INFLUENCE OF LONG-TERM N FERTILIZATION ON QUANTIN AND QUALITY OF ORGANIC C STORED IN A GRASSLAND SOIL

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INTRODUCTION

Sustainability of agriculture production is linked to soil quality which is a function of organic carbon (OC). Soils in the Canadian Prairies have shown substantial decrease in OC during the past 100 years since the grassland was brought under cultivation (McGill et al., 1988). The loss of C from soil may increase concentration of CO, in the atmosphere and the potential for global warming (Wang et ***al., 1976).***

Soil and crop management practices, which increase the input of C to soil and/or prevent loss of C from soil, can build OC in soil (Campbell et al., 1991; Nyborg et ***al., 1995).*** The loss of C from soil can be avoided by eliminating tillage, while input of C to soil is related to the amount of crop residues returned to the soil. The land use change from crop land to perennial grass cover can increase the SOC levels by sequestering more atmospheric CO_2 back into the soil (Gebhart et ***al., 1994).***

In Alberta and other Prairie Provinces, forage grasses play a major role in the production of beef, and are also a component of sustainable agriculture cropping systems. On perennial grasslands, tillage can be avoided but the amount of crop residues is associated with crop yield which in turn is influenced by other management factors. Good forage stands can increase C in soil, and consequently soil can function as a net sink of atmospheric C. Forage grass productivity can be increased considerably with N fertilization on most Prairie soils. The objective of this study was to determine the change in quantity and quality of organic C in a grassland soil receiving ***N*** fertilization for 27 years.

MATERIALS AND METHODS

A field experiment was conducted from 1968 to 1994 on smooth bromegrass (Bromus inermis Leyss.) at Crossfield, Alberta. The soil was a thin Black Chernozem with a pH of 7.0 and a loam texture. The mean annual precipitation of the area is about 450 mm. Ammonium nitrate (AN) was applied as surface-broadcast annually in early spring (mid to late April) at 0, 56, 112, 168, 224, and 336 kg N/ha. Each treatment was replicated six times in a randomized complete block design. Bromegrass was harvested for hay every year during growing season from May to

August. Soil samples were taken in the fall of 1994 from the O-5 (Layer 1), 5-10 (Layer 2), 1 O-l 5 (Layer 3) and 15-30 (Layer 4) cm depths. The air-dried ground samples were analyzed for total organic C (TOC) and light fraction organic C (LFC).

RESULTS AND DISCUSSION

The concentration of TOC (Leco method) in the O-5 cm soil layer increased markedly with N fertilization (i.e., 47.87, 68.61 and 84.46 g C/kg in the 0, 112 and 224 kg n?ha treatments) (Table 1). The TOC in soil also increased in the 5-10, 1 O-l 5 and 15-30 cm layers but to a lesser extent. The mass of TOC in soil increased with N fertilization in all four layers (Table 2). The mass of TOC in soil was increased by 16.56 Mg/ha (i.e., 10.95 kg C/kg N/ha/yr) with 56 kg N/ha and by 24.00 Mg/ha (i.e., 7.94 kg C/kg N/ha/yr) with the 112 kg N/ha as compared to the zero-N treatment (Table 3). The DMY of bromegrass increased substantially with N fertilization (Table 4). The hay was removed from the experimental area and the estimated amounts of TOC removed in hay were 18.02 and 14.90 kg C/kg N/ha/yr, respectively, from 56 and 112 kg N/ha rates.

The application of N fertilizer benefited both forage yield and soil organic C. This emphasizes the importance of nutrient management in improving forage production as well as soil quality. The increase in soil C storage appears to have arisen from root growth. Our other research (Malhi et al., 1996) has shown marked increase in root mass of cereals and perennial forages with N fertilization. The much greater increase in the concentration of TOC in the O-5 cm layer than the subsoil layers was most likely due to deposition of older leaves and grass stubble on the soil surface and sloughing of dead roots in the soil below near the surface. There was a close quadratic relationship between TOC in soil and the rate of N applied (R^2 = 0.92). The bulk density of soil decreased with increasing N rate, particularly in the O-5 cm layer (data not shown). This decrease in bulk density due to N fertilization was associated with increasing concentration of TOC in soil.

There was a large increase in concentration and mass of LFC in soil with N fertilization (Tables 5 and 6). The majority of LFC was found in the first layer (Tables 7 and 8). In this layer, the stored C in soil was mainly as LFC, especially at high N rates (Table 9). The light fraction organic matter is considered to be actively decomposing crop residues with rapid turnover and low specific density and thus is important for nutrient cycling. The fate of this LFC is not known when the land use changes from grassland to cultivated cropland and further research would be needed on this topic.

CONCLUSIONS

Long-term annual additions of N fertilizer to bromegrass resulted in substantial increases in OC in soil.

The results also showed marked changes in the quality of OC in soil due to N fertilization.

The implication is that grasslands can be managed by N fertilizer additions to sequester more C from the atmosphere and store in the soil. This may lessen the increase in atmospheric CO_2 concentration, and at the same time improving nutrient release potential and tilth of soil.

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REFERENCES

Campbell, C.A., V.O. Biederbeck, R.P. Zentner, and G.P. Lafond. 1991. Effect of crop rotations and cultural practices on soil organic matter, microbial biomass and respiration in a thin Black Chernozem. Can. J. Sci. 71: 363-376.

Ellert, B.H., and J.R. Tettany. 1995. Calculation of organic matter and nutrients stored in soils under contrasting management regimes. Can. J. Soil Sci. 75: 529-538.

Gebhart, D.L., H.B. Johnson, H.S. Mayeux, and H.W. Polley. 1994. The CRP increases in soil organic carbon. J. Soil Water Cons. 49: 488492.

Malhi, S.S., M. Nyborg, and K. Heier. 1996. influence of fertilization, soil type and crop species on root mass. Pages 268-272 *in* Proc. Alberta Soil Science Workshop, 20-22 February, 1996, Edmonton, Alberta.

McGill, W.B., J.F. Dormaar, and E. Reinl-Dwyer. 1988. New perspectives on soil organic matter quality, quantity and dynamics on the Canadian Prairies. Canadian Society of Soil Science and Canadian Society of Extension Joint Symposium, Land Degradation: Assessment and Insight into a Western Canadian Problem. August 23, 1988, Calgary, Alberta.

Nyborg, **M., E.D. Solberg, S.S. Malhi, and R.C. Izaurralde.** 1995. Fertilizer N, crop residue, and tillage alter soil C and N content in a decade. Adv. Soil Sci. 93-99.

Table 1. Concentration of total organic C (TOC) in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Rate of N (kg N/ha)	Concentration of TOC (g/kg) in soil layers (cm)			
	0-5	5-10	IO-15	15-30
0	47.87	40.14	31.09	18.41
56	60.22	46.54	38.92	22.80
112	68.61	46.05	41.09	25.31
168	79.69	46.39	41.51	24.74
224	84.46	47.62	43.24	30.75
336	87.56	46.55	40.21	24.27

Table 2. Mass† of total organic C (TOC) in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Rate of N (kg N/ha)	Mass of TOC (Mglha) in soil layers			
	Layer 1	Layer 2	Layer 3	Layer 4
0	21.25	18.06	15.28	33.53
56	25.76	20.37	17.05	41.50
112	28.31	20.19	17.56	46.06
168	31.33	20.73	18.11	45.03
224	32.45	21.25	20.24	55.97
336	33.18	20.31	17.05	44.18

†Equivalent-soil mass basis (B.H. Ellert and H.H. Janzen).

Table 3. Total amount of fertilizer N applied and increase in total organic C (TOC) stored in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Total amount of fertilizer N applied from 1968 to 1994 (kg N/ha)	Increase in TOC (Mg/ha) stored in soil layers			
	Top layer	Top 2 layers	Top 3 layers	Top 4 layers
1512	4.51	6.82	8.59	16.56
3024	7.06	9.19	11.47	24.00
4536	10.08	12.75	15.58	27.08
6048	11.20	14.39	19.35	41.79
9072	11.93	14.18	15.95	26.60

Table 4. Bromgrass hay yield (averaged over 19 yr from 1968 to 1986) and estimated mass of C removed in hay

Rate of N (kg N/ha)	Hay yield (Mg/ha)	Mass of C removed in hay (Mglha)	kg of C removed in hay/kg N/ha/yr
0	1.17	9.11	
56	3.63	28.28	18.02
112	5.24	40.82	14.90
168	5.41	42.14	10.35
224	5.69	44.33	8.28
336	5.45	42.46	5.22

Table 5. Concentration of light fraction organic C (LFC) in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Rate of N (kg N/ha)	Concentration of LFC (g/kg) in soil layers (cm)			
	o-5	5-10	10-15	15-30
0	4.03	1.63	1.03	0.41
56	10.63	3.26	2.53	0.95
112	21.97	3.58	2.64	1.21
168	35.60	5.45	2.65	0.92
224	43.19	6.67	3.26	1.22
336	40.25	7.33	3.75	0.89

Table 6. Mass of light fraction organic C (LFC) in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Rate of N (kg N/ha)	Mass of LFC (Mglha) in soil layers			
	Layer 1	Layer 2	Layer 3	Layer 4
0	1.74	0.38	0.50	0.74
56	4.13	0.77	1.01	1.64
112	7.83	0.84	1.12	2.21
168	11.87	1.28	1.02	1.68
224	13.87	1.57	1.28	2.22
336	13.10	1.72	1.27	1.62

Table 7. Total amount fertilizer N applied and increase in light fraction organic C (LFC) stored in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Total amount of fertilizer N applied from 1968 to 1994 (kg N/ha)	Increase in LFC (Mg/ha) stored in soil layers			
	Top layer	Top 2 layers	Top 3 layers	Top 4 layers
1512	2.39	2.78	3.29	4.19
3024	6.09	6.55	7.17	8.64
4536	10.13	11.03	11.55	12.49
6048	12.13	13.32	14.10	15.58
9072	11.36	12.70	13.41	14.29

Table 8. Ratio of light fraction organic C (LFC) to total organic C (TOC) in soil after 27 years of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

Rate of N (kg N/ha)	LFC as a percentage of TOC in soil layers			
	Layer 1	Layer 2	Layer 3	Layer 4
0	8.2	2.1	3.3	2.2
56	15.9	3.8	5.9	4.0
112	27.0	4.2	6.4	4.8
168	37.5	6.1	5.6	3.7
224	42.8	7.4	6.3	4.0
336	39.8	8.5	7.4	3.7

Table 9. Ratio of light fraction organic C (LFC) to total organic C (TOC) stored in soil from annual applications of ammonium nitrate for 27 years to bromegrass grown as hay at Crossfield, Alberta

Rate of N (kg N/ha)	Stored LFC as a percentage of stored TOC in soil layers			
	Layer 1	Layer 2	Layer 3	Layer 4
56	53.0	16.9	28.8	11.3
112	86.3	21.6	27.2	11.7
168	100.5	33.7	18.4	8.2
224	108.3	37.3	15.5	6.6
336	95.2	59.6	43.5	8.3