices and production costs can vary over time and from one producer to the next. In this example corn could be planted on the entire field or

Table 7. Non-growing season fallow efficiency and drainage.

--Fallow Efficiency		---ET + Drainage--		---------Drainage-----	
Corn	Sorghum	Corn	Sorghum	Corn	Sorghum
%	%	inches	inches	inches	inches
33	32	6.7	14.2	3.7	7.2
49	30	5.1	14.6	2.1	7.6
49	36	5.1	13.5	2.1	6.5
59	37	4.1	13.2	1.1	6.2
57	38	4.3	13	1.3	6.0
60	38	4.0	13	1.0	6.0

or planted on half the field and rotated with sorghum. Irrigation pumping capacity can limit the irrigation amount that can be delivered to the crop. If 9 inches of irrigation were available during the growing season, the net return would be approximately $280/ac or $36,400 for a 130 ac field. If corn was rotated with sorghum and 12 in of irrigation were applied to corn, the net return would be $350/ac for corn. Sorghum would receive 6 inches of water for a net return of $125/ac. The combined net return for 130 acres would be $30,800. The difference in net return between continuous corn and the rotation is not the only consideration. Income variability from one year to the next would be less for the rotation because the corn yield would be less variable.

Table 8. Net returns (gross income – production costs) for corn after corn.

Net Irrigation	Corn Price	Grain Yield	Gross Income	Irrigation Cost	Production Costs*	Net Return
inches	$/bu	Bu/ac	$/ac	$/ac-in	$/ac	$/ac
11.5	4	205	820	9	471	349
9.8	4	199	796	9	507	289
8.5	4	185	740	9	474	266
6	4	163	652	9	427	225
4.5	4	141	564	9	380	185
3.3	4	119	476	9	344	132

Table 9. Net returns (gross income – production costs) for irrigated sorghum.

Net Irrigation	Sorghum Price	Grain Yield	Gross Income	Irrigation Cost	Production Costs*	Net Return
inches	$/bu	bu/ac	$/ac	$/ac-in	$/ac	$/ac
7.3	3.5	119	416	9	301	115
6.3	3.5	116	406	9	286	120
5.3	3.5	114	400	9	270	131
3.5	3.5	107	376	9	253	123
2.5	3.5	109	382	9	246	136
2.0	3.5	109	381	9	235	146

*Includes Irrigation costs