

CONSERVATION TILLAGE



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ABSTRACT

The winter wheat-fallow rotation may not be the most efficient cropping system for using precipitation in the central Great Plains. This research evaluated the effects of nitrogen (N) fertilization on grain yield, crop water use efficiency (WUE) and precipitation use efficiency (PUE) of these dryland (rainfed) crop rotations: winter wheat-corn-fallow; winter wheat-sorghum-fallow; and an annual cropping (spring barley-corn) rotation. The studies were conducted on Platner loam and Weld silt loam soils using a no-till farming system. The three-year and annual cropping rotations used precipitation and stored-soil water more efficiently than a winter wheat-fallow rotation. Nitrogen fertilization improved crop yield, WUE, and PUE significantly. Under current economic conditions, adequately fertilized three-year and annual cropping rotations have a greater profit potential than the winter wheat-fallow rotation.

INTRODUCTION

Winter wheat-fallow is the dominant cropping system in the western portion of the central Great Plains (Greb et. al., 1974; Greb, 1979b). Plant available water is limited and highly variable in this area (Greb, 1979a and 1979b; Greb et. al. 1974 and 1979). Diversification in crop production has been limited, and producers have had few economic alternatives in years when wheat was in surplus and/or soil water supply was plentiful.

The winter wheat-fallow rotation is usually not the most efficient cropping system for utilizing precipitation with current management technology. Reduced- and no-till cropping systems in the central Great Plains have increased precipitation storage efficiency and increased the amount of soil water available for crop production (Greb, 1979a and 1983; Smika and Wicks, 1968; Wicks and Smika, 1973; Greb et al., 1974 and 1979; Mickelson, 1982). Saving this additional soil water increases the opportunity for successfully growing spring planted crops such as proso millet, grain sorghum, and corn in rotation with winter wheat. For example, proso millet grown in a winter wheat-proso millet-fallow rotation has been proven to be successful (Anderson et. al., 1986). Nitrogen management information for optimizing economic yields and water use within three-year and annual cropping systems is limited for the central Great Plains dryland conditions.

Objectives of this work were to evaluate the effects of N fertilization on crop yield, crop water use efficiency (WUE), and crop rotation precipitation use efficiency (PUE) in a winter wheat-corn-fallow, a winter wheat-sorghum-fallow, and a spring barley-corn rotation under

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rained conditions. A no-till system was used to enhance the feasibility of cropping more intensively. The specific objectives were to determine: 1) the long-term grain yields of each respective crop in each rotation; 2) the N fertilizer requirements to obtain optimum economical grain yields with each rotation; and 3) the effects of N fertilization on crop WUE and crop rotation PUE.

PROCEDURES

For the winter wheat-corn-fallow (W-C-F) and winter wheat-sorghum-fallow (W-S-F) rotations, N treatments (0, 25, 50, 75, and 100 lb N/acre) were arranged in a randomized complete block design with four replications. Identical sets of plots were established on three adjacent areas to allow each crop of each rotation to be grown each year. Winter wheat was planted on the area that had been previously summerfallowed. During the second year of the rotation, the wheat plots were split with half the plot planted to corn and half to grain sorghum. During the third year of the rotation, the plots were summerfallowed and maintained in a no-till condition. Glyphosate or paraquat was used to control weeds immediately after wheat harvest, with atrazine being applied soon after wheat harvest to provide residual herbicide control of weeds through the corn or sorghum crops. In 1986 and 1987, Bladex² and Dual were used to control weeds in the corn and sorghum rather than atrazine. Glyphosate plus 2,4-D, paraquat and/or Bladex (short term residual) were used during the summerfallow period to control weeds. The number of herbicide applications varied yearly. Broadleaf weeds were controlled in the wheat crop with 2,4-D. This study was located on a Platner loam soil at the Central Great Plains Research Station, Akron, CO.

The annual cropping study (spring barley-corn rotation) was conducted on a Weld silt loam. Nitrogen rates of 0, 20, 40, 60, 80, and 160 lb N/a were arranged in a randomized complete block design with four replications. The cropping sequence was summerfallow in 1983, spring barley in 1984, corn in 1985, spring barley in 1986, corn in 1987 (destroyed by hail on August 4th, therefore winter wheat was planted in September 1987), winter wheat in 1988, and corn in 1989. Glyphosate, paraquat, Bladex, and atrazine were used to control weeds between and within crops. A no-till condition was maintained.

Winter wheat grain yields from the 1984, 1986, 1987, 1988, and 1989 no-till plots of an adjacent long-term (Smika, 1990) winter wheat-fallow (W-F) tillage study were used for yield comparisons with the more intensive crop rotation studies. This W-F rotation was located approximately 250 ft from the annual cropping rotations on a Weld silt loam. The Weld silt loam had a deeper soil profile (>6 ft to sand and gravel) than the Platner loam soil (<4 ft to sand and gravel) and therefore had the higher crop yield potential because of its ability to retain a higher level of available water supply.

The plot areas were planted to the appropriate crop each year following the established rotation. Winter wheat (varieties: Vona, 1984; TAM 105, 1985, 1986; TAM 107, 1987-89) was planted about September

²Mention of trade names or manufacturer within the context of this article are included solely to provide specific information and does not constitute a guarantee or endorsement by U.S. Department of Agriculture, Agricultural Research Service.

20, spring barley (variety Otis) about April 1, corn (variety Pioneer 3732) about May 1, and grain sorghum (variety Pioneer 8790) about May 15 each crop year. Ammonium nitrate fertilizer was broadcast applied at the specified N rates prior to planting or banded below the seed at planting of each small grain crop. Anhydrous ammonia was applied post emergence to the corn and sorghum. The winter wheat variety was Vona in the W-F rotation.

Soil samples from six depth increments (0-6", 6-12", 1-2', 2-3', 3-4', and 4-6') were collected just prior to crop seeding and/or each spring and then again after crop harvest. Soil water content was determined gravimetrically. Because the Platner loam soil had a sand and gravel layer below the four-ft depth, a representative soil sample could not always be obtained. For this reason, soil water measurements and water use calculations were limited to the top four feet of soil for the W-C-F and W-S-F rotations. Precipitation was monitored daily during the study. Grain yields were measured. Crop-water use or evapotranspiration (ET) for each crop was calculated as growing season precipitation plus soil-water use assuming negligible runoff or deep percolation. Standard statistical procedures were used to analyze the data.

RESULTS AND DISCUSSION

Winter wheat grain yields (five-year average) from the W-C-F and W-S-F rotations increased significantly with increasing N rate (Fig. 1). Application of 75 lb N/a increased winter wheat yields an average of 17 bu/a over the check (no N) treatment. Corn grain yields in Fig. 1 represent a three-year average (1986, 1988, 1989) and a four-year average. The four-year average includes 1987 data when at least 60% of the yield was lost to hail on August 4th. Sorghum grain yields were also affected by the hail. Therefore, three- and four-year average

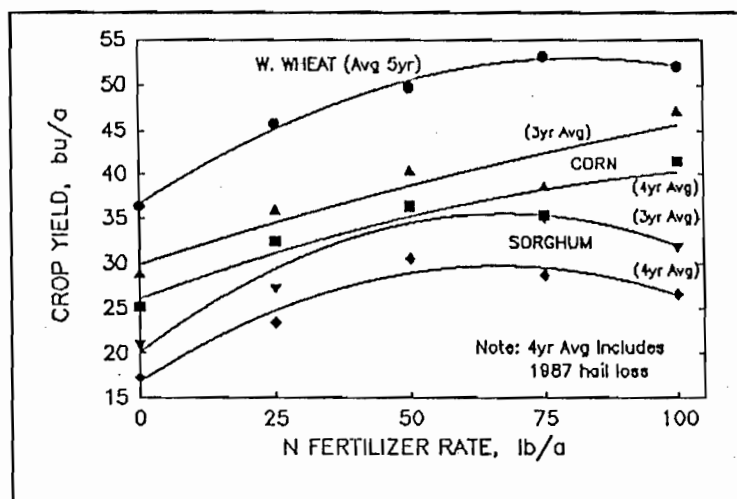


Fig. 1. Average winter wheat, corn, and sorghum yields as a function of N rate.

grain yields are presented for sorghum. Corn grain yields increased significantly with increasing N rate up to 100 lb N/a. Sorghum yields increased up to 50 lb N/a and then declined with further increases in N rate. The year by N-rate interaction was significant for each crop because of periods of limited water supply and crop water stress during the 1988 and 1989 crop production years that limited yield responses to N fertilization. In this paper, only the average yields are presented.

Effects of N fertilization on WUE by each crop of the W-C-F and W-S-F rotations are shown in Fig. 2. Soil-water use by each crop generally was not significantly altered by N fertilization. Therefore, crop WUE was calculated as grain yield divided by evapotranspiration (ET). Nitrogen fertilization significantly increased the WUE of winter wheat (five-year average), with WUE increasing with N rate up to 75 lb N/a.

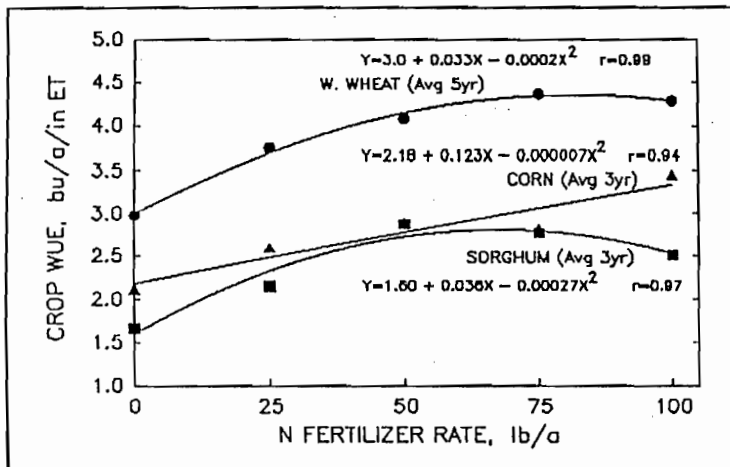


Fig. 2. Average crop water use efficiency (WUE) as a function of N rate.

Grain yields for the annual cropping rotation increased significantly with increasing rate of N application each crop year (Fig. 3). Annual crop grain yields were optimized only when sufficient N was applied. The 1987 corn crop was destroyed by hail on August 4th. Therefore, after a short fallow period, winter wheat was planted in late September 1987 on the plots with only half of the N rate being applied to the winter wheat.

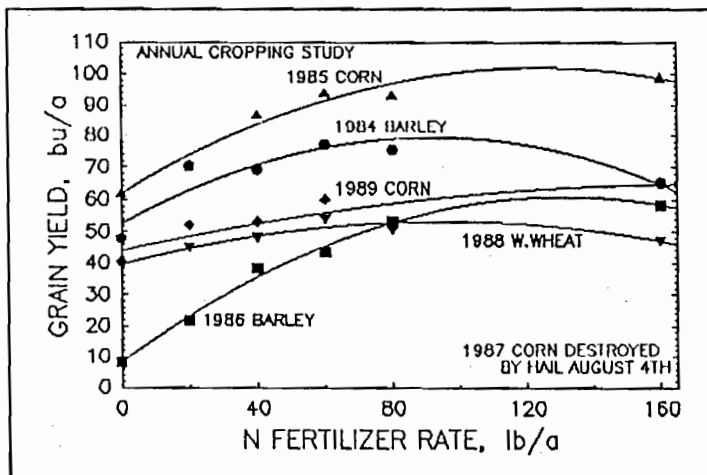


Fig. 3. Crop yields as a function of N fertilization rate for the annual cropping rotation.

At this N rate, 4.4 bu/a of winter wheat were obtained for each inch of ET. The WUE of corn (three-year average) also increased with increasing N rate, with 3.5 bu/a obtained for each inch ET at the 100 lb N/a rate. Sorghum WUE (three-year average) was optimized (2.9 bu/a/in) with the application of 50 lb N/a. Crop WUE was in the order winter wheat > corn > sorghum under the conditions of this study. Adequate N fertilization is essential if water use by crops is to be optimized.

Nitrogen fertilization in the annual cropping study significantly increased soil water use by the crop in only one year, 1986, when spring barley was grown. Spring barley, corn, and winter wheat crop WUE's were significantly increased by N fertilization in the annual cropping rotation (Fig. 4). Crop WUE efficiency was optimized with the application of 60-80 lb N/a. Lodging was a severe problem with the barley at the 160 lb N/a rate.

Precipitation use efficiency (PUE) of each three-year cropping rotation was calculated for four completed sequences of each rotation, including the reduced corn and sorghum yields caused by hail in 1987. The precipitation totals are for a 36-month period starting with the summerfallow period on October 15 after corn (or sorghum) harvest and ending with corn (or sorghum) harvest. Inches of total precipitation for the four sequences used here were 50.7 from October 15, 1983 to October 14, 1986; 50.9 from October 15, 1984 to October 14, 1987; 50.4 from October 15, 1985 to October 14, 1988; and 49.9 from October 15, 1986 to October 14, 1989. The long-term (81 yr) average 36-month total precipitation is 49.6 inches. Therefore, the years evaluated in this study received normal precipitation amounts, although timeliness and distribution of the precipitation was a problem for crop production in 1988 and 1989. The PUE was calculated by summation of the

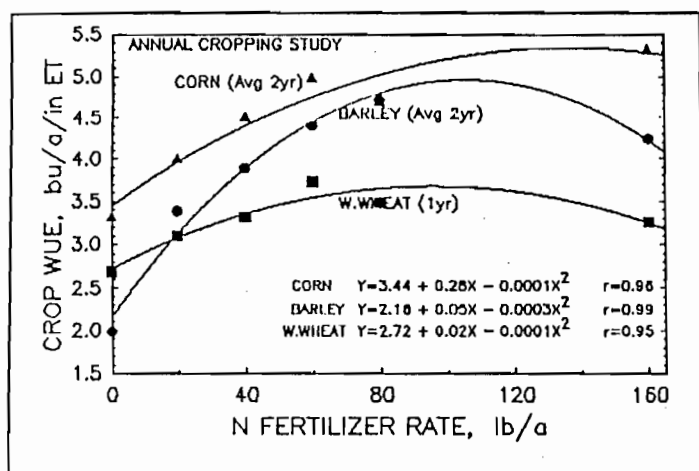


Fig. 4. Crop WUE for corn, spring barley, and winter wheat as a function of N fertilization rate for the annual cropping rotation.

lb grain/a/in water) of the annual cropping system was maximized with the application 160 lb N/a.

Nitrogen obviously had a significant impact on precipitation utilization by these rainfed crops. The PUE of the three-year and annual crop rotations were higher than that of a long-term W-F rotation (69 lb grain/a/inch). These more intensive rotations make efficient use of precipitation and reduce the potential of leaching agricultural chemicals through the soil profile.

Halvorson (1990) projected the yearly gross income for the W-C-F and W-S-F rotations to be optimum with the application of 75 and 50 lb N/a, respectively. An estimated gross income, minus N fertilizer cost for the 50 or 60 lb N/a rate, was calculated for the W-F, W-C-F, and annual-cropping rotations (Tables 1, 2, 3) using the following assumptions:

winter wheat = \$3.13/bu,
 corn = \$2.52/bu,
 barley = \$2.74/bu,
 ammonium nitrate = \$0.23/lb N,
 anhydrous ammonia = \$0.10/lb N.

The crop prices are the nine-year average market prices paid at grain elevators in Colorado from 1980 to 1988 (Colorado Agricultural Statistics Services, 1989).

Total gross income, minus N costs, from each rotation expressed on a per year basis (includes fallow year) shows that the projected per year gross income was highest for the annual-cropping rotation (\$126/a/yr), which includes a crop loss in 1987, followed by the W-C-F rotation (\$80/a/yr) (Tables 2 and 3). This compares to an estimated \$45/a/yr return for the last 6 winter wheat crops produced with a crop-fallow rotation in the long-term tillage study which received 50 lb N/a or an

total pounds of grain produced per acre (i.e. wheat + corn) over the three-year sequence and dividing the result by the 36-month precipitation total. The PUE of the W-C-F sequence increased significantly with increasing N rate, with the highest PUE (112 lb grain/a/in water) obtained with the 100 lb N/a treatment (Fig. 5). The PUE of the W-S-F sequence increased significantly with increasing N rate up to 75 lb N/a which had a PUE of 98 lb grain/a/in water. The W-C-F sequence had a higher level of PUE than the W-S-F rotation. This would probably change in southeast Colorado where sorghum is better adapted than corn. The PUE (166

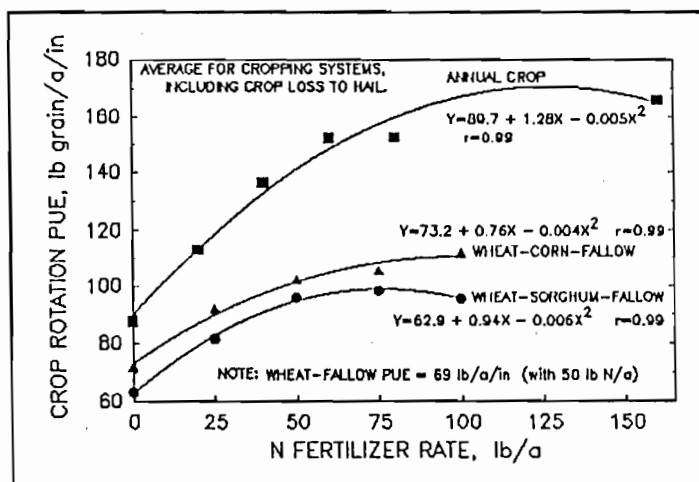


Fig. 5. Crop rotation precipitation use efficiency (PUE) as a function of N rate.

estimated \$55/a/yr return if 1985 is excluded because the crop was destroyed because of a severe infestation of jointed goatgrass (Table 1). Therefore, profit potential appears to be greater with the annual-cropping and three-year rotations than for W-F, assuming adequate N fertilization.

Table 1. Estimated economics of winter wheat-fallow rotation at Akron.

YEAR	CROP	YIELD, bu/a	GROSS INCOME - N COSTS
1984	W.WHEAT	35	\$98/a/2yr
1985	W.WHEAT	DESTROYED (J.GOATGRASS)	-12/a/2yr
1986	W.WHEAT	42	120/a/2yr
1987	W.WHEAT	51	148/a/2yr
1988	W.WHEAT	33	92/a/2yr
1989	W.WHEAT	33	92/a/2yr
AVG (EXCLUDING 1985)		39	\$110/a/2yr or \$55/a/yr
AVG (INCLUDING 1985)		32	\$ 90/a/2yr or \$45/a/yr

Note: 50 lb N/a Weld silt loam

Table 2. Estimated economics of winter wheat-corn-fallow rotation at Akron.

YEARS	W.WHEAT YIELD, bu/a	CORN YIELD, bu/a	GROSS INCOME - N COSTS
1985-86	52.2	40.6	\$249/a/3yr
1986-87	63.7	24.5 (60% hail loss)	245/a/3yr
1987-88	51.7	49.7	270/a/3yr
1988-89	40.0	30.8	192/a/3yr
AVG	51.9	36.4	\$239/a/3yr or \$80/a/yr

Note: 50 lb N/a Platner loam (sand, gravel >4ft.)

Table 3. Estimated economics of annual cropping rotation at Akron.

YEAR	CROP	YIELD, bu/a	GROSS INCOME - N COSTS
1984	BARLEY	78	\$150/a/yr
1985	CORN	94	231/a/yr
1986	BARLEY	44	79/a/yr
1987	CORN	HAILED OUT	- 6/a/yr
1988	W.WHEAT	54	156/a/yr
1989	CORN	60	145/a/yr
			AVERAGE = \$126/a/yr

Note: 60 lb N/a Weld silt loam

Other potential benefits from more intensive crop rotations that include winter wheat...

of the time and more crop residues on the soil surface due to reduced tillage; 3) a reduction in weed, disease, and insect problems by crop rotation; 4) reduced risk of crop failure due to weather (hail, low precipitation) by having greater crop diversification; 5) more efficient and timely use of farm machinery as a result of more acres in crop production per farm unit; and 6) spreading the work load out over more of the year. With the current emphasis on environmental quality and economic sustainability of agriculture, the more intensive crop rotations offer possibilities for improved crop production in the central Great Plains.

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