CORN SOYBEAN YIELDS AND SOIL CONDITION UNDER RIDGE AND CHISEL-PLOW TILLAGE IN THE NORTHERN CORN BELT

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ABSTRACT

Ridge tillage is a special conservation tillage method, but the long-term effect of this tillage system on crop yield and soil quality in a corn (Zea mays L.) and soybean {Glycine max (L.) Merr.} rotation are largely unknown in the northern Corn Belt. Objectives were to compare crop performance and soil condition at three nitrogen-fertilizer levels with ridge tillage (RP) and conventional tillage (CT). Experiments were started in 1990 at Brookings, South Dakota, on a Barnes clay loam (fine-loamy, mixed Udic Haploboroll). Conventional tillage included moldboard or chisel plowing, seedbed preparation with tandem disk and field cultivator, and row cultivation. Raised beds on RP plots were maintained using only row cultivation. Corn grain yield was greater on CT than on RP plots in only 2 of 10 years. Average corn yield was 6190 kg ha^{-1} (98 bu/acre) with RP and 6430 kg ha^{-1} (102 bu/acre) with CT. Soybean grain yield was significantly greater on RP than on CT plots in only 1 of 10 years. Average soybean yield was 2020 kg ha^{-1} (30 bu/acre) with RP and CT. In 9 of 10 years there was a significant soybean-yield response to N starter fertilizer. In the top 0.2 m of soil, average organic C was 53 Mg ha^{-1} with RP and 40 Mg ha^{-1} with CT, total N was 4.8 Mg ha^{-1} with RP and 3.6 Mg ha^{-1} with CT, and bulk density was 1.38 g cm^{-3} with RP and 1.08 g cm^{-3} with CT. Soil organic C has increased with ridge tillage without a large decline in corn or soybean production.

INTRODUCTION

Ridge tillage is "a tillage system in which ridges are reformed atop the planted row by cultivation, and the ensuing row crop is planted into ridges formed the previous growing season" (Soil Sci. Soc. Am., 1997). Advantages and disadvantages of ridge tillage have been identified. In southwestern Ontario, Canada, ridge tillage reduced soil erosion, but increased P loss (Gaynor and Findlay, 1995). Studies in Ohio showed that older consolidated ridges were resistant to soil erosion (Norton and Brown, 1992

Ridge tillage offers a compromise between no tillage and other intensive, whole-field tillage systems such as chisel-plow and generally has been viewed as an economically viable tillage/crop production system. Lighthall (1996) evaluated farmer adoption of ridge tillage in the Corn Belt and reported that ridge tillage was a positive step towards low-input grain production. Exner et al. (1996) reported that on-farm studies by Practical Farmers of Iowa, found ridge tillage without herbicides to be an effective and economical system for row crop production.

MATERIALS AND METHODS

Our study was located on the Eastern South Dakota Soil and Water Research Farm near Brookings, SD on a Barnes clay loam with nearly level topography. Whole plots (tillage) in the split plot experiment were arranged as a randomized complete block with three replications. Split plots were N treatments. Corn was grown in rotation with soybean. Each crop was present each year. Plots were 30 m (100 feet) long and 30 m wide. The experiment was started in 1990.

On conventional tillage (CT) plots, primary tillage has been with a moldboard or chisel plow in the fall of the year. Primary tillage since 1996 has been with a chisel plow. Ridge-tillage, also called ridge-plant (RP), plots receive only row cultivation for both corn and soybean crops. Cultivation has maintained a raised seedbed on RP plots and no effort has been made to build or knock down soil ridges. Rows are oriented in the east-west direction on the CT and RP plots.

Seedbeds for corn and soybean on CT plots were prepared in spring using a tandem disk and field cultivator. Corn and soybean were no-till planted on the previous crop row in RP plots. Seeding date, rate, and variety were the same for all tillage and nitrogen treatments in a given year. Depending on weather, seeding has been as early as 5 May for corn and 11 May for soybean. Row spacing for corn and soybean was 76 cm (30 inches). Both CT and RP plots were cultivated twice during the growing season.

Nitrogen treatments were: corn fertilized for a yield goal (YG) of 8.5 Mg grain ha^{-1} (135 bu/acre) (HN), corn fertilized for a YG of 5.3 Mg grain ha^{-1} (85 bu/acre) (MN), and corn not fertilized (LN). Samples for soil nitrate-N were collected in the fall or spring, depending on weather conditions. Nitrate-N was measured using a 2 M KCl extraction and automated copperized Cd reduction column procedure (Zellweger Analytics, 1992).

Nitrogen fertilizer prescription (NP) for corn on each N treatment was calculated as NP = 0.022YG - STN (1.2 lb N/bu corn), where STN is the total soil nitrate-N. Adjustments (Gerwing and Gelderman, 1996) to NP for previous crop or sampling date were not made. Nitrogen prescriptions for each tillage and N treatment were met by applying starter fertilizer with the seed and sidedressing with appropriate amounts of urea (46-0-0). Starting with the 1996 crop year, 112 kg ha^{-1} (100 lb/acre) of starter fertilizer as 14-36-13, 7-36-13, and 0-36-13 (N-P_2O_5-K_2O) have been applied on HN, MN, and LN plots, respectively. Soil phosphorous levels were rebuilt on all plots prior to spring field work in 1996 with an application of triple super phosphate (0-45-0) equivalent to 89 kg ha^{-1} (80 lb/acre) of elemental P.

Fertilizer treatments for soybean were starter fertilizer only. Starter fertilizer was applied as 14-36-13, 7-36-13, and 0-36-13 (N-P_2O_5-K_2O) on HN, MN, and LN plots, respectively, at 112 kg ha^{-1} (100 lb/acre). Starter fertilizer for both corn and soybean was applied at seeding and placed 5 cm (2 inches) to the side and 5 cm deeper than seed.

Corn and soybean grain yield has been measured with a Massey Ferguson MF 8-XP Research Plot Combine (Kincaid Equipment Manufacturing[1], Haven, Kansas) equipped with an electronic weigh bucket. On each plot, 8 rows, 30 m (100 feet) long (1/5 of the plot area) were harvested for grain yield, grain moisture, test weight, and N content. Corn grain yields were adjusted to 15.5% moisture and soybean grain yield adjusted to 10% moisture.

[1] Mention of trade names is for the benefit of the reader and does not constitute endorsement by the U.S. Department of Agriculture over other products not mentioned.

Selected soil quality indicators were measured in corn plots in 1998 following four complete rotations of corn soybean (eight years). Potentially mineralizable N was estimated using a modified aerobic incubation method (Stanford and Smith, 1972). Samples were incubated for 189 days. Sample NO_3-N was quantified using copperized Cd reduction column procedure and NH_4-N was analyzed using a blue indophenol-type compound (Zellweger Analytics, 1996). Concentrations of NO_3-N and NH_4-N were converted to kg-N ha^{-1} using appropriate soil bulk density values and dilution factors.

Additional measurements on samples collected from the top 20 cm (8 inches) of soil were extractable P, soil organic carbon, total soil N, bulk density and pH. Extractable P was determined using the $NaHCO_3$ method P (Olsen et al., 1954). Soil organic carbon and total N were determined by combustion using a Carlo Erba NA 1500 C-N analyzer. Soil bulk density, adjusted to a dry basis, was calculated from the mass and volume of the bulked soil samples. Soil pH was measured using 0.01 M $CaCl_2$ and a soil:solution (weight basis) ratio of 1:2.

Prior to establishment of this tillage study, the experimental area was sampled on a 30-m by 30-m grid (Maursetter, 1992). Core samples were taken according to soil horizon and soil organic matter was estimated by loss on ignition (Gelderman et al., 1995).

Statistical comparisons of all measurements were made using analysis of variance and multiple factor analysis of variance (MINITAB, Release 12, 1998). The split plot arrangement within randomized blocks was such that factor 1 was tillage (whole plot).

RESULTS AND DISCUSSION

Our field trials covered some of the wettest and coldest periods in the South Dakota climate record. Precipitation totals from 1991-1995 were the greatest in more than 100 years and the 1992 and 1993 summers were the coldest consecutive summer seasons on record beginning 1890 (Alan Bender, South Dakota State Climatologist, Brookings, SD). Corn and soybean yields were least in 1992 and 1993 compared with other years in the study. However, even during these adverse growing seasons, corn and soybean yields on RP were equal to CT.

Corn grown using conventional tillage has outyielded corn grown using ridge plant by an average of 240 kg grain ha^{-1} (4 bu/acre) during the past 10 years (Table 1). However, only in 2 of 10 years was corn yield with CT significantly greater than corn yield with RP (Table 1). Often, there are not clear relations between tillage intensity and crop yield and our findings are typical of other cropping and tillage studies. Chase and Duffy (1991) found that moldboard plow tillage resulted in the highest corn yield in a 10-year tillage study conducted in Iowa. In contrast, Buhler (1992) found that corn yields were not affected by tillage systems in Wisconsin.

There was not a consistent tillage x N interaction every year, but there was a significant response to N each year. Tillage could be expected to change distribution of N, concentration of N, soil temperature, and soil water content. These factors could result in differences in grain yield. There were no differences due to tillage in corn plant populations (Data not shown).

Soybean yield using conventional tillage was about the same as soybean yield using ridge plant. Average yield of soybean was 60 kg grain ha^{-1} (1 bu/acre) greater with CT than with RP during the past 10 years. Only once in 10 was there a significant difference in yield due to tillage treatments and this occurred in 1997. Soybean grain yields with RP exceeded grain yield with CT by 370 kg grain ha^{-1} (6 bu/acre) in 1997. We attribute this yield difference to early stand establishment on RP plots. Spring 1997 turned unusually dry and plant emergence on CT plots was delayed until late June following a series of rain storms that re-wetted the seed zone.

There was a significant soybean yield response in 9 of 10 years to low rates of N fertilizer applied as starter at seeding time (Table 1). Generally, N fertilizer has not produced yield response in other studies. We are uncertain why soybean was responsive to low rates of applied N, but we think that fertilizer N may stimulate early plant development. Rapid and early stand establishment could be important to soybean production in northern climates. Our findings are consistent with recent research from northern Minnesota where soybean yield has been improved by additional N. Nitrogen, at low rates, may stimulate infection of soybean roots with rhizobium resulting in improved nodulation (Personal communication with George Rehm, professor, University of Minnesota, Saint Paul, Minnesota).

There were no differences in NUE due to tillage treatments (data not shown). Average NUE for the past 4 years for both tillage systems was 44.8 kg corn per kg N on HN plots. This ratio is very close to the ratio of 45.45 kg corn per kg N (0.8 bu corn/lb N) used in the South Dakota and Minnesota fertilizer management guides (Gerwing and Gelderman, 1996; Rehm et al., 1994). Other long-term experiments in the central Great Plains of the USA suggest 43 kg corn per kg N (Merle Vigil, Akron, CO, USA, Personal communication).

There is not a definitive set of soil measurements that, when taken together, adequately defines soil quality. We measured soil properties thought to be important in respect to nutrient management and plant growth.

Efficient use of N can minimize potential for ground water contamination by water soluble nitrates. We did not detect significant differences in nitrate accumulation due to RP and CT tillage treatments. Samples for these tests were taken before the 1998 crop year and reflect soil conditions after 8 years. Total nitrate-N in the top 3 m (10 feet) of soil on RP plots was 111 kg ha^{-1} (99 lb/ac) and 121 kg ha^{-1} (108 lb/ac) on CT plots (Data not shown).

Following a 189-day incubation period, potentially mineralizable N was 177 kg N ha^{-1} (158 lb/ac) on RP plots and 156 kg N ha^{-1} (139 lb/ac) on CT plots. Plots with RP also had greater amounts of organic C than plots with CT (Data not shown).

In many studies, soil organic C has been identified as an important soil quality indicator and tillage, or no tillage, have been identified as having a profound effect on carbon cycling. Organic carbon in the initial grid samples corresponding to the location of present-day plots in even-year corn of RP and CT plots, was 16.3 g kg^{-1} (sd =2.2) on RP plots and 16.9 g kg^{-1} (sd =1.6) on CT plots. In 1998, organic carbon expressed on a gravimetric basis was 19.0 g kg^{-1} on RP and 18.2 g kg^{-1} on CT plots. Different analytical procedures were used to determine organic carbon of samples collected in 1989 and 1998, so it is difficult to quantify exact gains or losses in OC between tillage plots. However, in 1998 soil with RP had greater amounts of organic C than soil with CT and that is opposite of conditions measured in 1989.

CONCLUSION

Corn-soybean production in the northern Corn Belt of the United States can be difficult because of cool and wet conditions. Some tillage may be desirable to accelerate soil drying and warming and to reduce chemical input for weed control. Our study has shown no differences in soybean yield between ridge tillage and chisel tillage. However, on either tillage treatment we found that soybean yield was increased by additional N applied at seeding. These results were unusual because studies conducted in southern climates show soybean yield unaffected by N addition. In cooler climates, low rates of N at seeding may simply stimulate rapid plant development and improve nodulation of soybean. Corn yield, averaged over 10 years, was 240 kg grain ha^{-1} (4 bu/acre) greater on chisel tillage than on ridge tillage plots. There was little difference in NUE or soil nitrate accumulation due to the two tillage systems. Ridge tillage can protect soil from erosion because crop residues remain undisturbed on the soil surface in contrast to conventional tillage where residue was incorporated. We anticipated finding greater contrasts in soil properties due to these two tillage systems because soil on the ridge tillage plots has not been stirred by tillage. We found only subtle differences in soil properties between the two tillage systems. Notably, soil organic C on ridge tillage plots was 34 percent greater than on chisel tillage plots. The increase of soil organic C on ridge tillage plots occurred during the past 9 years and we equate a gain of soil organic C to soil improvement. Soil organic C is difficult to rebuild using even the best tillage or cropping system and it is important to seek management practices that sustain the soil resource while maintaining competitive grain yields. Ridge tillage has improved soil quality in respect to organic carbon without a large decline in grain production.

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Table 1. Mean corn yield (15.5% grain moisture) and soybean yield for ridge plant (RP) and conventional tillage (CT). Nitrogen treatments for soybean were starter fertilizer only. Starter was applied to corn and soybean as 14-36-13, 7-36-13, and 0-36-13 (N-P_2O_5-K_2O) on H, M, and L treatments, respectively, at 112 kg/ha. Corn N fertilizer treatments were corn fertilized for a yield of 8.5 Mg/ha (H), corn fertilized for a yield of 5.3 Mg/ha (M), and corn not fertilized (L).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Ave.
	Corn yield (kg/ha)										
Tillage (T)											
RP	8450	8320	4400	2160	5050	5360	7500	6750	7620	6290	6190
CT	8050	8300	4190	2240	6080	5800	8260	6930	7870	6540	6430
Fertilizer (N)											
H	9130	9800	6440	3880	8780	7160	9090	7280	8690	6800	7700
M	8710	9580	4690	2520	5840	5070	7710	7220	7880	6920	6610
L	6910	5540	1750	200	2070	4510	6840	6020	6660	5520	4600
p value T	ns	ns	ns	ns	ns	ns	0.057	ns	0.076	ns	
p value N	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.001	0.002	
p value TxN	0.061	ns	ns	0.047	0.031	ns	ns	ns	0.008	ns	
	Soybean yield (kg/ha)										
Tillage (T)											
RP	2090	2190	1580	1220	1740	1830	2640	2480	2110	2060	1990
CT	2240	2100	1590	1660	2010	2050	2740	2110	2110	1920	2050
Fertilizer (N)											
H	2410	2520	2030	1820	2780	2300	2700	2410	2200	2080	2320
M	2070	2060	1800	1380	1590	1760	2810	2270	2020	1970	1970
L	2030	1840	920	1110	1260	1760	2570	2200	2100	1910	1770
p value T	ns	ns	ns	ns	ns	ns	ns	0.049	ns	ns	
p value N	0.082	0.001	0.001	0.001	0.001	0.001	0.006	0.025	ns	0.029	
p value TxN	ns	ns	ns	ns	ns	0.018	ns	ns	ns	ns	

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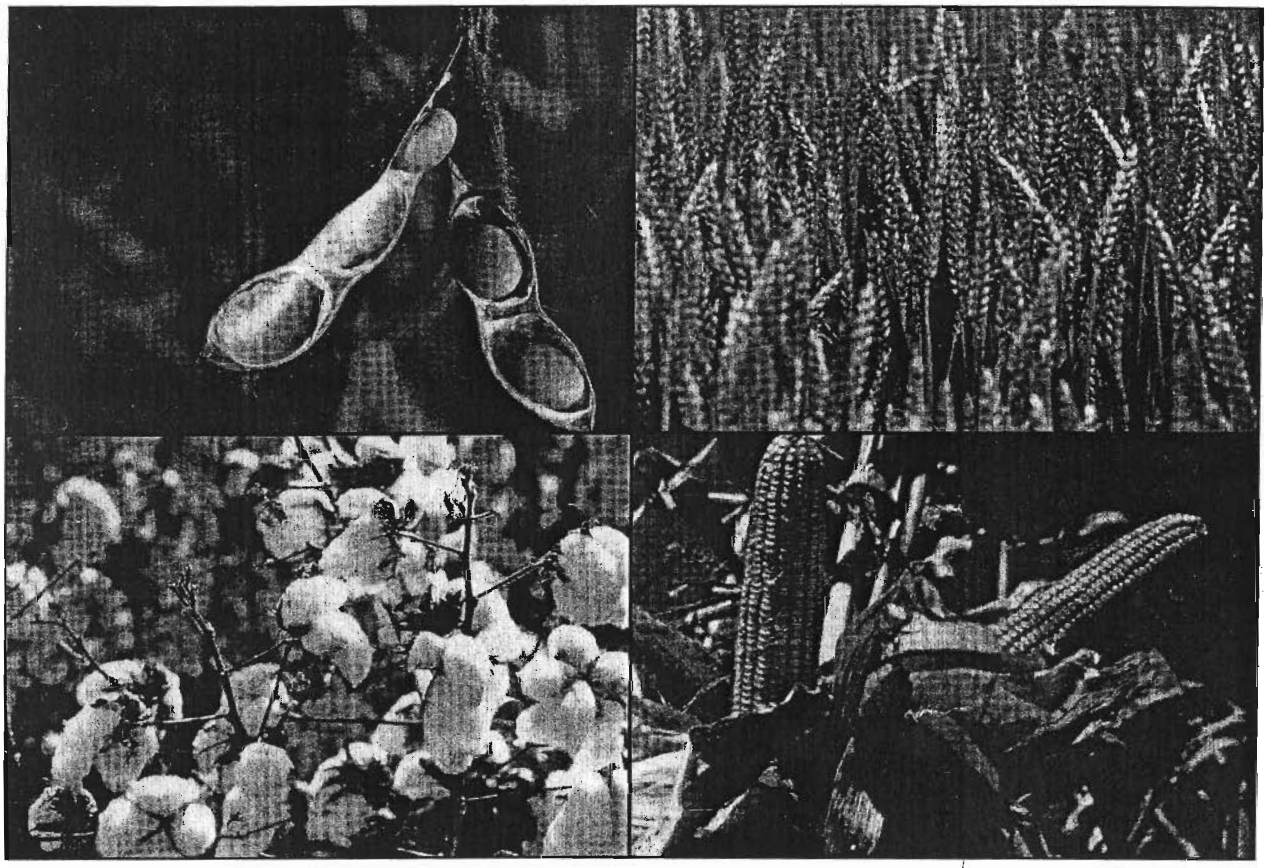

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