
Long-term Tillage, Straw and N Rate Effects on Quantity and Quality of Organic C and N in a Gray Luvisol 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 of Canada, 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 Gray Luvisolic soil after 19 years.

Materials and Methods

<i>Location:</i>	Breton, Alberta
<i>Soil Classification (Texture):</i>	Gray Luvisol (Loam)
<i>Initiation of Experiment:</i>	Autumn 1979
<i>Tillage:</i>	ZT - no tillage, direct seeding CT – Two (one in autumn and one in spring)
<i>Straw:</i>	Straw-On (chopped straw was returned to plots) Straw-Off (all straw was removed from plots)
<i>N Fertilizer (Urea):</i>	0, 50 and 100 kg N ha ⁻¹
<i>Data Collected:</i>	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 had greater mass of TOC and TN in the top 0-15 cm soil than CT.
- ❖ Returning straw to soil increased TOC and TN in soil compared to straw removal.
- ❖ The TOC and TN in soil increased with increasing rate of applied N. This was due to increase in crop yield and root mass from N application.
- ❖ Returning straw under ZT with applied N gave the maximum mass of TOC and TN in soil.

Light Fraction Organic C and N (Table 3)

- ❖ Both LFC and LFN in soil increased with elimination of tillage, retaining straw and increasing rate of N.
- ❖ Mass of LFC as a percentage of TOC ranged between 2 to 2.5% and LFN as a percentage of TN ranged between 0.8 to 1.2%.

Mineralizable C and N (Table 4)

- ❖ Mineralizable C and N mass in soil was much greater under ZT than under CT.
- ❖ Straw retention increased the C and N supplying capacity of soil compared to when straw was removed.
- ❖ Application of N fertilizer increased mineralizable C and N in soil over zero-N control.
- ❖ This suggested that management practices of ZT, straw retention and N fertilizer can improve the capacity of soil to supply C and N for soil micro-organisms and plants.

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

- ❖ Biomass C in soil tended to be greater under CT than ZT.
- ❖ MOM-C was greater under ZT than CT.
- ❖ Biomass-C tended to decrease and MOM-C increased with N fertilization.

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, but tillage and straw treatments had little effect on soil pH.
- ❖ 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).
- ❖ There were low levels of nitrate-N in soil in all treatments. Nitrate-N in soil increased with N rate, but tillage and straw management had no effect on soil nitrate-N.

Conclusions

- ❖ Elimination of tillage, straw retention and proper fertilization improved quantity and quality of organic matter in soil, and C and N supplying capacity of soil.

- ❖ The long-term implication of the findings is that these management practices are important to improve soil quality for sustaining crop production and better for the environment.

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

Parameter	TOC mass (Mg C ha ⁻¹) in soil depth (cm)				
	0-7.5	7.5-15	15-30	30-40	0-40
Tillage Effect					
ZT	18.53	14.26	15.20	6.99	54.98
CT	16.31	10.85	13.68	7.39	48.23
Straw Effect					
NS	14.67	9.68	12.67	7.11	44.13
S	16.27	11.90	12.56	6.98	47.71
N rate Effect					
0 kg N ha ⁻¹	16.27	11.90	12.56	6.98	47.71
50 kg N ha ⁻¹	19.00	13.38	16.32	7.48	56.18
100 kg N ha ⁻¹	19.73	15.26	16.19	7.04	58.22

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

Parameter	TN mass (kg N ha ⁻¹) in soil depth (cm)				
	0-7.5	7.5-15	15-30	30-40	0-40
Tillage Effect					
ZT	1775	1405	1763	885	5828
CT	1595	1158	1588	757	5098
Straw Effect					
NS	1440	1040	1385	818	4683
S	1585	1215	1580	838	5218
N rate Effect					
0 kg N ha ⁻¹	1585	1215	1580	841	5218
50 kg N ha ⁻¹	1815	1350	1835	861	5861
100 kg N ha ⁻¹	1900	1520	1900	788	6108

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

Parameter	LFC (kg C ha ⁻¹) in soil depth (cm)			LFN (kg N ha ⁻¹) in soil depth (cm)		
	0-7.5	7.5-15	0-15	0-7.5	7.5-15	0-15
Tillage Effect						
ZT	434	196	630	18.6	5.9	24.5
CT	378	153	531	16.8	4.9	21.7
Straw Effect						
NS	294	89	383	11.6	3.0	14.6
S	367	200	567	14.9	5.8	20.7
N rate Effect						
0 kg N ha ⁻¹	367	200	567	14.9	5.8	20.7
50 kg N ha ⁻¹	468	216	684	20.2	6.7	26.9
100 kg N ha ⁻¹	489	194	683	23.0	6.0	29.0

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

Parameter	Mineralizable C (kg C ha ⁻¹) in soil depth (cm)			Mineralizable N (kg N ha ⁻¹) in soil depth (cm)		
	0-7.5	7.5-15	0-15	0-7.5	7.5-15	0-15
Tillage Effect						
ZT	254	119	373	23.0	9.8	32.8
CT	213	119	332	15.2	5.8	21.0
Straw Effect						
NS	182	98	280	14.7	5.3	20.0
S	211	104	315	18.4	6.0	24.4
N rate Effect						
0 kg N ha ⁻¹	211	104	315	18.4	6.0	24.4
50 kg N ha ⁻¹	261	159	420	21.5	9.2	30.7
100 kg N ha ⁻¹	280	114	394	21.8	11.3	33.1

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

Parameter	Biomass C (kg C ha ⁻¹) in soil depth (cm)			MOM-C (kg C ha ⁻¹) in soil depth (cm)			MOM-N mass (kg N ha ⁻¹) in soil depth (cm)
	0-7.5	7.5-15	0-15	0-7.5	7.5-15	0-15	0-7.5
Tillage Effect							
ZT	517	451	968	370	48	418	15
CT	561	468	1029	428	40	468	15
Straw Effect							
NS	494	436	930	220	15	235	15
S	562	468	1030	330	50	380	15
N Rate Effect							
0 kg N ha ⁻¹	562	468	1030	330	50	380	15
50 kg N ha ⁻¹	560	428	988	535	55	590	20
100 kg N ha ⁻¹	540	504	1044	510	85	595	20

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

Parameter	pH in soil depth (cm)		Extractable P (kg P ha ⁻¹) in soil depth (cm)			Nitrate-N (kg N ha ⁻¹) in soil depth (cm)		
	0-7.5	7.5-15	0-7.5	7.5-15	0-15	0-7.5	7.5-15	0-15
Tillage Effect								
ZT	6.42	6.68	52.1	13.2	65.3	1.2	0.5	1.7
CT	6.54	6.67	38.3	11.4	49.7	1.5	0.7	2.2
Straw Effect								
NS	6.68	6.76	50.4	12.0	62.4	0.7	0.1	0.8
S	6.63	6.78	59.8	15.6	75.4	0.8	0.3	1.0
N Rate Effect								
0 kg N ha ⁻¹	6.63	6.78	59.8	15.6	75.4	0.8	0.2	1.0
50 kg N ha ⁻¹	6.40	6.57	34.5	10.0	44.5	1.8	0.8	2.6
100 kg N ha ⁻¹	6.20	6.58	36.0	11.5	47.5	2.2	1.3	3.5