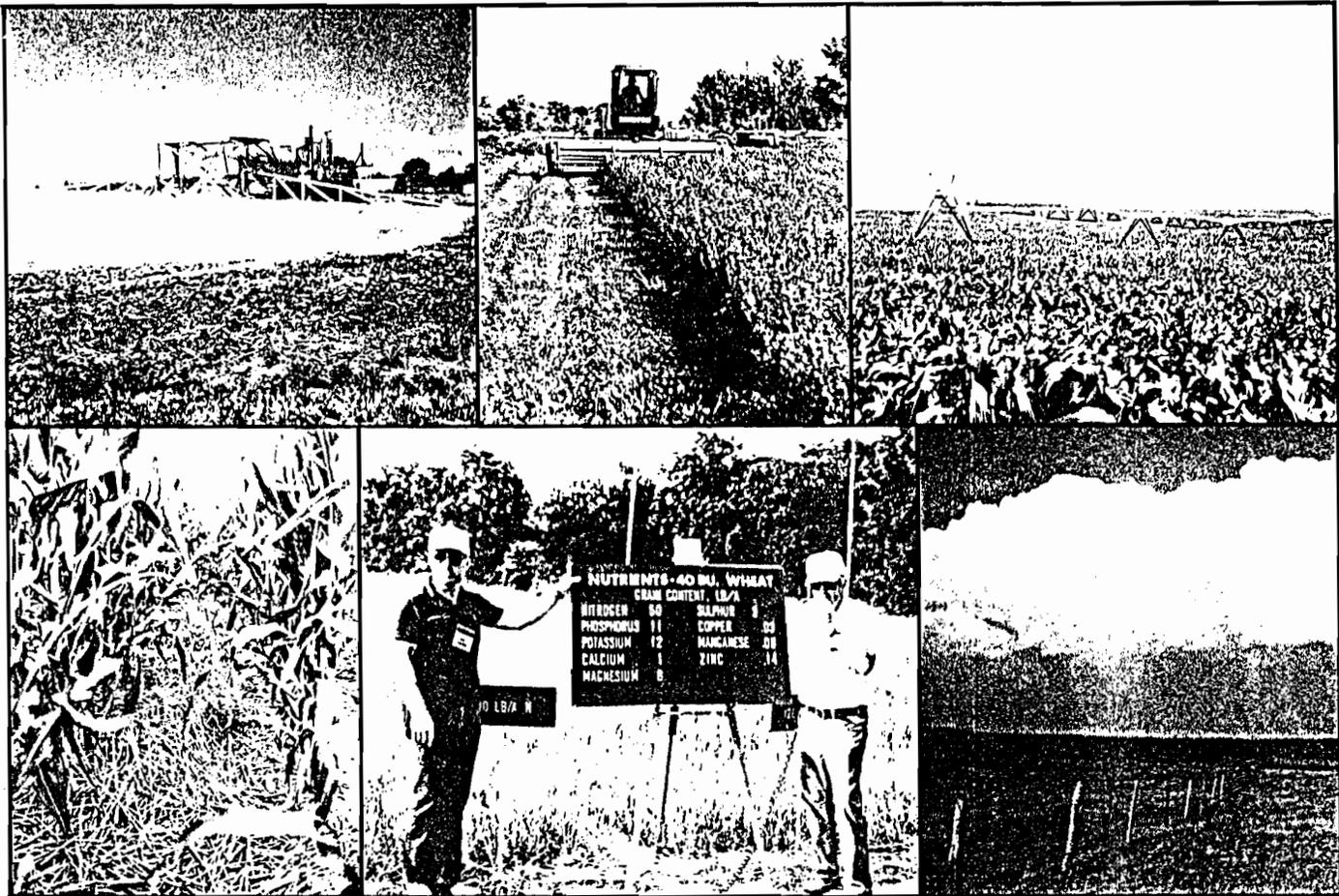


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CROPPING SYSTEMS AND FERTILIZATION FOR EFFICIENT WATER USE AND SUSTAINABILITY¹

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ABSTRACT

The winter wheat-fallow system of farming usually is not the most efficient cropping system for utilization of precipitation in the Great Plains. This study evaluated 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 and a winter wheat-sorghum-fallow rotation under dryland conditions. The study was conducted on a Planter loam soil using a no-till farming system. These 3-year 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 3-year rotations have a greater profit potential than the winter wheat-fallow rotation.

OBJECTIVE

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). Thus, 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 system usually is not the most efficient cropping system for utilizing precipitation with modern tillage technology. Reduced tillage and no-tillage 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). This additional soil water savings increased the opportunity for successfully growing spring planted crops such as proso millet, grain sorghum, and corn in rotation with winter wheat. For example, the 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 utilization within these 3-year cropping systems is limited.

This study evaluated 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 and a winter wheat-sorghum-fallow rotation under dryland conditions. A no-till system was used to enhance the feasibility of cropping more intensively (2 crops in 3 years) than is

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currently being done in the Central Great Plains with the winter wheat-fallow system. The study objectives were: 1) To determine the long-term grain yields of each respective crop in a wheat-corn(sorghum)-fallow rotation under dryland conditions; 2) To determine the N fertilizer requirements to obtain optimum economical grain yields in these 3-year rotations; and 3) To determine the effects of N fertilization on crop water use efficiency and crop rotation precipitation use efficiency. The purpose of this paper is to present a summary of the yield and crop water use data from this study.

PROCEDURES FOLLOWED

Nitrogen treatments (0, 25, 50, 75, and 100 lb N/acre) were arranged in a randomized complete block design with 4 replications. Identical sets of plots were established in the fall of 1984 on 3-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 (Pioneer 3732) and half to grain sorghum (Pioneer 8790). During the third year of the rotation, the plots were chemically summerfallowed to maintain the plots in a no-till condition. Glyphosate or paraquat were 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, bladex and dual were used to control weeds in the corn and sorghum rather than atrazine. Glyphosate plus 2,4-D or paraquat was used during the summerfallow period as well as bladex (short term residual) to control weeds. The number herbicide applications needed to control weeds varied with yearly climatic conditions. Broadleaf weeds were controlled in the wheat with 2,4-D. The study was located on a Platner loam soil at the Central Great Plains Research Station, Akron, CO.

The plot areas were planted to the appropriate crop each year following the established winter wheat-corn(sorghum)-fallow rotation. Winter wheat (Vona, 1984; Tam 105, 1985, 1986; Tam 107, 1987-89) was planted about September 20, corn (Pioneer 3732) about April 25, and grain sorghum (Pioneer 8790) about May 15 each crop year. Nitrogen fertilizer was applied at the specified rates prior to or at planting each crop year.

Soil samples from the 0- to 4-ft and where possible 0- to 6-ft depth in increments of 0-6", 6-12", 1-2', 2-3', 3-4', and 4-6' were collected just prior to seeding of each crop and/or each spring and again after winter wheat, corn and sorghum harvest. Soil water content was determined gravimetrically. The Platner loam soil used in this study had a sand and gravel layer below the 4-ft depth; therefore, a representative soil sample could not always be obtained. For this reason, soil water use measurements were limited to the top 4 ft of soil. Precipitation was monitored daily during the study. Grain yields were measured and crop water use or evapotranspiration (growing season precipitation plus soil water use) determined for each crop. Standard statistical procedures were used to analyze the data.

RESULTS AND DISCUSSION

Winter wheat grain yields (5-yr average) increased significantly with increasing N rate (Fig. 1). The application of 75 lb N/a increased winter wheat yields 17 bu/a over the check (no N) treatment. Corn yields in Fig. 1 represent a 3-year average grain yield (1986, 1988, 1989) and a 4-year average which includes 1987 data when at least 60% of the yield was lost to hail on August 4th. Sorghum yields were also affected by the hail. Therefore, a 3- and 4-year average grain yield is also 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 x N rate interaction was significant for each crop. This occurred 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. For purposes of this paper, only the average yields will be presented realizing that response to N fertilization can vary from year to year with climatic conditions.

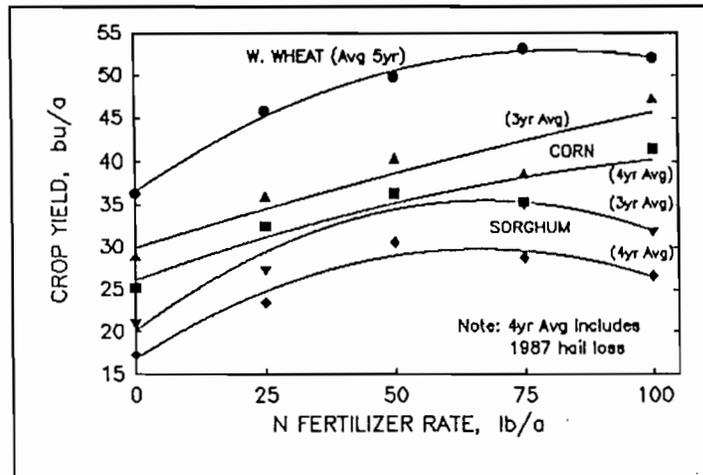


Fig. 1. Average winter wheat, corn, and sorghum yields as a function of N rate.

The effects of N fertilization on water use efficiency (WUE) by each crop are shown in Fig. 2. Soil water use (0- to 4-ft soil depth) by each crop generally was not greatly affected by increasing N fertilizer rate. Therefore, crop WUE was calculated as grain yield divided by evapotranspiration (ET), where ET was calculated as the sum of the precipitation received between the time of spring soil water determination and soil water determination after crop harvest plus the water depleted from the soil in the 0- to 4-ft depth. Nitrogen fertilization significantly increased the WUE of winter wheat (5-yr average), with WUE increasing with N rate up to 75 lb N/a. At this N rate, 4.4 bu/a of winter wheat were obtained for each inch of ET. The WUE of corn (3-yr 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 (3-yr 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. These data show that N fertilization is essential in the Central Great Plains if water use by crops is to be optimized.

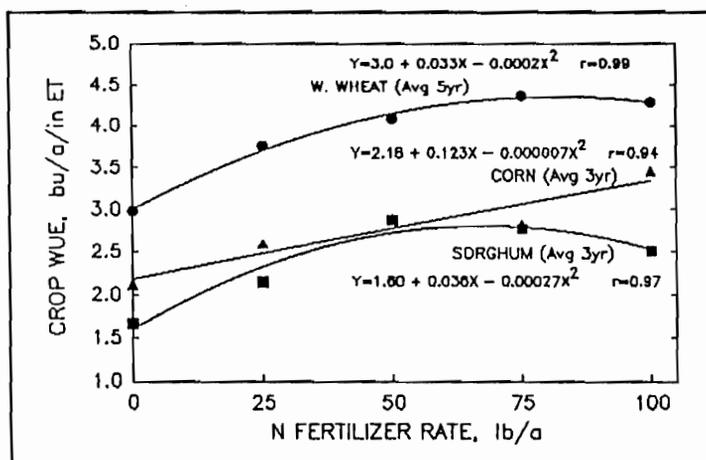


Fig. 2. Average crop water use efficiency (WUE) as a function of N rate.

Precipitation use efficiency (PUE) of each 3-year cropping system 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(sorghum) harvest and ending with corn(sorghum) harvest 36 months later. Precipitation totals for the 4 sequences used here were 50.7" for October 15, 1984 to October 14, 1986; 50.9" for October 15, 1985 to October 14, 1987; 50.4" for October 15, 1986 to October 14, 1988; and 49.9" for October 15, 1987 to October 14, 1989. The long-term (81 yr) average 36-month total precipitation is 49.6". Therefore, the years evaluated in this study received normal precipitation levels, 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 total pounds of grain produced per acre (i.e. wheat + corn) over the 3-year sequence and dividing the result by the 36-month precipitation total. The PUE of the wheat-corn-fallow 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. 3). The PUE of the wheat-sorghum-fallow 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 wheat-corn-fallow sequence had a higher level of PUE than the wheat-sorghum-fallow rotation at this location. This would probably change for other areas of Colorado, such as southeast Colorado where sorghum is better adapted than corn. Nitrogen had a significant impact on precipitation utilization by these dryland crops in the Central Great Plains. The PUE of these 3-year rotations were higher than that of a long-term winter wheat-fallow rotation (85 lb grain/a/inch) conducted at a near by site at the Akron Station (Smika, 1990). These more intensive rotations made better use of the precipitation received and will reduce the potential of leaching agricultural chemicals through the soil profile toward the groundwater table.

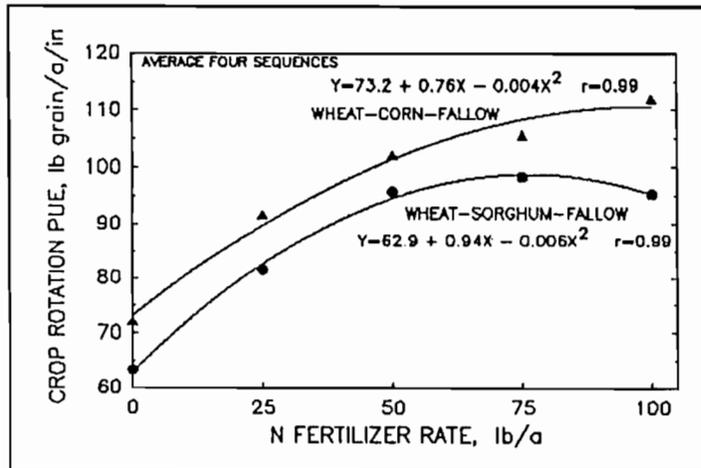


Fig. 3. Crop rotation precipitation use efficiency (PUE) as a function of N rate.

An estimated gross income, less N fertilizer cost, is shown in Fig. 4 for the average winter wheat (5yr), corn (3yr), and sorghum (3yr) yields obtained in this study. Assumptions made were: wheat = \$3.80/bu; corn = \$2.40/bu; sorghum = \$2.13/bu; ammonium nitrate applied to wheat = \$0.23/lb N; and anhydrous ammonia applied to corn and sorghum = \$0.10/lb N. Based on these assumptions, maximum economic yield was obtained with 75 lb N/a on wheat, with 100 lb N/a on corn, and with 50 lb N/a on sorghum (Fig. 4).

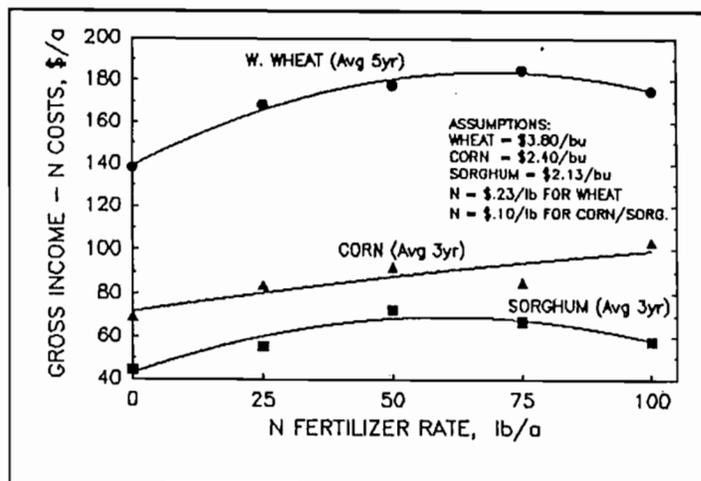


Fig. 4. Estimated gross income less fertilizer cost based on average crop yields.

Total gross income, less N costs, from each rotation expressed on a per year basis (includes fallow year) shows that per year income was higher for the wheat-corn-fallow rotation than for the wheat-sorghum-fallow rotation (Fig. 5). Yearly gross income for the winter wheat-corn-fallow rotation at optimum N rate was \$93/a/yr and for the winter wheat-sorghum-fallow rotation \$84/a/yr. This compares to an estimated \$68/a/yr return for the last five wheat-fallow cycles of the long-term study of Smika (1990) which received 50 lb N/a. Thus with adequate N fertilization, profit potential is greater with the 3-year rotations.

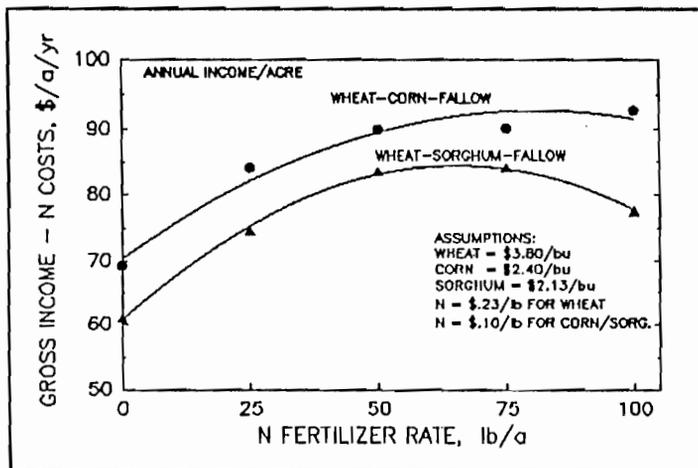


Fig. 5. Estimated yearly gross return minus N costs for the 3-year rotations as a function of N rate.

Other potential benefits from a 3-year rotation vs winter wheat-fallow would be: a reduction in the severity of winter annual grassy weed problems, especially downy brome and jointed goatgrass; reduction in amount of soil erosion due to a reduction in time that a crop is not covering the soil surface, and added surface residues due to reduced tillage system; a reduction in weed, disease, and insect problems by crop rotation; reduced risk of crop failure due to weather (hail, low precipitation) by having greater crop diversification; more efficient use of farm machinery as a result of more acres in crop production per farm unit; and spreading the work load out over more of the year. With the current emphasis on environmental quality and economic sustainability of agriculture, the 3-year rotation offers great possibilities for improved crop production in the Central Great Plains.

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USDA-ARS SOIL FERTILITY RESEARCH AT AKRON, COLORADO

The purpose here is to briefly outline the soil fertility research projects being conducted by USDA-ARS and cooperators at the Central Great Plains Research Station at Akron, Colorado.

PROJECT TITLE: Effect of N fertilization on water use efficiency by winter wheat, barley, and corn in the Central Great Plains.

Objective: Determine the effects of N fertilization on crop yields, quality, and water use efficiency with reduced tillage and annual cropping under dryland conditions.

Personnel: Ardell D. Halvorson and C. A. Reule, USDA-ARS, Akron, CO.

PROJECT TITLE: Management of P fertilizer for dryland winter wheat in reduced tillage systems.

Objective: Determine most efficient method of P placement for optimum economic yields and the value of residual fertilizer P for future wheat production.

Personnel: Ardell Halvorson, USDA-ARS, Akron, CO and John Havlin Kansas State University, Manhattan.

PROJECT TITLE: Crop rotation and N fertilization for efficient water use.

Objective: Determine the potential of producing economical dryland corn or sorghum yields following winter wheat in a wheat-corn(sorghum)-fallow rotation using reduced tillage systems. The N fertilizer requirements for optimum crop production and efficient water use are being evaluated.

Personnel: Ardell Halvorson and David Nielsen, USDA-ARS, Akron, CO.

PROJECT TITLE: Winter wheat variety response to N fertilization.

Objective: Determine the interaction between winter wheat varieties and rate of N fertilization under dryland conditions.

Personnel: Jim Quick, CSU Agronomy Dept., Fort Collins and Ardell Halvorson, USDA-ARS, Akron, CO.