Long-term Tillage, Straw and N Rate Effects on Quantity and Quality of Organic C and N in a Black Chernozemic Soil

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Background

Soil organic matter is the primary source and temporary sink for plant nutrients, and it maintains soil tilth, aids air and water movement, promotes water retention and reduces soil erosion. In the Prairie Provinces, the cultivation of land over the last 100 years has substantially decreased soil organic C. The amount and quality of organic C in soil can be affected by tillage, crop residue and fertilization. Zero-tillage (ZT or no-till or direct seeding) is becoming very popular in the Prairie Provinces, as it prevents soil erosion and reduces loss of C. Crop residues play an important role in maintaining soil productivity and quality by providing a source of organic matter for soil and nutrients for plants. Information was needed to determine the long-term effects of soil, crop and nutrient management practices on quantity and quality of soil organic matter. The objective of this study was to determine the effect of tillage, straw and N rate on total organic C (TOC) and N (TN), light fraction organic C (LFC) and N (LFN), mineralizable C and N, biomass C, macro organic matter C (MOM-C) and N (MOM-N), pH, extractable P and nitrate-N in a Black Chernozemic soil after 19 years.

Materials and Methods

Location:	Ellerslie, Alberta
Soil Classification (Texture):	Black Chernozem (Loam)
Initiation of Experiment:	Autumn 1979
Tillage:	ZT - no tillage, direct seeding CT – Two (one in autumn and one in spring)
Straw:	Straw-On (chopped straw was returned to plots) Straw-Off (all straw was removed from plots)
N Fertilizer (Urea):	0, 50 and 100 kg N ha^{-1}
Data Collected:	Crop (Seed and Straw Yield Yearly) Soil in Autumn 1998 (TOC, TN, LFC, LFN, Mineralizable C and N, Biomass C, Macro Organic Matter C and N, Soil pH, Extractable P and Nitrate-N)

Results

Total Organic C and N (Tables 1 and 2)

- ZT tended to had greater mass of TOC and TN in the top 0-15 cm soil than CT.
- Returning straw to soil tended to increase TOC and TN in soil compared to straw removal.
- Mass of TOC and TN in soil tended to be more in the N-fertilized plots than the zero-N control.

Light Fraction Organic C and N (Table 3)

- LFC tended to increase with straw retention and rate of applied N, and tended to be greater under CT than ZT.
- LFN in soil tended to increase with elimination of tillage, retaining straw and increasing rate of applied N.

Mineralizable C and N (Table 4)

- Mineralizable C and N mass in soil was only slightly greater under ZT than under CT.
- Straw retention tended to increase the C and N supplying capacity of soil compared to when straw was removed.
- Application of N fertilizer tended to increase mineralizable C and N in soil over the zero-N control.

Biomass C, and Macro-Organic Matter C and N (Table 5)

- Biomass C in soil was slightly greater under ZT than CT, but MOM-C was slightly greater under CT than ZT.
- Straw-on had greater MOM-C and MOM-N, and tended to had greater biomass-C compared to straw-off.
- MOM-C and MOM-N increased but biomass-C decreased with application of N.

Soil pH, Extractable P and Nitrate-N (Table 6)

- There was some depression in soil pH in the surface 0-7.5 cm layer from N fertilizer application.
- ZT tended to have lower soil pH than CT in the 0-7.5 cm depth, but CT tended to have lower pH than ZT in the 7.5-15 cm depth.
- ZT and straw retention had greater amounts of extractable P in soil compared to CT and straw removal, respectively.
- Extractable P in soil decreased with increasing rate of applied N (most likely from increased crop yield with N application and subsequent P uptake).
- The nitrate-N in soil increased with N rate, but tillage and straw management had little effect on soil nitrate-N.

Conclusions

- Elimination of tillage, straw retention and proper fertilization tended to improve quantity and quality of organic matter in soil, and C and N supplying capacity of soil.
- Unlike the Gray Luvisol soil at Breton, Alberta, the effects of soil, crop and N fertilizer management practices on soil quality improvement were not statistically significant in most cases in the Black Chernozemic soil at Ellerslie, Alberta. This was

due to much higher inherent organic matter content in this soil compared to Breton soil.

Table 1. Effect of long-term tillage, straw management and N rate on total organic C in soil at Ellerslie, Alberta, Canada (Black Chernozemic soil, Experiment was established in the autumn of 1979)

Parameter	TOC mass (Mg C ha^{-1}) in soil layers (cm)		
	0-7.5	7.5-15	15-30
Tillage Effect			
ZT	49.29	45.72	56.58
CT	48.36	44.70	52.22
Straw Effect			
NS	47.04	43.57	52.10
S	49.01	45.22	52.40
N rate Effect			
0 kg N ha^{-1}	49.01	45.22	52.40
50 kg N ha^{-1}	49.60	45.97	58.11
100 kg N ha^{-1}	49.64	46.10	55.00

Table 2. Effect of long-term tillage, straw management and N rate on total N in soil at Ellerslie, Alberta, Canada (Black Chernozemic soil, Experiment was established in the autumn of 1979)

Parameter	TN mass (kg N ha^{-1}) in soil layers (cm)		
	0-7.5	7.5-15	15-30
Tillage Effect			
ZT	4348	4030	5048
CT	4288	4000	4740
Straw Effect			
NS	4155	3875	4770
S	4325	3990	4710
N rate Effect			
0 kg N ha^{-1}	4325	3990	4710
50 kg N ha^{-1}	4385	4105	5160
100 kg N ha^{-1}	4405	4090	4935

Table 3. Effect of long-term tillage, straw management and N rate on light fraction organic C and N in soil at Ellerslie, Alberta, Canada (Black Chernozemic soil, Experiment was established in the autumn of 1979)

Parameter	LFC (kg C ha^{-1}) in soil layers (cm)		LFN (kg N ha^{-1}) in soil layers (cm)	
	0-7.5	7.5-15	0-7.5	7.5-15
Tillage Effect				
ZT	700	376	41.1	17.6
CT	740	434	43.6	22.4
Straw Effect				
NS	552	396	31.5	18.6
S	700	385	40.5	18.8
N rate Effect				
0 kg N ha^{-1}	700	385	40.5	18.8
50 kg N ha^{-1}	747	390	44.0	19.9
100 kg N ha^{-1}	880	450	53.4	22.5

Table 4. Effect of long-term tillage, straw management and N rate on mineralizable C and N in soil at Ellerslie, Alberta, Canada (Black Chernozemic soil, Experiment was established in the autumn of 1979)

Parameter	Mineralisable C mass (kg C ha^{-1}) in soil layers (cm)		Mineralisable N mass (kg N ha^{-1}) in soil layers (cm)	
	0-7.5	7.5-15	0-7.5	7.5-15
Tillage Effect				
ZT	356	232	40.8	32.0
CT	343	237	37.1	31.5
Straw Effect				
NS	306	217	31.3	27.4
S	340	226	37.2	30.5
N rate Effect				
0 kg N ha^{-1}	340	226	37.2	30.5
50 kg N ha^{-1}	370	276	42.6	38.2
100 kg N ha^{-1}	382	219	44.6	31.0

Table 5. Effect of long-term tillage, straw management and N rate on biomass C, and macro organic C and N in soil at Ellerslie, Alberta, Canada (Black Chernozemic soil, Experiment was established in the autumn of 1979)

Parameter	Biomass C mass (kg C ha^{-1}) in soil layers (cm)		MOM-C mass (kg C ha^{-1}) in soil layers (cm)		MOM-N mass (kg N ha^{-1}) in soil layers (cm)	
	0-7.5	7.5-15	0-7.5	7.5-15	0-7.5	7.5-15
Tillage Effect						
ZT	748	653	647	92	29.8	3.7
CT	739	636	662	94	28.1	3.4
Straw Effect						
NS	728	612	460	108	19.0	2.6
S	776	614	603	92	25.6	3.9
N Rate Effect						
0 kg N ha^{-1}	776	614	603	92	25.6	3.9
50 kg N ha^{-1}	754	682	748	86	33.4	3.2
100 kg N ha^{-1}	715	671	807	88	37.8	4.4

Table 6. Effect of long-term tillage, straw management and N rate on soil pH, extractable P and nitrate-N at Ellerslie, Alberta, Canada (Black Chernozemic soil, Experiment was established in the autumn of 1979)

	Soil pH in layers (cm)		Extractable P (kg P ha^{-1}) in soil layers (cm)		Nitrate-N (kg N ha^{-1}) in soil layers (cm)	
Parameter	0-7.5	7.5-15	0-7.5	7.5-15	0-7.5	7.5-15
Tillage Effect						
ZT	5.76	6.05	45.1	10.0	6.5	2.6
CT	5.86	5.94	35.9	10.9	5.2	4.0
Straw Effect						
NS	5.96	6.04	51.1	10.8	3.4	2.5
S	5.98	6.01	55.2	14.7	4.0	2.4
N Rate Effect						
0 kg N ha^{-1}	5.98	6.01	55.2	14.7	4.0	2.4
50 kg N ha^{-1}	5.74	5.96	28.0	7.7	5.2	4.2
100 kg N ha^{-1}	5.58	5.96	27.9	8.6	10.8	4.2