No-Till Cropping Systems with Limited Irrigation

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Abstract. *Research was initiated in 2001 and conducted through 2010 under sprinkler irrigation in western Kansas to evaluate limited irrigation in several no-till crop rotations on grain yield, water use, and profitability. Crop rotations were 1) continuous corn, 2) corn-winter wheat, 3) corn-wheat-grain sorghum, and 4) corn-wheat-grain sorghum-soybean. Irrigation was limited to 10 inches annually with 5 inches applied to wheat, 15 inches to corn (when in rotation with wheat), and 10 inches to grain sorghum, soybean, and continuous corn. Crop water productivity and yield of corn was greater when grown in rotation than with continuous corn. The length of the rotation did not affect grain yield or crop water productivity of grain sorghum or winter wheat. Continuous corn was generally the most profitable cropping system. However, relatively small changes in prices or yields could result in multi-crop rotations being more profitable, indicating the potential for alternate crop rotations to reduce risk under limited irrigation.*

Keywords. No-till, crop rotations, limited irrigation

Introduction

Irrigated crop production is an important component of agriculture in western Kansas. However, with declining water levels in the Ogallala Aquifer and high energy costs, optimal utilization of limited irrigation water is required. Precipitation is limited and sporadic in the region with annual precipitation supplying about 60-90% of the seasonal water requirement for grain sorghum and only 50-75% for corn (Doorenbos and Kassam, 1979). While crop rotations have been used extensively in many dryland systems, the most common crop grown under irrigation in western Kansas is corn (about 50% of the irrigated acres), often in a continuous corn system. While corn responds well to irrigation, it also requires substantial amounts of water to maximize production. Almost all of the groundwater pumped from the High Plains (Ogallala) Aquifer is used for irrigation (97% of the groundwater pumped in western Kansas in

1995 [Kansas Department of Agriculture, 1997]) with 57% applied to corn (Kansas Water Office, 1997). This amount of water withdrawal from the aquifer has reduced saturated thickness in some areas up to 150 ft. Although crops other than corn are grown under irrigation, they have not been grown as extensively because of relatively inexpensive water and a ready market for corn to the livestock feeding industry in the area. The trend in western Kansas during the 1990s has been towards increasing acreage of irrigated corn (665,000 acres in 1990 compared with 1.2 million acres in 2000) with corresponding reductions in grain sorghum (326,000 acres in 1990 compared with 71,000 acres in 2000) and winter wheat (692,000 acres in 1990 compared with 455,000 acres in 2000) (Kansas Farm Facts, 1991 and 2001). Although corn is expected to remain the dominant irrigated grain crop (especially in areas with abundant groundwater), the need exists to develop strategies to more effectively utilize limited irrigation water for corn. While there have been increases in irrigated soybean acreage (71,000 acres in 1990 compared with 134,000 acres in 2000), there has been limited research on water use characteristics in western Kansas.

Alternative crop management practices are needed to reduce the amount of irrigation water required while striving to maintain economic returns sufficient for producer sustainability. To prepare for less water available for irrigation in the future, whether from physical constraints (lower well capacities and declining water tables) or from regulatory limitations, information on crop productivity and profitability with less irrigation water will be beneficial for agricultural sustainability.

Materials and Methods

A field study was conducted at the Kansas State University Southwest Research-Extension Center near Tribune, KS from 2001 to 2010 on a deep silt loam soil (Ulysses silt loam [fine-silty, mixed, superactive, mesic Aridic Haplustolls]). Only data collected beginning in 2003 are presented to allow time for establishment of the crop rotations. The region is semi arid with a summer precipitation pattern and an average annual precipitation of 440 mm. The study consisted of four crop rotations; continuous corn (CC), corn-winter wheat (CW), corn-winter wheat-grain sorghum (CWS), and corn-winter wheat-grain-sorghum-soybean (CWSB). Each phase of each rotation was present each year and replicated four times. The plots were approximately 60 ft wide and 120 ft long. Irrigations were scheduled to supply water at the most critical stress periods (near flowering) for the specific crop and were limited to 1.5 inches per week. If precipitation was sufficient within a week, then irrigation was postponed. In some years, the maximum amount of irrigation was not applied because of above normal precipitation. The average first irrigation was 14 June for corn in rotation, 23 June for continuous corn, and 4 July for sorghum and soybean. The final irrigation averaged 28 August for corn in rotation, 15 August for continuous corn, and 22 August for sorghum and soybean. If needed to aid emergence of wheat, irrigation was initiated in the fall (four years) otherwise irrigation was reserved for spring application with average final irrigation on 6 June.

Average plantings dates were 3 May for corn, 20 May for soybean, and 27 May for grain sorghum. Winter wheat was planted after corn harvest (average of 1 October). Cultural practices (e.g., pesticides, tillage, and fertilization) typical for the region were used in all years of the study. The center portion of all plots was machine harvested with grain yields adjusted to 15.5% moisture (wet basis) for corn, 13% for soybean, and 12.5% for sorghum and wheat. Plant densities were determined along with the other yield components (kernels/ear and kernel mass).

The plots were irrigated with a linear move sprinkler irrigation system which had been modified to allow for water application from different span sections as needed to accomplish the randomization of plots. Soil water measurements (8-ft depth in 1-ft increments) were taken throughout the growing season using neutron attenuation. Available soil water was calculated by subtracting unavailable water from measured soil water. All water inputs, precipitation and irrigation, were measured. Crop water use was calculated by summing soil water depletion (soil water near emergence less soil water at harvest) plus in-season irrigation and precipitation. Non-growing season soil water accumulation was the increase in soil water from harvest to the amount at emergence the following year. Precipitation storage efficiency was calculated as non-growing season soil water accumulation divided by non-growing season precipitation. Crop water productivity (WP) was calculated as grain yield (bu $acre^{-1}$) divided by crop water use (inches).

Statistical analyses were performed using the GLM procedure from SAS version 9.1 (SAS Institute, Cary, North Carolina).

Local crop prices and input costs were used to perform an economic analysis to determine net return to land, management, and irrigation equipment for each treatment. Custom rates were used for all machine operations. Harvest prices and input costs were kept uniform for all years based on 2010 prices.

The objectives of this research were to determine the effect of limited irrigation on crop yield, water use, and profitability in several crop rotations.

Results and Discussion

All rotations were limited to an average of 10 inches of irrigation annually; however, corn following wheat received 15 inches because the wheat received only 5 inches. This extra 5 inches of irrigation water increased the level of irrigation to nearly full and increased corn yields about 40 bu $acre^{-1}$ compared with continuous corn (Table 1). Thus, limited irrigated corn yielded about 80% of full irrigation. Klocke et al. (2007) reported that limited irrigation (no more than 6 in water) yields were 80 to 90% of fully irrigated yields. Corn yields in the multi-crop rotations were similar regardless of length of rotation. Wheat and grain sorghum yields were similar in all rotations.

Table 1. Average grain yields of four crops as affected by crop rotation, KSU Southwest Research-Extension Center, Tribune, KS, 2003-2010.

Crop	Crop rotation†			
	CC	CW	CWS	CWSB
	---------- bu acre^{-1} ----------			
Corn	163 b‡	203 a	202 a	203 a
Wheat	—	35 a	36 a	37 a
Sorghum	—	—	134 a	138 a
Soybean	—	—	—	43

† CC = continuous corn; CW = corn-wheat; CWS = corn-wheat-grain sorghum; CWSB = corn-wheat-grain sorghum-soybean.
‡ Means within a row with different letters are significantly different (P≤0.05).

Crop water productivity was in the order of corn>sorghum>wheat=soybean (Table 2). Crop water productivity of corn was increased when irrigation was increased to 15 inches and grown in rotation with other crops. Grain sorghum grown in 4-yr rotations had slightly greater crop water productivity than grown in 3-yr rotations. The length of rotation had no effect on crop water productivity of wheat.

Table 2. Average crop water productivity of four crops as affected by crop rotation, KSU Southwest Research-Extension Center, Tribune, KS, 2003-2010.

Crop	Crop rotation†			
	CC	CW	CWGS	CWSB
	---------- lb acre-inch^{-1} ----------			
Corn	377 b‡	411 a	398 a	410 a
Wheat	—	115 a	125 a	122 a
Sorghum	—	—	314 b	326 a
Soybean	—	—	—	110

† CC = continuous corn; CW = corn-wheat; CWS = corn-wheat-grain sorghum; CWSB = corn-wheat-grain sorghum-soybean.
‡ Means within a row with different letters are significantly different (P≤0.05).

An economic analysis (based on grain prices and input costs in 2010 with average crop yields) found that the most profitable crop was corn in rotation followed by continuous corn (Table 3). Profitability was similar for grain sorghum and soybean in the 3- and 4-yr rotations. The least profitable crop was wheat, primarily because of reduced yields caused by hail and spring freeze injury in about 50% of the years. However, the most profitable crop rotation was continuous corn. All multi-crop rotations had net returns of \$12-24 acre^{-1} less than CC. Lower returns in the multi-crop rotations were due to low returns from wheat.

Table 3. Net return to land, irrigation equipment, and management from four crop rotations, KSU Southwest Research-Extension Center, Tribune, KS, 2003-2010.

	Crop rotation†			
Crop	CC	CW	CWS	CWSB
	---------------------------- $ $acre^{-1}$ ----------------------------			
Corn	237	332	326	321
Wheat	—	4	1	5
Sorghum	—	—	189	198
Soybean	—	—	—	198
Net for rotation	192	168	172	180

† CC = continuous corn; CW = corn-wheat; CWS = corn-wheat-grain sorghum; CWSB = corn-wheat-grain sorghum-soybean.

Conclusions

With limited irrigation (10 inches annually), continuous corn has been more profitable than multi-crop rotations including wheat, sorghum, and soybean primarily because of spring freeze and hail damage to wheat in the multi-crop rotations. In multi-crop rotations, relatively poor results with one crop (in this case wheat) can reduce profitability compared with a monoculture, especially when the monoculture crop does well. However, the multi-crop rotation can reduce economic risk when the monoculture crop does not perform as well. All multi-crop rotations had net returns only \$12-24 $acre^{-1}$ less than continuous corn. Therefore, relatively small changes in prices or yields could result in any of the rotations being more profitable than continuous corn, indicating the potential for alternate crop rotations under limited irrigation.

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References

Doorenbos, J., and A.H. Kassam. 1979. Yield response to water. Irrig. and Drain. Pap. 33. FAO, Rome.

Kansas Department of Agriculture. 1997. Kansas reported water use summary, calendar year 1995. State of Kansas, Topeka, KS.

Kansas Farm Facts. 1991 and 2001. Kansas Agricultural Statistics. Kansas Dept. of Agriculture and U.S. Dept. of Agriculture, Topeka, KS.

Kansas Water Office. 1997. 1995 Kansas irrigation water use. State of Kansas, Topeka, KS.

Klocke, N.L., J.O. Payero, and J.P. Schneekloth. 2007. Long-term response of corn to limited irrigation and crop rotations. Trans. ASABE 50:2117-2124.