Integration of Tillage, Fertility and Crop Rotation in a Cropping System

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Abstract

Production agriculture in North Dakota is represented by a large number of diverse crops and contrasting tillage practices. A long term cropping systems study was established in 1987 at the North Dakota State University Carrington Research Extension Center to evaluate the impact of crop rotation, tillage systems, and N fertility on crop performance and soil parameters. The fifth cycle of the long-term study which occurred from 2003 through 2006 is reported.

Grain production among the crops evaluated in the four years of the current cycle varied significantly across years. Field pea and spring wheat were generally stable in performance while canola, barley, soybean, and corn were more variable. Sunflower yields were similar all four years of this cycle.

Crop performance was typically affected by the tillage system evaluated. No-till crop production resulted in a trend for reduced grain yield with many of the crops evaluated. The effect of tillage system on the legume crops generally differed from the non-legume crops. Soybean grain yields were highest in the no-till system while field pea yielded similar across all three tillage systems.

Nitrogen fertility applications resulted in increased grain yield among the non-legume crops. The increase in grain yield of corn, sunflower, and spring wheat due to added N were similar across the N levels evaluated. Barley grain yield increased significantly with application of increased amounts of N. The N fertilizer available from the manure application was not sufficient to optimize canola grain yield.

Crops differed in the amount of total crop biomass produced under the nitrogen fertility treatments evaluated. Corn produced more biomass when the N fertility was supplied by a manure application. Sunflower and spring wheat produced increased amounts of biomass with additional N although N level did not influence the response. Increased levels of N application resulted in more increased biomass with barley and canola crops.

Soil tests indicate that the application of 90 kg ha^{-1} of N resulted in increased levels of residual N throughout the soil profile. This elevated N suggests an application level beyond crop demand during this cropping cycle. Manure applications as a source of N fertility resulted in an increase in both soil organic matter and phosphorus.

Objectives

Evaluate the effect of crop rotation, tillage system and N fertility on the performance of the cropping system.

Introduction

Production agriculture in North Dakota has a strong history of diversified crops. Diversified cropping systems could minimize farming risk, provide sustainable production, and increase environmental conservation. To examine the benefits of cropping systems, the North Dakota State University Carrington Research Extension Center initiated a long-term cropping system in 1987. The goal of the study is to determine the effects of tillage system, N fertility level, and crop rotation on crop yield and quality, biomass production, and changes in soil quality. Hard red spring wheat, soybean, sunflower, barley, field pea, canola and corn were planted in three different four-year crop rotations in conventional-, minimum-, and no-tillage systems. This report is an overview of the fifth cycle of the study which occurred from 2003 through 2006.

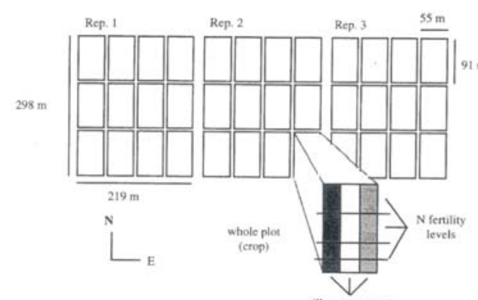
Materials and Methods

This study was initiated in 1987 and is conducted at the North Dakota State University Carrington Research Extension Center near Carrington, North Dakota, on a Heimdal-Emrick loam soil. It consists of three, four-year, crop rotations with three replicates. Each crop in each rotation occurs in every year. Within each crop (0.5 ha main plot) in a rotation, three tillage systems (0.17 ha sub-plots) are imposed, and four N fertility treatments are imposed perpendicular to the tillage systems (0.042 ha sub-sub-plots) (Figure 1). The crop rotations for the 2003-2006 crop cycle were the traditional rotation Hard Red Spring Wheat (HRSW) (*Triticum aestivum* L.) - Sunflower (*Helianthus annuus* L.) - Barley (*Hordeum vulgare* L.) - Soybean (*Glycine max* L.) (Rot 1), the alternating grass legume rotation HRSW - Soybean - Corn (*Zea mays L.)* - Field Pea (*Pisium sativum* L.) (Rot 2), and the compound or stacked rotation HRSW - HRSW - Soybean - Canola (*Brassica napus* L.) (Rot 3). The tillage systems are conventional (T), minimum tillage (M), and no-till (N). The nitrogen (N) fertility treatments are ammonium nitrate fertilizer broadcast applied each spring to the non-legume crops at 0, 45, or 90 kg ha^{-1} or as composted manure applied at 179 kg ha^{-1} of N applied the first spring of each four-year cycle. The crop rotations were designed to evaluate potential production synergies among the crop diversity that exists in

Materials and Methods (cont.)

central North Dakota. The crops represented in these rotations have contrasting characteristics relative to length of maturity, water use intensity, pest-host relationships, N fertility requirements, and residues. Assessment of cropping system impact will be based on data collected to quantify crop seed and biomass yield, crop quality (oil and protein), pest (disease, weed, and insect) pressure, and soil parameters including nitrogen, phosphorus, organic matter, and pH. The timing of planting, harvest, and tillage operations are based on best management practices and influence of seasonal weather conditions.

Figure 1. Layout of the study.



Results

Year

The growing seasons associated with the four years of this cycle generally influenced grain yield of the crops evaluated (Table 1). Sunflower was the exception as grain yields were similar all years of this cycle. Crops such as field pea and spring wheat were more consistent in yield, while canola, barley, soybean, and corn had more variable performance.

Tillage System

Tillage systems influenced grain yield although the response varied widely among crops (Table 2). Grain quality factors of oil content and grain protein were not affected by tillage (data not reported). A trend for reduced grain yield was apparent with the no-till system with many of the crops. In the case of sunflower the difficulty attaining adequate weed control in a no-till system is the primary reason for yield reductions. Soybean grain yield in the no-till system was significantly higher than either of the other tillage systems. Field pea, the other legume evaluated, yielded similar across all tillage systems.

Table 1. The effect of year on grain yield of rotational crops when averaged across N fertility and tillage system treatments.

Year	Barley	Canola	Corn	Field Pea	Soybean	Sunflower	HRSW
	---------- kg ha^{-1} ----------						
2003	3,033	746	7,120	2,722	2,339	1,359	2,442
2004	2,737	1,769	7,052	2,671	1,723	1,377	2,548
2005	3,889	539	6,022	2,593	1,758	1,298	2,240
2006	2,252	863	3,291	2,018	1,136	1,399	3,054
Mean	2,978	979	5,871	2,501	1,739	1,358	2,571
C.V.	28	40	18	22	18	29	29
LSD 0.05	396	186	520	252	105	NS	177

Results (cont.)

Table 2. The effect of tillage system on grain yield of rotational crops when averaged across N fertility treatments and years.

Tillage	Barley	Canola	Corn	Field Pea	Soybean	Sunflower	HRSW
	---------- kg ha^{-1} ----------						
M	3,234	985	6,007	2,565	1,690	1,387	2,671
N	2,760	893	5,471	2,405	1,843	1,178	2,462
T	2,940	1,060	6,136	2,533	1,685	1,510	2,580
Mean	2,978	979	5,871	2,501	1,739	1,358	2,571
C.V.	28	40	18	22	18	29	29
LSD 0.05	343	161	450	NS	71	166	154

Effect of N fertility treatment on spring wheat.

Nitrogen Fertility

Grain yield of the non-legume crops responded positively to additions of N fertilizer whether it was from a commercial nitrogen fertilizer or the manure application (Table 3). During the four years of this cropping cycle the grain yields of corn, sunflower, and spring wheat were similar among the treatments where additional levels of nitrogen were applied. Barley responded with increased yield with the 90 kg ha^{-1} application of N versus the 45 kg ha^{-1} treatment. Canola yield in the manure treatment was significantly lower than the yield attained with 90 kg ha^{-1}.

The effect of nitrogen fertility on the amount of total biomass produced by non-legume crops was significant and varied among crops (Table 4). Sunflower and spring wheat produced more biomass with additional N but the response was similar across the added N levels. Total biomass in the corn crop was similar among N treatments with the exception of more biomass produced when manure was the source of N. Barley and canola generally produced more biomass with increasing levels of N.

The soil N data indicate that applications of 90 kg ha^{-1} of N resulted in increased levels of residual N throughout the soil profile tested (Table 5). The level of soil N associated with the 90 kg ha^{-1} N treatment is especially apparent as shown in the 61-122 cm level of the soil. This elevated N in the deeper depths of the soil profile suggest N not utilized by the crops and now leached to depths only utilized by deeper rooting crops. The differences in soil organic matter and pH reflect a long-term trend that has been associated with the N fertility treatments of this long-term study. Manure applications have significantly increased soil organic matter and the level of phosphorus.

Table 3. The effect of N fertility on grain yield of non-legume rotational crops when averaged across rotation, tillage systems, and years.

Fertility	Barley	Canola	Corn	Sunflower	HRSW
	---------- kg ha-1 ----------				
0	2,290	675	5,135	1,176	2,297
45	3,027	1,073	6,095	1,419	2,707
90	3,425	1,182	6,054	1,467	2,555
M	3,170	987	6,202	1,371	2,724
Mean	2,978	979	5,871	1,358	2,571
C.V.	28	40	18	29	29
LSD 0.05	396	186	520	178	177

Table 4. The effect of N fertility on total biomass yield of non-legume rotational crops when averaged across rotations, tillage systems, and years.

Fertility	Barley	Canola	Corn	Sunflower	HRSW
	---------- kg ha-1 ----------				
0	4,056	4,031	13,725	7,285	4,647
45	5,134	5,820	14,822	8,183	5,608
90	5,940	6,066	14,645	8,721	5,722
M	5,161	5,246	16,060	8,419	5,648
Mean	5,073	5,291	14,813	8,152	5,406
C.V.	27	32	17	26	26
LSD 0.05	650	781	1,171	884	328

Effect of tillage treatment on corn.

Effect of tillage and N fertility treatments on sunflower.

Table 5. The effect of N fertility on soil traits when averaged across crop rotations, tillage systems, and years.

Fertility	Soil Sample Depth (cm) 0-15	15-30	30-61	0-61	61-122	0-122	OM	P	pH
	---------- N kg ha^{-1} ----------						%	ppm	
0	14	4	6	25	15	45	2.9	9	6.7
45	17	6	10	33	30	68	3.0	9	6.6
90	20	9	23	52	81	144	3.0	8	6.4
M	19	6	8	33	22	61	3.2	26	7.0
Mean	18	6	12	36	37	80	3.0	13	6.7
C.V.	59	81	115	58	104	66	104.2	66	15.0
LSD 0.05	1	1	2	3	7	10	0.1	1	0.1

Table 6. Average monthly air temperature and precipitation

Air Temperature (°C)

Month	Normal	2003	2004	2005	2006
Apr	6	7	6	8	9
May	13	12	10	11	14
June	18	17	16	18	18
July	21	19	19	20	22
Aug	20	21	16	18	20
Sept	14	13	14	16	13

Precipitation (mm)

Month	Normal	2003	2004	2005	2006
Apr	37	12	21	13	31
May	63	118	141	69	29
June	96	78	30	161	88
July	79	73	52	15	27
Aug	63	75	43	29	54
Sept	47	31	85	6	25

Source: North Dakota Agricultural Weather Network

Conclusion

- Grain yield response of crops across years varied which reflects the biological diversity of crops grown in this region.
- No-till production resulted in a trend of reduced yields except for the legume crops of soybean and field pea.
- Non-legume crops were responsive to additional N fertility although the response to N rate was minimal.
- The amount of total crop biomass produced by the crops varied significantly in response to the N fertility treatments evaluated.
- When manure was utilized as the source of N fertility the long-term response has been an increase in organic matter, phosphorus, and pH of the soil.