LIMITED IRRIGATION AND CROP ROTATIONS

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Limited irrigation cropping system research at North Platte has demonstrated that continuous crop rotations including winter wheat and row crops has possibilities for stretching limited water supplies while conserving soil. The goal has been to conserve all water with no-till farming and crop residue management and to apply water when the best potential yield benefit occurs. Timely management of all operations is critical for the system to work. Maintenance of crop residues traps snow, reduces evaporation and runoff during intense rainfall events and reduces wind and water erosion. Yields with only 6 inches of irrigation have been excellent for wheat, corn and soybeans.

Rainfall throughout most of the central Great Plains is not sufficient most years to allow continuous dryland cropping using conventional tillage. Advances in no-till dryland farming in southwest Nebraska (Ecofallow) have shown the advantages of improved soil moisture storage during chemical fallow (Wicks, 1976). Because of advances in this system continuous dryland cropping may be successful in many years if weed control is sufficient. In many years enough moisture falls to sustain continuous cropping but a high percentage of water often is lost before it can be stored or used by the crop. In the ecofallow system as soon as one crop reaches maturity, crop water use declines and soil moisture begins to accumulate for the next crop. Regardless of the duration of the fallow period, storage of the natural precipitation must be maximized. Controlling weeds completely and keeping crop residue on the soil surface conserves this moisture. If the weed control from herbicides is adequate, no tillage is required other than seeding next crop. This reduced tillage also conserves stored soil moisture.

Ground water levels have declined in southwest Nebraske since 1976. During the period 1980 to 1984 there was some optimism as water level declines stabilized. However, the stabilized water table resulted from decreased pumpage during the PIK program, Conservation Reserve, and above normal precipitation. Computer simulations suggest that ground water levels and stream flows in south west Nebraska will continue to decline even if no additional irrigation development occurs. Reverting irrigated land to dryland would have a significant negative economic impact on this area. Rainfall throughout most of this region is not sufficient in most years to allow continuous dryland cropping. Consequently fallow has always been practiced. Recently, cropping management with ecofarming techniques have shown how limited amounts of rainfall can be stretched to improve water use efficiency. Crop rotations which incorporate this moisture conservation can be adapted to this area utilizing limited irrigation.

Limited irrigation management has been coupled with season long water conservation techniques from the ecofallow system for a limited irrigation cropping system at North Platte. Limited irrigation is applying less water than is required to meet the full evapotranspiration (ET) demand of the crop. As a result, the crop will be stressed for water when the full ET demand is not met. In Nebraska irrigated crops sometimes experience water stress when root development or irrigation system capacity cannot meet crop ET demand. In limited irrigation management, crop water stress is planned to occur. The goal is to manage the water stress in the crop so that the minimum impact on grain yield occurs. This paper will report on one management scheme used at North Platte, Nebraska (19 inches, average annual precipitation) to limit irrigation in any year to a maximum of 6 inches.

PROCEDURES

A field study with several crop rotations has been conducted at North Platte with a severe water allocation (maximum of 6 inches of net irrigation per year) since 1982. The soil is a Cozad silt loam with a water holding capacity of 1.5-1.8 inches of plant available water per foot. Crops including winter wheat, corn, and indeterminant soybeans were grown in three cropping systems: winter wheat-corn-soybeans, winter wheat-soybeans and continuous corn. The limited irrigated crops were watered primarily according to stage of growth. Several field studies including those conducted by Gilley et al (1980) and Kadhem et al (1985) showed that these crops respond best to limited irrigation during pollination and grain-fill periods and least to irrigation during vegetative growth. Therefore, irrigation was given highest priority during pollination and lowest priority during vegetative growth.

Weed control began in the growing winter wheat for those rotations including wheat. Reduction of weed pressure in the growing wheat and maintenance of a weed free wheat stubble following harvest provided for maximum interception and storage of precipitation. A mixed N-P-Zn starter was row-applied at planting for all crops. Nitrogen was broadcast in early spring for winter wheat and also at planting for corn. Ammonium nitrate was the N source used. Timeliness of spraying and planting and selection of soybean varieties to mature before planting of winter wheat was critical. Preplant irrigation for the wheat seedbed was applied to the maturing soybeans. Much of the work to date has been used to evaluate varieties and populations that can maximize the yield for the cropping system used.

For limited irrigated wheat an irrigation application of 1 to 2 inches was usually applied near maturity of the soybeans. The timing of this irrigation provided sufficient moisture for later wheat emergence, was late enough so the soybeans did not use the water, and was early enough to allow soil drying for soybean harvest. The amount of this irrigation was determined by soil moisture content during mid-

September to provide soil moisture 2 feet deep at wheat planting. The remaining 4 to 5 inches of irrigation was usually applied the following spring, depending on rainfall. Irrigations were applied during pre-boot and heading growth stages. During the last 7 years the total of 6 inches of water for the limited irrigated wheat was used 5 years. During the other years rainfall was sufficient and spring irrigation was unnecessary because it could have decreased yield. The same general procedure was followed for the fully irrigated wheat, except in drier years, more early spring irrigation was applied.

The limited irrigated corn usually was not irrigated until tassel or silk emergence. Stored soil moisture was usually sufficient to allow crop development without too much stress during vegetative growth. Irrigations of 1.5 to 2 inches were applied at silk emergence then at approximately 2 week intervals with the final irrigation occurring during the grain filling period. Fully irrigated corn was irrigated based on meeting the evapotranspiration demand of the crop.

The limited irrigated soybeans received their first irrigation in the early pod elongation period when the first pods set were 1/4 to 1/2 inch long. The irrigation amount was 1.5 to 2 inches. The remaining irrigations were timed at about 2 week intervals, but were based on stage of crop development, soil moisture, and rainfall. The fully irrigated soybeans were irrigated to meet the evapotranspiration demand of the crop.

RESEARCH RESULTS - CROP YIELDS

Yields for the dryland and limited irrigation treatments have been collected for 6 and 7 years, respectively (Table 1). To simplify presentation, data have been average over varieties. The average yearly rainfall the past six crop moisture years (Sept. 1 to Aug. 31) was about 1 inch above the long term average of 19.3 inches per year at North Platte. During 1984-1985 precipitation was 3 inches below normal, however even in this year there were no crop failures in the dryland crops.

Because of the high pH (7.5) in this soil, herbicide selection and use in soybeans was difficult. Depending upon the sequence of rainfall and herbicide application plus the amount of residue present, there may or may not be herbicide damage. For two out of 6 years the soybean crop was lost due to herbicide (Sencor) damage. The same rate of herbicide was used in both rotations including soybeans but damage varied. Soybeans in the wheat-soybean rotation were killed in 1983; whereas, soybeans in the wheat-corn-soybeans rotation were killed in 1986. Where the beans survived, the yields were very good and the weed control was excellent. If a given crop is lost due to herbicide damage it may or may not have an influence on the following crop. The dryland winter wheat yields in 1984 in the wheat-soybean rotation were not affected by the lack of the soybean crop in 1983, but the 1987 dryland wheat benefited from moisture storage from lack of a soybean crop in 1986 in the wheat-corn-soybean rotation. Winter wheat yields in the same wheat-soybean rotation under limited irrigation showed a higher yield than the plots where the soybeans were present before the wheat crop. Command is now being used for soybeans and no damage has occurred.

To date no significant rotation effects have been shown on either the winter wheat or the soybean yields. A significant rotation effect was apparent for the corn (Table 1). The dryland continuous corn had less available moisture than the corn in the wheat-corn-soybean rotation. Standing wheat stubble had a better opportunity to accumulate moisture during the late fall and winter than continuous corn stubble. Even in an above average precipitation year (1985-1986), corn following wheat had greater early growth. Although the yields of the dryland continuous corn were quite good considering this limited rainfall area, they did not match those of corn in the wheat-corn-soybean rotation. The limited irrigated corn benefited from the same "rotation" effect.

Irrigated corn had the highest water use among the crops (Table 2). The influence of the various irrigation levels, dryland vs limited vs fully irrigated corn, were shown in yield increases with increased water. No rotation effect was shown for the fully irrigated corn yields the first 3 years but some difference resulted in 1988. The production levels attained for the various crops in the different rotations are encouraging because they indicate that management of this no-tillage cropping rotation can produce high yields.

The wheat yields were somewhat lower than might be expected but the winter wheat was planted after soybean harvest about the first of October. Winter wheat normally is planted during the middle of September in West Central Nebraska. The two week delay in planting may reduce the yield potential by 10 bushel/acre compared to wheat planted normally based on date of planting studies. This is one limitation of the crop rotations. The advantage is the additional moisture storing for crops following winter wheat and the soil conservation aspect of maintaining the standing stubble. Corn and soybean yields benefited from the additional soil water.

IRRIGATION WATER USE EFFICIENCY

The data from Tables 1 and 2 can be used to calculate irrigation water use efficiency. Yield data for the dryland, limited, and fully irrigated blocks can be compared for 4 years (1985-1988). Irrigation amounts for the various crops by irrigation are given in Table 2. A given crop has received the same amount of irrigation regardless of rotation. Data from Table 1 and Table 2 were combined for Figure 1 which shows the yield vs irrigation relationship. The irrigation response of all crops between dryland and limited irrigation was linear. Above this point, the response was curvilinear.

For purposes of this discussion, irrigation water use efficiency (IWUE), was defined as follows:

$$\text{IWUE (Limited Irr.)} = \frac{\text{Limited Irrigation Yield - Dryland Yield}}{\text{Limited Irrigation - Dryland Irrigation (0)}}$$

$$\text{IWUE (Full Irr.)} = \frac{\text{Full Irrigation Yield - Limited Irrigation Yield}}{\text{Full Irrigation - Limited Irrigation}}$$

Irrigation water use efficiency is the return in yield for the irrigation water applied over and above the other water treatment level in each of the respective equations.

How much yield was gained from adding each increment of irrigation water? Irrigation returned positive yield gains in all cases except fully irrigated wheat (Table 3). IWUE was greater for limited irrigated corn and soybeans than for fully irrigated corn and soybeans. There was more soil moisture left in the root zone at the end of the season in the fully irrigated than in the limited irrigated plots, which contributed to lower IWUE in the fully irrigated plots.

Can the extra yield return offset the extra pumping and operating costs? With yield-irrigation response functions generated from data in Figure 1, an economic analysis can be run. If irrigation costs are low, both corn and soybeans are good crops to fully irrigate. Wheat, however, does very well with only 3-5" irrigation depending on the year. As irrigation costs increase or as water is limited, the response functions can be used to determine how much water different crops should receive. In the future a detailed economic analysis will be developed as a decision aid for irrigators who face water shortages.

CONCLUSIONS

The limited irrigation cropping system research at North Platte has demonstrated that continuous crop rotations including winter wheat and row crops have possibilities for stretching limited water supplies. The goals have been to conserve all water with no-till farming and crop residue management and to apply water when the best potential yield benefit occurs. Timely management of all operations is critical for the system to work. Soybean weed control in the no-till environment is still the most troublesome cultural practice.

The other limitation to the system was pointed out by Gilley et al (1980); "Where climatic conditions are more extreme in terms of water demand during the vegetative period, one would expect yield depression if extreme drought stress occurred during vegetative development. However, our results suggest that some water savings can be obtained with little negative effect by permitting moderate stress development during early growth periods. The hazard involved is in not getting irrigation started soon enough so as to avoid excessive stress during the pollination period. We emphasize that early stress development can be encouraged only where there is an ample soil water supply so that stress will come on gradually rather than rapidly." These comments mirror what is occurring in the minimum tillage cropping systems research at North Platte.

Challenges remain with the limited irrigation cropping system, however there are possibilities for the approach in areas of limited water allocations.

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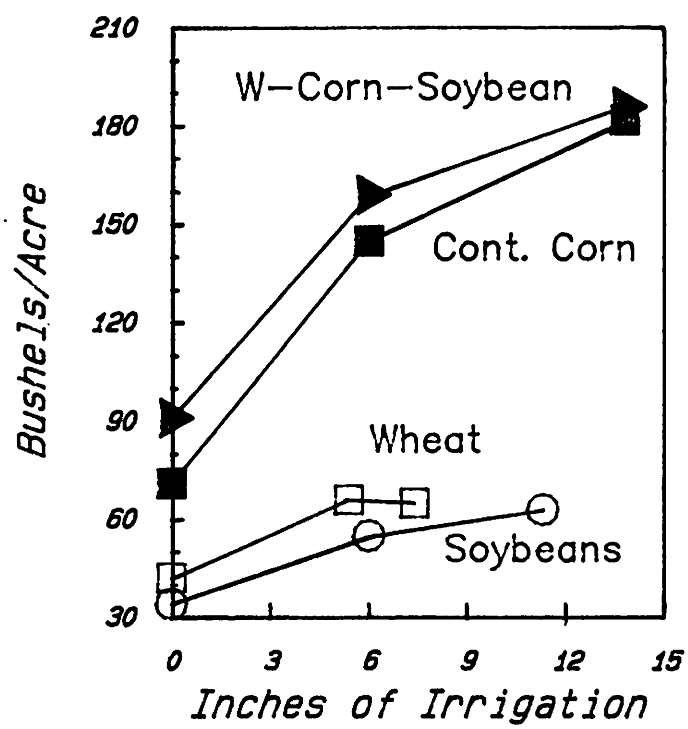

Figure 1. Four year (1985-1988) average yield of crops in the wheat-corn-soybean rotation and continuous corn as influenced by irrigation.

Table 1. Grain yields from cropping system research at North Platte, NE.

CORN YIELDS

Rotation	Dryland		Limited Irrig.		Fully Irrig.	
	Cont. Corn	Wht-Corn-Soy	Cont. Corn	Wht-Corn-Soy	Cont. Corn	Wht-Corn-Soy
Year	bu/A					
1983	72	75	117	123	---	---
1984	72	77	129	131	---	---
1985	36	42	125	135	165	159
1986	78	100	135	155	179	185
1987	62	96	146	157	192	194
1988	108	125	175	190	192	206
6 Year Avg (82-88)	71	86	138	149	---	---
4 Year Avg (85-88)	71	91	145	159	182	186

WHEAT YIELDS

Rotation	Dryland		Limited Irrig.		Fully Irrig.	
	Wht-Corn-Soy	Wht-Soy	Wht-Corn-Soy	Wht-Soy	Wht-Corn-Soy	Wht-Soy
Year	bu/A					
1983	35	33	63	67	--	--
1984	66	65**	63	75	--	--
1985	30	24	83	81	79	74
1986	62	53	67	59	62	63
1987	51***	40	58**	59	58	60
1988	25	+	57	+	60	+
6 Year Avg (83-88)	45	--	65	--	--	--
4 Year Avg (85-88)	42	--	66	--	65	--

SOYBEAN YIELDS

Rotation	Dryland		Limited Irrig.		Fully Irrig.	
	Wht-Corn-Soy	Wht-Soy	Wht-Corn-Soy	Wht-Soy	Wht-Corn-Soy	Wht-Soy
Year	bu/A					
1983	21	(21)*	50	(50)*	--	--
1984	31	25	54	57	--	--
1985	19	29	47	50	61	69
1986	(46)*	46	(62)*	62	67	67
1987	18	17	52	53	60	64
1988	48	46	55	54	61	58
6 Year Avg (83-88)	30	31	53	54	--	--
4 Year Avg (85-88)	33	35	54	55	62	65

*Herbicide damage - value calculated as missing plot

**No 1983 and 1986 soybean crop had no influence on 1983 and 1987 wheat yield.

***No soybean crop in 1983 and 1986 significantly increased 1984 and 1987 wheat yields.

+ = Rotation discontinued.

Table 2. Irrigation applied on cropping system research at North Platte, NE.

Year	WHEAT Irrigation Limited	WHEAT Irrigation Full	CORN Irrigation Limited	CORN Irrigation Full	SOYBEANS Irrigation Limited	SOYBEANS Irrigation Full
	--------	--------	-------- inches	--------	--------	--------
1985	5.8	8.5	6.1	14.0	6.1	11.9
1986	3.8	3.8	6.1	15.7	6.1	13.0
1987	6.0	6.6	6.0	15.4	6.0	12.4
1988	6.0	10.7	6.0	10.0	6.0	7.8
4 Yr Avg	5.4	7.4	6.0	13.8	6.0	11.3

Table 3. Irrigation water use efficiencies for different crops in three cropping systems at North Platte, NE - 1985-1987.

	CORN IWUE			
	Limited Irrigation		Full Irrigation	
Year	Cont. Corn	Wht-Corn-Soy	Cont. Corn	Wht-Corn-Soy
1985	14.6	15.3	5.1	3.0
1986	9.3	9.0	4.6	3.1
1987	14.0	10.2	4.9	3.9
1988	11.2	10.8	4.3	4.0
Average	12.3	11.3	4.7	3.5
	SOYBEANS IWUE			
	Limited Irrigation		Full Irrigation	
	Wht-Soy	Wht-Corn-Soy	Wht-Soy	Wht-Corn-Soy
1985	3.4	4.6	3.3	2.4
1986	2.6	2.6	0.7	0.7
1987	6.0	5.7	1.7	1.3
1988	1.3	1.2	2.2	3.3
Average	3.3	3.5	2.0	1.9
	WHEAT IWUE			
	Limited Irrigation		Full Irrigation	
	Wht-Soy	Wht-Corn-Soy	Wht-Soy	Wht-Corn-Soy
1985	9.8	9.1	0	0
1986	1.6	1.3	0	0
1987	3.2	1.2*	0	0
1988	-	5.3	-	0.6
Average	4.9	4.2	0	0.2

*No soybean crop in 1986 increased dryland yield and decreased IWUE.