

The Effects of Integration of Tillage, Fertility, and Crop Rotations in a Cropping System on Soil Fertility

E.Z. Aberle, B.G. Schatz, G.J. Endres, R.A. Henson, S.F. Zwinger, and T.J. Indergaard
North Dakota State University

INTRODUCTION

Numerous cash crops are grown in North Dakota. This long term study investigates the effects of tillage system and N fertility regime on the profitability and sustainability of differing crop rotations.



OBJECTIVE

Investigate the effects of Cropping Systems on crop yield and quality, crop pest frequency and severity, and soil fertility and quality.

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 (0.45 ha main plot) in a rotation, three tillage systems (0.15 ha sub-plots) are imposed, four N fertility treatments (0.0375 ha sub-sub-plots) are imposed perpendicular to the tillage systems (Figure 1). The crop rotations for the 1999-2002 crop cycle were the traditional rotation Hard Red Spring Wheat (HRSW) (*Triticum aestivum* L.)/Sunflower (*Helianthus annuus* L.)/Barley (*Hordeum vulgare* L.)/Fallow (Rot 1), the alternating grass legume rotation HRSW/Soybean (*Glycine max* L.)/Durum (*Triticum turgidum* L.)/Field Pea (*Pisum sativum* L.) (Rot 2), and the compound or stacked rotation HRSW/Corn (*Zea mays* L.)/Soybean/Canola (*Brassica napus* L.) (Rot 3). The tillage systems are conventional (T), minimum tillage (M), and no-till (N). The N fertility treatments are ammonium nitrate broadcast applied each spring to non-leguminous non-fallow plots at 0, 45, or 90 kilograms (kg) of nitrogen per hectare (ha) or as manure (M) applied at 179 kg ha⁻¹ of N the first spring of each four-year rotation to all. The crop rotations were designed to test varying crop types and water use intensities on crop yield, diseases, insects, weeds, and soil nitrogen (N), phosphorous (P), organic matter (OM), and pH against the traditional crop rotation in the area. The crops are planted and harvested each year in a timely fashion as weather and time permit. Plots were soil sampled each fall after harvest.

RESULTS AND DISCUSSION

Year:

- Year affected N levels at all depths, OM, P, and pH (Tables 1, 2, 3, & 4).

Crop Rotation:

- Rot 1 elevated P and N levels at all depths (Table 5).
- Rot 3 increased OM (Table 5).

Tillage System:

- The no-till system resulted in lower N levels at all depths, higher OM, higher P, and lower pH (Tables 6, 7, & 8).

Fertility:

- The manure treatment produced significantly higher OM, higher P, and higher pH (Tables 4, 8, 9, & 10).
- N fertility treatment affected N levels at all depths, OM, P, and pH across years (Table 4).

Table 1. Year

Year	N				OM	P	pH
	0-15cm	15-30cm	30-45cm	46-60cm			
	kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
1999	13.73	13.73	13.73	13.73			
2000	10.42	9.09	22.10		38.17	15.86	6.71
2001	20.58	7.41	11.68		33.99	13.42	6.45
2002	23.93	14.70	15.76		35.81	17.25	6.48
Average	17.17	11.23	15.82	13.73	35.99	15.51	6.55

Table 2. Year by Rotation

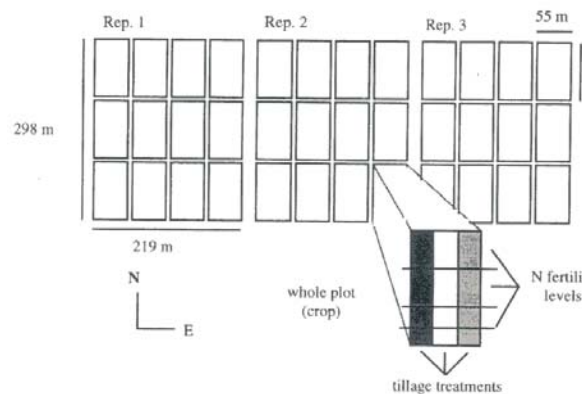
Year	Rotation	N				OM	P	pH
		0-15cm	15-30cm	30-45cm	46-60cm			
		kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
1999	Rot 1	15.69	7.71	13.52	38.48			
	Rot 2	14.42	5.58	7.68	28.30			
	Rot 3	11.09	4.67	8.52	30.92			
2000	Rot 1	8.91	9.38	24.21	36.32	17.10	6.76	
	Rot 2	11.48	7.87	19.29	38.24	15.22	6.68	
	Rot 3	10.32	10.00	23.43	39.15	15.73	6.71	
2001	Rot 1	23.17	9.51	14.50	34.42	14.55	6.44	
	Rot 2	25.43	6.54	9.70	33.10	13.08	6.44	
	Rot 3	13.99	6.43	11.09	34.44	12.79	6.48	
2002	Rot 1	34.92	21.64	22.55	35.67	18.95	6.39	
	Rot 2	21.30	14.07	13.40	35.58	16.38	6.52	
	Rot 3	17.10	9.44	12.21	36.15	16.62	6.52	
Average		17.32	9.40	15.01	32.57	15.60	6.55	
LSD 0.05		4.63	2.74	2.74	19.42	1.37	1.97	0.14

Table 3. Year by Tillage

Year	Tillage ¹	N				OM	P	pH
		0-15cm	15-30cm	30-45cm	46-60cm			
		kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
1999	M	15.34	7.24	13.59	40.54			
	N	13.11	4.72	6.66	16.39			
	T	12.75	6.00	9.53	40.77			
2000	M	10.65	10.01	23.39	37.55	15.35	6.72	
	N	11.22	8.20	15.90	39.83	16.48	6.60	
	T	9.39	9.04	27.03	37.15	15.74	6.81	
2001	M	22.43	8.25	14.29	33.67	13.32	6.47	
	N	19.76	6.59	7.36	35.44	15.28	6.37	
	T	19.56	7.39	13.37	32.86	11.67	6.53	
2002	M	26.99	17.35	20.04	35.10	16.53	6.50	
	N	17.99	9.36	8.50	38.11	19.44	6.43	
	T	26.82	17.39	18.76	34.23	15.79	6.50	
Average		17.17	9.29	14.87	32.57	15.51	6.55	
LSD 0.05		4.63	2.74	2.74	19.42	1.37	1.97	0.14

¹ M=Minimum, N=No-till, T=Conventional

Figure 1. Main plot layout.



RESULTS AND DISCUSSION

Table 4. Year by Fertility

Year	Fertility ¹	N				OM	P	pH
		0-15cm	15-30cm	30-45cm	46-60cm			
		kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
1999	0	8.30	3.64	5.62	12.89			
	45	13.48	5.18	8.78	26.65			
	90	17.45	9.37	16.97	69.62			
	M	15.71	5.74	8.22	21.11			
2000	0	8.86	6.37	14.84	36.71	10.68	6.72	
	45	10.31	9.44	23.06	38.21	11.08	6.65	
	90	10.83	11.40	29.18	37.73	8.42	6.27	
	M	11.67	9.14	21.33	40.05	33.24	7.21	
2001	0	14.84	4.71	6.87	32.57	8.50	6.46	
	45	20.80	6.98	9.34	34.20	7.25	6.33	
	90	26.28	10.97	22.06	33.83	7.53	6.08	
	M	20.41	6.96	8.43	35.35	30.42	6.94	
2002	0	15.51	9.54	7.41	34.64	11.37	6.46	
	45	22.50	15.09	14.32	35.86	13.74	6.47	
	90	35.73	23.03	31.57	35.38	10.46	6.02	
	M	21.99	11.15	9.76	37.38	33.44	6.97	
Average		17.17	9.29	14.86	32.57	15.51	6.55	
LSD 0.05		5.35	3.17	3.17	NA	1.58	2.28	0.16

¹ M=Manure, numbers indicate kg of total N applied

Table 5. Rotation

Rotation	N				OM	P	pH
	0-15cm	15-30cm	30-45cm	46-60cm			
	kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
Rot 1	23.12	12.89	18.20	38.48	35.28	16.81	6.48
Rot 2	19.18	8.87	12.33	28.30	35.32	14.85	6.53
Rot 3	13.63	7.76	13.54	30.92	36.28	14.97	6.55
Average	18.64	9.84	14.69	32.57	35.63	15.55	6.52

Table 6. Tillage

Tillage ¹	N				OM	P	pH
	0-15cm	15-30cm	30-45cm	46-60cm			
	kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
M	20.18	11.15	17.61	40.54	35.13	15.03	6.54
N	16.27	7.35	9.16	16.39	37.49	17.15	6.45
T	18.49	10.47	16.78	40.77	34.39	14.20	6.58
Average	18.32	9.66	14.51	32.57	35.67	15.46	6.52

¹ M=Minimum, N=No-till, T=Conventional



Tillage treatments in the cropping system, (left to right) minimum tillage, no-till, and conventional tillage.

Table 7. Rotation by Tillage

Rotation	Tillage ¹	N				OM	P	pH
		0-15cm	15-30cm	30-45cm	46-60cm			
		kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
Rot 1	M	28.00	16.69	24.48	46.80	34.90	16.61	6.48
	N	17.21	8.41	10.33	17.09	36.89	17.85	6.48
	T	24.14	13.57	19.78	51.56	34.06	15.98	6.48
Rot 2	M	20.06	9.19	12.81	36.15	34.77	14.29	6.56
	N	19.38	8.25	9.85	18.63	37.31	16.79	6.39
	T	18.09	9.16	14.36	30.12	33.85	13.46	6.64
Rot 3	M	13.93	8.46	16.47	38.67	35.63	14.48	6.57
	N	12.62	5.66	7.56	13.45	38.11	16.95	6.48
	T	14.32	9.15	16.57	40.63	35.11	13.50	6.61
Average		18.64	9.84	14.69	32.57	35.63	15.55	6.52
LSD 0.05		4.01	2.38	2.38	16.81	1.18	1.71	0.12

¹ M=Minimum, N=No-till, T=Conventional

Table 8. Rotation by Fertility

Rotation	Fertility ¹	N				OM	P	pH
		0-15cm	15-30cm	30-45cm	46-60cm			
		kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
Rot 1	0	15.62	8.41	10.48	12.14	3.35	11.74	6.48
	45	23.26	13.85	18.08	35.12	3.62	11.53	6.46
	90	31.93	18.42	29.59	78.27	3.54	9.07	5.98
	M	21.66	10.89	14.62	28.39	3.60	34.91	7.00
Rot 2	0	13.95	6.04	7.98	15.69	3.47	9.55	6.45
	45	19.05	8.66	11.02	26.71	3.50	10.97	6.44
	90	21.32	11.41	19.28	49.32	3.40	8.20	6.28
	M	22.46	9.36	11.02	21.48	3.76	31.03	6.95
Rot 3	0	8.89	4.75	6.74	10.83	3.46	9.36	6.61
	45	12.39	6.88	11.54	18.12	3.62	9.63	6.47
	90	21.37	13.91	27.28	81.26	3.65	9.30	6.03
	M	11.88	5.54	8.61	13.45	3.78	31.27	7.09
Average		18.65	9.84	14.69	32.57	3.56	15.55	6.52
LSD 0.05		4.63	2.74	2.74	13.73	0.14	1.97	0.14

¹ M=Manure, numbers indicate kg of total N applied

Table 9. Fertility

Fertility ¹	N				OM	P	pH
	0-15cm	15-30cm	30-45cm	46-60cm			
	kg ha ⁻¹				g kg ⁻¹	mg kg ⁻¹	0-15cm
0	12.60	6.28	8.27	12.89	34.33	10.11	6.52