# 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

| | |
|---|---|
| *Location:* | Breton, Alberta |
| *Soil Classification (Texture):* | Gray Luvisol (Loam) |
| *Initiation of Experiment:* | Autumn 1979 |
| *Tillage:* | ZT - no tillage, direct seeding<br>CT – Two (one in autumn and one in spring) |
| *Straw:* | Straw-On (chopped straw was returned to plots)<br>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)<br>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)

| | TOC mass (Mg C $ha^{-1}$) in soil depth (cm) | | | | |
|---|---|---|---|---|---|
| Parameter | 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)

| | TN mass (kg N $ha^{-1}$) in soil depth (cm) | | | | |
|---|---|---|---|---|---|
| Parameter | 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)

| | LFC (kg C $ha^{-1}$) in soil depth (cm) | | | LFN (kg N $ha^{-1}$) in soil depth (cm) | | |
|---|---|---|---|---|---|---|
| Parameter | 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)

| | Mineralizable C (kg C $ha^{-1}$) in soil depth (cm) | | | Mineralizable N (kg N $ha^{-1}$) in soil depth (cm) | | |
|---|---|---|---|---|---|---|
| Parameter | 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)

| | 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) |
|---|---|---|---|---|---|---|---|
| Parameter | 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)

| | 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) | | |
|---|---|---|---|---|---|---|---|---|
| Parameter | 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 |