Effect of Repeated Additions of Liquid Swine Manure and Solid Cattle Manure on Soil Organic Carbon

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Abstract

The agronomic effects of liquid swine manure and solid cattle manure application on soil nitrogen (N) and crop yield in Saskatchewan soils has been well documented (Mooleki et al. 2002b, Mooleki et al. 2004). However, the effect of manure addition on soil organic carbon and light fraction carbon has not been explored in detail. The objective of this study was to assess the differences in total soil organic carbon (SOC) and light fraction organic carbon (LFOC) forms and amounts as related to the field application of different rates of liquid swine manure and solid cattle manure at four sites (Dixon, Melfort, Plenty and Riverhurst) located in Saskatchewan. Application of solid cattle manure directly adds to the soil organic matter (OM) and increases both soil organic carbon (SOC) and light fraction carbon. Injection of liquid swine manure adds OM indirectly by way of stimulating increased plant growth and, as such, the effect of liquid swine manure on SOC and LFOC is not as large and the effects were more variable than for solid cattle manure. After five to eight years of swine manure applications only one of the four sites (Regina Association at Plenty, SK.) showed a significant ($p \leq 0.10$) increase in SOC (0-15 cm depth) with manure additions. Cattle manure addition at the Dixon site produced the largest increases in LFOC, reflecting large amounts of organic inputs as straw and solids added directly in this manure application.

Introduction

Over the past several years, the expansion of the swine and cattle livestock industries in Saskatchewan has seen a correspondingly similar increase in the amount of liquid swine manure and solid cattle manure that needs to be land-applied in an agronomically sound and environmentally safe manner. There has been interest in determining what effect different management practices such as conversion from conventional till to no till or forage seed down have on soil organic carbon in prairie soils (Malhi et al., 2003). This study extends these practices to include land application of animal manure.

Light fraction organic matter consists of recent inputs of crop residues and the remains of organisms that may be in different stages of decomposition in the soil. This pool of organic matter is important as it serves as substrate material for microorganisms and is a precursor to stable humus (Gregorich et al., 1994). Bremer et al. (1995) reported that LFOC is an important indicator of management induced effects on soil organic carbon. Liquid swine manure and solid cattle manure have been documented as a valuable source of plant nutrients such as nitrogen

(Mooleki et al., 2004). However, the effects of the application of liquid swine manure and solid cattle manure on SOC and LFOC have not been explored in detail on Saskatchewan soils. The objective of this study was to assess the differences in total SOC and LFOC forms and amounts as related to the field application of different rates of liquid swine manure and solid cattle manure at four sites located in Saskatchewan.

Materials and Methods

The experimental design for the field experiment was a random complete block design with manure applied at different rates, sequences and methods of application and are located at Dixon, Melfort, Plenty and Riverhurst, SK. Liquid swine effluent has been applied for 4 (Melfort) 5 (Plenty and Riverhurst) and 7 years (Dixon site) to date (Table 1). The solid cattle manure study has been in place for 7 years at the Dixon site. The low rate of liquid swine manure addition (37,000 L ha^{-1}) in Table 1 is considered an agronomic rate, representing about 100 kg N ha^{-1}, while the high rate (148,000 L ha^{-1}) is considered an excessive rate (400 kg N ha^{-1}) when added every year.

The Dixon site is a Cudworth Association loam textured Black Chernozem soil on silty lacustrine parent material. The Melfort site is a Kamsack Association loam textured Gray-Black Chernozem soil. The Plenty site is a Regina Association clay-heavy clay textured Dark Brown Chernozem soil on clay lacustrine parent material. The Riverhurst irrigated site is a Birsay Association sandy-loam textured Brown Chernozem soil on sandy glaciolacustrine parent material.

Liquid swine manure and solid cattle manure were collected from intensive livestock operations located near the study sites. The manure was applied at rates listed in Table 1 in the fall of each year of the study. A low disturbance injector using coulter type openers (Prairie Agriculture Machinery Institute manure injection truck) was used to inject effluent 10-13 cm deep into the plots at each of the four sites. Solid cattle manure was obtained from a local feedlot operation and was broadcast on the cattle manure plots and rototilled to incorporate the manure into the soil.

Table 1: Application rates of manure and fertilizer at four Saskatchewan sites.

	------------------------------Site------------------------------				
Treatment	**Dixon Hog**	**Dixon Cattle**	**Melfort**	**Plenty**	**Riverhurst**
Control	Disturbed	Check	Check	Check	Check
Low	37000 L ha^{-1}	7.6 T ha^{-1}	37000 L ha^{-1}	37000 L ha^{-1}	37000 L ha^{-1}
Medium	74000 L ha^{-1}	15.2 T ha^{-1}	67000 L ha^{-1}	74000 L ha^{-1}	74000 L ha^{-1}
High	148000 L ha^{-1}	30.4T ha^{-1}	NA	NA	NA
B & I Low†	37000 L ha^{-1}	NA‡	NA	NA	NA
Urea	112 kg N ha^{-1}	112 kg N ha^{-1}	80 kg N ha^{-1}	80 kg N ha^{-1}	80 kg N ha^{-1}

†Broadcast and Incorporated at low rate.
‡Treatment not applied at that particular site.

Soil samples were obtained from the treatment plots at all four locations in the early spring of 2003. Except for the Dixon site, the other three sites had liquid swine manure applied in the fall of 2002. The soil samples from Dixon were obtained approximately 2 weeks prior to liquid manure and urea fertilizer application in the spring of 2003. Soil samples were taken using polyvinylchloride (PVC) pipes measuring 15 cm in height and 10 cm in diameter. Four PVC cores per plot were inserted at random into the soil and then removed by excavation. Samples were air dried, ground to < 2mm and stored at room temperature.

Samples for SOC determination were ground to pass a 100 mesh sieve using a ball mill grinder and measured by the dry combustion method using the LECO CR-12 Carbon Analyzer set at 840 ^{O}C (Wang and Anderson, 1998). Samples for LFOC determination were obtained by density separation using Sodium Iodide (Gregorich and Ellert,1993). The light fraction was collected, dried at 45 ^{O}C for 72 hours and then analyzed using the LECO CR-12 Carbon Analyzer set at 840 ^{O}C.

Results and Discussion

Of the four sites, the Melfort site has the greatest amount of SOC, but a lower amount of LFOC compared to the other three sites (Figure 1). The Plenty site has the lowest overall amount of SOC in the 0-15 cm layer. The Melfort site is located in the Gray-Black soil climatic zone and is expected to have more SOC reserves due to the greater amount of moisture received versus the Plenty site, which is located in the Dark Brown soil zone.

Application of liquid swine manure at the Dixon site significantly increased grain and straw production over the first four years of the study (Mooleki et al., 2002a), however, SOC values were not significantly different between the control and manure treated plots (Figure 1). This could reflect an enhancement of microbial activity by the added nutrients in the swine manure (Charles, 1999; deFrietas et al., 2003) that resulted in more rapid decomposition of plant biomass organic matter additions to the soil. Other researchers (Eiland, 1980) have reported instances of no increase in soil organic matter or even decreases associated with the application of liquid effluents.

The application of liquid swine manure at the Dixon site had no significant impact at $\alpha = 0.10$ on SOC levels in the 0-15 cm depth. Swine manure added each year at the low (agronomic rate) increased SOC levels from 48.6 Mg ha^{-1} in the control plot to 50.7 Mg ha^{-1}, similar to that in the urea plots (50.8 Mg ha^{-1}) (Figure 1).

Soil organic carbon levels for the solid cattle manure treatments at Dixon showed no significant differences at the $\alpha = 0.10$ level amongst the treatments. The medium cattle manure treatment showed the greatest amount of SOC at 55.3 Mg ha^{-1} versus 53.5 Mg ha^{-1} for the control treatment (Figure 1). Solid cattle manure was not applied for the 2003 crop year until May 2003, several weeks after soil samples were taken. The cattle manure study is located on the same field site as the swine manure study and the flax crop was thus subject to the same drought conditions that affected the entire field site in 2002. The short duration of manure application (7 years) and relatively low rates of addition may explain the lack of a significant impact of cattle manure on total SOC.

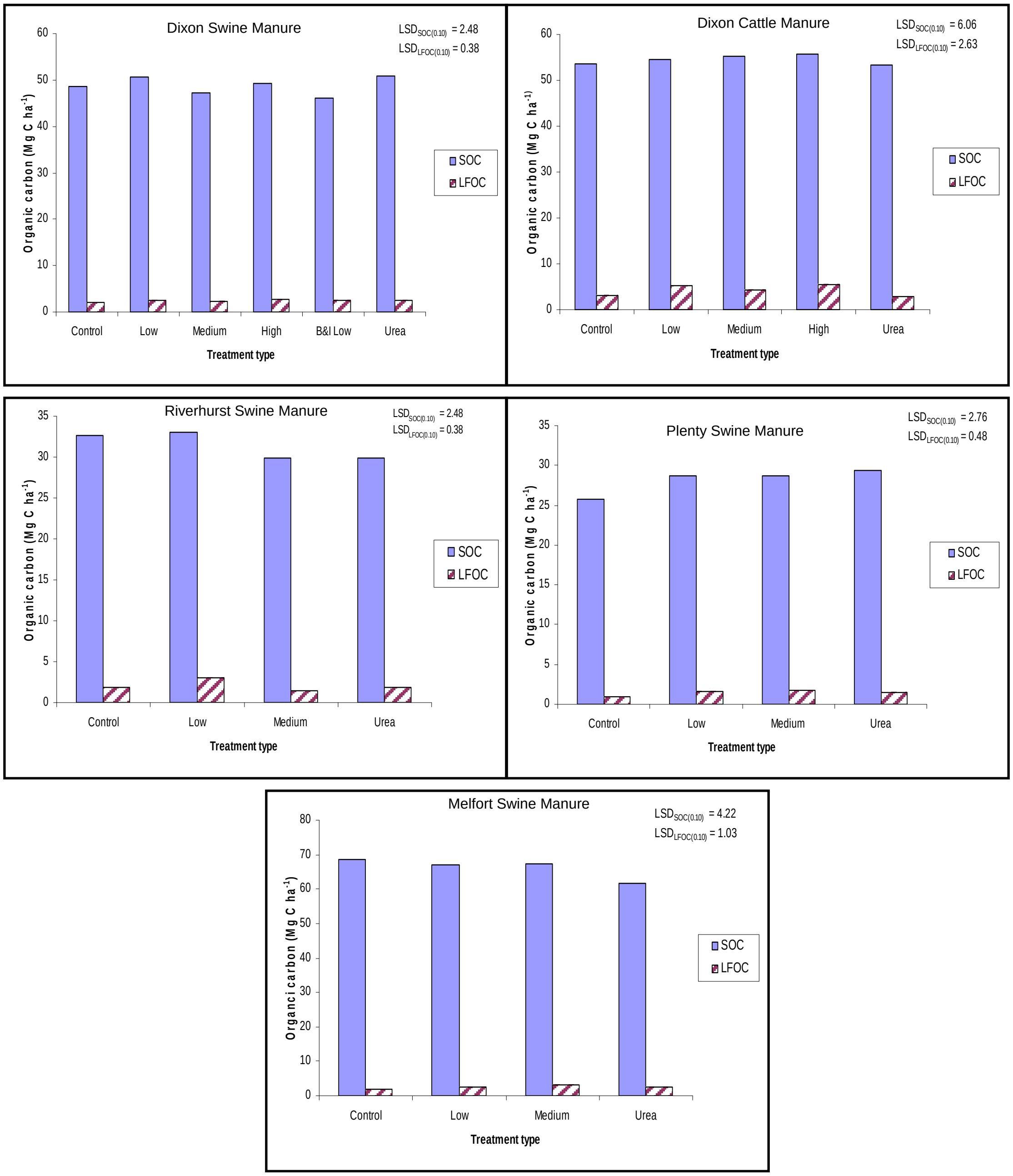

Figure 1: Soil organic carbon and light fraction carbon in the 0-15 cm depth at the liquid swine manure and solid cattle manure (Dixon) trials at four Saskatchewan sites.

Light fraction organic carbon levels in the Dixon liquid swine manure plots were not significantly different among the six manure and urea treatments. The mean LFOC levels increased from 2.10 Mg ha^{-1} in the control plot to 2.32 and 2.68 Mg ha^{-1} in the low and high liquid swine manure treatments, respectively (Figure 1). The LFOC in the solid cattle manure treatments showed the same pattern as the liquid swine manure, but with a greater impact of manure in that LFOC levels increased from 3.08 Mg ha^{-1} in the control to 5.28 and 5.44 Mg ha^{-1} in the low and high cattle manure treatments, respectively (Figure 1). The cattle manure is more than 50% solid material, which adds directly to the fresh young soil organic matter as opposed to liquid swine manure, which on average contains less than 2% solids (Schoenau et al., 2003).

Soil organic carbon levels at the Melfort site for the control, low and medium liquid swine manure treatments were significantly higher than the SOC levels (Figure 1) for the urea treatment (61.7 Mg ha^{-1}). Low SOC in the urea treatment at this site likely reflects a sulfur deficiency which greatly limited yield and straw production over the years on these treatments (Mooleki et al., 2002). The SOC levels for the low and medium rate manure treatments were lower than the 68.7 Mg ha^{-1} in the control (Figure 1). The LFOC for the medium swine manure treatment was significantly higher than the control (Figure 1). The medium manure treatment produced 3.13 Mg ha^{-1} of LFOC, while the control produced 1.84 Mg ha^{-1} of light fraction carbon. The carryover of nutrients from the previous year's application of manure likely aided in producing more plant biomass.

Soil organic carbon levels at Riverhurst were significantly higher for the control and low liquid swine manure rate versus the high manure rate and urea rate (Figure 1). The high manure rate and urea treatments each had 29.9 Mg ha^{-1} of SOC, while the control and low manure rate had 32.6 and 33.1 Mg ha^{-1}, respectively, of SOC in the 0-15 cm layer. This site was devastated in 2002 due to grasshopper infestation, which resulted in a crop failure. The low crop biomass production would have added only a small amount of plant biomass to the soil for the 2002 year. Light fraction organic carbon levels were the same for the control and urea fertilizer plots, and were significantly lower than the LFOC for the low rate manure treatment (Figure 1). The low rate liquid swine manure treatment produced 3.02 Mg ha^{-1} of LFOC versus 1.88 Mg ha^{-1} for both the control and urea fertilizer treatments.

Soil organic carbon levels at the Plenty site were significantly higher in the low and high rate liquid swine manure treatments versus the control plots (Figure 1). The low and high rate swine manure treatments produced 28.7 and 28.8 Mg ha^{-1}, respectively, versus 25.8 Mg ha^{-1} in the control plot. The Plenty site has received low amounts of precipitation since the swine manure trials began in 1999. Grevers (2002) reported that the 2000 and 2001 crop suffered from drought and that there was a complete crop failure in 2002. Low inputs of moisture would restrict crop biomass production, which in turn would limit the amount of plant biomass that is incorporated back into the soil. This would limit the inputs to SOC and LFOC, but would also limit the decomposition rate. Further, the Plenty site has low amounts of soil organic matter and there is a considerable capacity to build up the pool of SOC and LFOC given the high clay content which can protect organic matter against decomposition.
The LFOC levels for the two rates of liquid swine manure applied at the Plenty site were significantly higher at the $\alpha = 0.10$ than the control LFOC levels, but not significantly different from each other (Figure 1). Light fraction organic carbon levels were 1.64 and 1.73 Mg ha^{-1} for the low and high manure treatments, respectively, while the control LFOC was 0.92 Mg ha^{-1}. The LFOC for the two rates of swine manure followed the same pattern as for the SOC levels for both rates of manure. The significant difference in LFOC between the two rates of swine manure

and the control suggest that in the future, there should be greater increases in SOC levels receiving liquid swine manure, versus the untreated control plots.

Summary and Conclusions

After several years of repeated applications of liquid swine and solid cattle manure, the effects on surface SOC at the four different Saskatchewan sites were quite variable. The sites with high indigenous soil OM content (Dixon and Melfort) did not show increases in SOC from liquid swine manure additions for 5 to 7 years. This may reflect low amounts of carbon added directly in the liquid swine effluent and the influence of the manure nutrients in enhancing decomposition. High organic matter may be associated with a limited capacity to store additional carbon. As well the residues' carbon may be decomposed more rapidly under the moist conditions. This is supported by the lack of significant differences at the Riverhurst irrigated site. The soil at the Plenty site that is low in organic matter content and of high clay content was the only site that showed a large significant increase.

Increases in LFOC were largest with additions of cattle manure and can be attributed to the high organic matter content of the solid manure. Increases in OM with liquid swine manure can be attributed to plant biomass increases through the uptake of nutrients (nitrogen) contained in the manure, but these nutrients may also enhance the decomposition rate of crop residues and humus.

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