2002

Manure as Carbon Source for Soil Improvement and Crop Production: Site-Specific Application

Bahman Eghball
United States Department of Agriculture, beghball1@unl.edu

Daniel Ginting
University of Nebraska-Lincoln, dginting2@unl.edu

Charles A. Shapiro
University of Nebraska-Lincoln, cshapiro1@unl.edu

James S. Schepers
University of Nebraska-Lincoln, james.schepers@gmail.com

Christopher J. Bauer
USDA-ARS

Proceedings of the Great Plains Soil Fertility Conference,
Denver, Colorado, March 5-6, 2002, ed. Alan J. Schlegel.

MANURE AS CARBON SOURCE FOR SOIL IMPROVEMENT AND CROP PRODUCTION: SITE-SPECIFIC APPLICATION

Bahman Eghball, Daniel Ginting, Charles A. Shapiro, James S. Schepers,
and Christopher J. Bauer
USDA-ARS and University of Nebraska
Lincoln, NE 68583-0934
Phone: (402) 472-0741
Email: **BEGHBALL1@UNL.EDU**

Manure, a renewable resource, is an excellent source of nutrients that can be substituted for synthetic types of fertilizers. The C in manure can enhance the physical and chemical properties of soils, especially infertile soils, as these soils typically contain low levels of organic matter and nutrients. The objective of this study was to evaluate the effects of C and nutrients in manure on soil C dynamics and crop production. The treatments included applications of site-specific manure (SSM), uniform manure (UM), uniform commercial fertilizer, and a no treatment check. Field strips 40 ft (16 corn rows) wide and 2200 ft long and under center-pivot irrigation were used in three years (1998 to 2000). For the SSM treatment, manure was applied to areas within the field where organic C was < 1.4%. Manure application resulted in significantly greater soil C level and a positive C balance in the soil. Fertilizer application resulted in negative C balance in the soil (more C lost as CO_2 than added from plant biomass). Averaged across years, the UM and SSM treatments produced significantly greater grain yields and N uptakes than the commercial fertilizer treatment. Stalk NO_3-N concentration was less for uniform manure than fertilizer application indicating over-application of N with the fertilizer treatment. Site-specific manure application is a good method of improving less productive soils or sites within a field.

INTRODUCTION

Degraded or sandy soils typically contain low levels of organic matter, nutrients, water holding capacities, and overall poor soil structure. These soils can lead to nutrient and water stress during important crop growth stages, potentially leading to substantial yield declines. Denmead and Shaw (1960) indicated that water stress at the R1 stage affected the grain yield by as much as 50%. By increasing organic matter levels in less productive soils, the chemical and physical properties of those soils can be improved.

Manure is an excellent source of organic C. Sommerfeldt and Chang (1985) found that manure application to irrigated land tended to decrease the amount of soil aggregates < 1 mm while increasing the amount of aggregates >1 mm in the 6-12 in soil depth. The formation of larger soil aggregates as a result of the addition of organic matter in manure can lead to better soil structure and in turn lead to an increased water holding capacity, increased infiltration (reduced runoff), and reduced surface erosion. By reducing erosion, the amounts of P transported by runoff is also reduced (Eghball and Gilley, 2001), thus reducing the potential for eutrophication of surface waters from P contamination. Hornik and Parr (1987), Hornik (1988) and Larney and Jenzen (1996 and 1997) used manure to improve productivity of sandy or infertile soils.

With the advent of yield monitors and Global Positioning Systems (GPS), site-specific manure applications can allow a producer to apply manure and needed nutrients to less productive areas of the field. This should improve crop productivity in nutrient deficient areas while limiting the over-application of manure and nutrients to productive sites within a field. The objective of this study was to evaluate manure application as a source of C and nutrient for improving soil properties and crop productivity within a field.

MATERIALS AND METHODS

The experiment was conducted from 1998 to 2000 on a private farm in Hamilton County near Phillips, Nebraska on a center pivot irrigated field with continuous corn. A ridge-till system, consisting of stalk chopping, cultivation, and ridging was utilized. The experimental area consisted of Hord silt loam, Invale loamy sand, Thurman fine sandy loam, Ortello fine sandy loam, Uly silt loam, and Alda loam soils.

The experimental design was a randomized complete block with four blocks and four treatments within each block. Treatments included strips (40 ft wide and 2200 ft long) of site-specific manure, uniform manure, uniform commercial fertilizer, and a no-treatment check. Each year, organic C levels were determined by grid sampling of the area, with two samples taken, 20 to 30 in apart, to a depth of 6 in at each grid point. Samples were collected every 80 ft in the middle of each strip. Each point was geo-referenced using a differential global positioning system (DGPS). Samples were air-dried in a greenhouse drying room. Dried samples were hand-ground using a mortar and pestle and analyzed for organic C. In the site-specific manure treatment, manure was applied to areas within the strips with a soil C concentration $< 1.4\%$.

Beef cattle feedlot manure was uniformly applied to manure strips on December 9, 1997 and December 15, 1998 using a manure spreader at a rate of 25 ton ac^{-1} wet weight basis to provide for 170 lb N ac^{-1}. Manure was applied on January 18, 2000 at a rate of 15.4 ton ac^{-1} to provide for 137 lb N ac^{-1}. Manure analysis results are reported in Table 1. Nitrogen availability in the first year after application was assumed to be 40% of total manure N (Eghball and Power, 1999). Nitrogen availability in subsequent years was estimated by soil sampling for nitrate. In 1997, the site-specific manure strips received uniform application of manure to the entire strip since almost all of the strips had soil organic C content $<1.4\%$.

The N rate was chosen to provide for a corn production level of 170 bu ac^{-1} (Hergert et al., 1995) in compliance with the landowners request. Starter fertilizer as liquid ammonium polyphosphate (10-34-0, N-P-K+ Zn) was band applied at planting to fertilizer strips only at a rate of 9 lb P ac^{-1} in all three years. Anhydrous ammonia (82-0-0) was side dressed to fertilizer strips on June 22, 1998 at a rate of 180 lb N ac^{-1}. Anhydrous ammonia was applied pre-plant at a rate of 190 lb N ac^{-1} in 1999 and 2000. The field was planted on May 5, 1998 using the corn hybrid Circle 6215 with an 8-row planter at ~29,000 plants ac^{-1}. In 1999, the field was planted on May 11, using the corn hybrid Pioneer 33A63 (waxy corn) with an 8-row planter at ~28,000 plants ac^{-1}. In 2000, the plots were planted on April 29 using Wilson 1851 (white corn) hybrid. Row spacing of 30 in was used in all years.

Table 1. Analysis results for beef cattle feedlot manure applied to plots in 1997, 1998, and 2000 (average of four samples; nutrient analysis is on dry weight basis).

Element	1997	1998	2000
Total N (TKN), %	2.30	1.52	1.54
Phosphorous, %	0.65	0.34	0.72
Potassium, %	1.82	1.67	1.33
EC, mmho cm^{-1}	24	15	20
pH 1:1	8.2	8.7	8.3
Moisture, %	26.2	44.0	27.4
Organic Matter, %	49.1	18.6	30.6
Organic Carbon, %	28.5	10.8	17.8
C:N ratio	12	12	12

Measurement of soil CO_2-C emission was made using the vented surface gas chamber technique (Hutchinson and Mosier, 1981) in 1999 and 2000. The measurements were made once every two weeks (or longer in winter) throughout the year. A cylindrical surface chamber, 75-cm diam. and 45-cm high, was placed on a weed free representative-interrow within each plot. The chamber was inserted 7.6-cm deep into the soil and capped. Gas samples were collected from the chambers at times 0, 15, 30, 45, and 60 minutes with a 20-mL polypropylene syringe. Before each sampling, gas in the chamber was mixed by taking and purging the gas repeatedly for 10-20 times with the syringe. Then 20-mL samples were transferred to 12-mL evacuated serum vials and transported to the laboratory. Gas samples collected were analyzed for CO_2-C within 24-72 h after sampling. The CO_2-C content was determined using a gas-chromatographic system with a thermal conductivity detector maintained at 110 ^oC as described by Weier et al. (1993).

Statistical Analysis Systems (SAS) was performed on all data using the Proc-Mixed procedure (Littell et al., 1996). Least Significant Difference (LSD) was then used to separate the means. A probability level ≤ 0.10 was considered significant.

RESULTS AND DISCUSSION

Weather conditions and initial soil

Rainfall during the growing season from planting to the end of September in 1998, 1999, and 200 were 14.6, 20.2 and 11.4 in, respectively. Growing degree days (50/85) from May through September were 3091, 2823, and 3135 in 1998, 1999, and 2000, respectively. The average initial soil surface (0-6 in) pH was 5.3 and the average soil organic C was 1.17% in the experimental area.

Soil C balance

Soil C concentration (0-6 in) was 1.17% before initiation of the site-specific manure application in 1997 and increased to 1.52% in 2000 following three years of manure application. This was a soil C increase of 2.8 tons/acre. Carbon input into the soil in the synthetic fertilizer or check plots were less than the annual CO_2-C emissions in both 1999 and 2000 (Table 2) indicating a negative net C sequestration. However, when manure was applied, the net C balance

Table 2. The least square means and standard error of carbon input and output at an irrigated site near Phillips, NE.

Treatment†	Carbon Input Sources: Plant Biomass‡	Manure	Total	CO_2-C emission	C - Balance
	----------	----------	Mg C ha^{-1}	----------	----------
			1998 - 1999		
CON	3.98 ± 0.35 c¶	0	3.98	9.68 ± 0.77 a	-5.70 ± 0.85
FER	5.17 ± 0.31 b	0	5.17	9.00 ± 0.63 a	-3.83 ± 0.70
SSM	6.11 ± 0.40 a	3.88	9.99	10.05 ± 1.09 a	-0.01 ± 1.16
UM	6.31 ± 0.35 a	3.88	10.18	9.34 ± 1.09 a	+0.84 ± 1.14
			1999 – 2000		
CON	6.08 ± 0.42 b	0	6.08	7.75 ± 1.13 a	-1.67 ± 1.21
FER	8.43 ± 0.39 a	0	8.43	9.28 ± 1.06 a	-0.85 ± 1.13
SSM	8.28 ± 0.47 a	3.60	11.88	8.97 ± 1.32 a	+2.91 ± 1.40
UM	7.84 ± 0.51 a	3.60	11.44	9.02 ± 1.32 a	+2.42 ± 1.42

† Con, control;FER, synthetic fertilizer; SSM, site specific manure application; UM, uniform manure application.

‡ From stover, root, rhizodeposits (root turnover, slough and exudates), and weeds. Root C contribution after harvest are based on shoot/root ratio of 1.18 and root C content of 26.1% (Buyanovsky and Wagner, 1997). Rhizodeposits is estimated at 150% of the root C (Lucas and Vitosh, 1978). Due to good weed control, C contribution is based on 5% of root and stover C.

¶ Values followed by different letter are significantly different at $P < 0.10$.

in the soil was positive indicating soil C sequestration (Table 2). Site-specific manure application resulted in a similar C balance as uniform manure even though some part of the field did not receive manure in the site-specific treatment. The differences in estimated annual CO_2-C emissions were not significant at the 0.10 probability level indicating that the C sequestration in manure plots was due to C input with manure application.

Grain yield

In all three years, there were significant differences among the treatments for grain yield (Table 3). Commercial fertilizer and manure treatments resulted in greater grain yield than the untreated check. No significant yield difference was observed between the UM and the SSM treatments but both yielded significantly greater than the commercial fertilizer treatment in 1998 and 1999 (Table 3). In 2000, fertilizer application resulted in greater grain yield than uniform manure application. This was because manure was applied to provide N (137 lb ac^{-1}) for a corn yield of 170 bu ac^{-1} while the farmer applied fertilizer N at a rate of 195 lb ac^{-1}. Across years, site-specific and uniform manure application resulted in 12 and 7 bu ac^{-1} more yield than fertilizer application, respectively, even though the average annual available N application rate was 31 lb ac^{-1} greater for fertilizer than manure. This indicates that the added nutrients and organic matter from the application of manure to less productive areas within this field increased productivity. The increase in grain yield may also be attributed to improved soil health due to manure application by improving the physical properties of the soil, such as increased water holding capacities, increased aeration and better overall soil structure. In addition to N, manure also contains other nutrients and calcium carbonate (Eghball 1999). The average pH in the soil was approximately 5.3 and would have benefited from manure lime application.

N uptake

There were significant differences in N uptake among all treatments in 1998 (Table 3). No significant N uptake difference was observed between the UM and the SSM treatments but both resulted in greater N uptake than the commercial fertilizer treatment (Table 3). In 1999, significant differences among treatments were observed for N uptake (Table 3). Commercial fertilizer and manure treatments resulted in greater N uptake than the check. Uniform manure application resulted in similar corn N uptake to that of the site-specific manure treatment. Manure treatments resulted in significantly greater N uptake than the fertilizer treatment in 1999.

Stalk NO_3-N

In 1998, all stalk NO_3-N values were below the critical value of 2000 ppm and above 250 ppm (Table 3). This indicates that all treatments provided adequate but not excessive amounts of N. The chemical fertilizer treatment resulted in higher stalk NO_3-N concentration than the manure treatments in 1998. These results suggested that adequate N was applied for the manure and fertilizer treatments but slightly more N was available in the fertilizer treatment at the end of the growing season. The mean stalk NO_3-N concentrations for 1999 were much higher than those observed in 1998 (Table 3). The stalk NO_3-N concentrations for the commercial fertilizer and SSM treatments were well above the critical stalk NO_3-N concentration of 2000 ppm in 1999 (Table 3). The highest stalk NO_3-N values were observed in the fertilizer and SSM treatments with 5580 and 3030 ppm, respectively, both higher than the UM treatment in 1999 (1870 ppm)(Table 3). The SSM treatment had higher stalk NO_3-N value than the uniform manure because the SSM also received chemical fertilizer in non-manure areas. The higher stalk NO_3-N levels for the fertilizer and SSM treatments indicated that there was an over-application of commercial fertilizer in 1999.

CONCLUSIONS

The positive soil C balances for the site-specific and uniform manure treatments as compared with the fertilizer treatment indicated that the C sequestered in the soil was primarily due to manure addition. The C input from crop for all treatments was less that that emitted as soil CO_2-C pointing to the potential of manure application for soil C sequestration in this irrigated ridge-till corn system.

Manure application resulted in greater grain yield and N uptake than fertilizer application indicating that in less productive or sandy soils manure can be a great soil amendment. The uniform and site-specific manure treatments had similar grain yields and N uptakes. This suggests that the application of manure was successful in increasing productivity in infertile or unproductive soils within the field while reducing the potential environmental effects as indicated by less post-harvest stalk nitrate concentration for manure than fertilizer treatment. Manure not only provides macronutrients for the crop but also provides C, lime, secondary, and micronutrients. Manure application can improve soil quality, water holding capacity, and nutrient availability.

Table 3. Treatment effects on corn grain yield, total N uptake, stalk nitrate, and analysis of variance for each in 1998, 1999, 2000.

		Grain yield			Total N uptake		Stalk nitrate	
Variable		**1998**	**1999**	**2000**	**1998**	**1999**	**1998**	**1999**
		------------ bu ac^{-1} ----------			------ lb ac^{-1} ------		------- ppm -------	
Treatments								
Uniform manure (UM)		**150**	**166**	**132**	**152**	**190**	**1340**	**1870**
Site-specific manure (SSM)		**152**	**164**	**147**	**151**	**191**	**780**	**3030**
Fertilizer (FER)		**136**	**143**	**149**	**135**	**179**	**1900**	**5580**
Check (CHK)		**111**	**123**	**100**	**97**	**113**	**90**	**210**
Analysis of variance	**df**	------------------------------- P>F ------------------------------						
Treatment	**3**	**0.0002**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
All Treat. vs. CHK	**1**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
SSM + UM vs. FER	**1**	**0.0186**	**0.0001**	**0.0018**	**0.0299**	**0.0341**	**0.0111**	**0.0001**
UM vs. SSM	**1**	**0.7790**	**0.2761**	**0.0001**	**0.8574**	**0.8906**	**0.1243**	**0.0841**

REFERENCES

Buyanovsky, G. A., and G. H. Wagner. 1997. Crop residue input to soil organic matter in Sanborn Field. P 73-84. *In* E.A. Paul et al. (ed.) Soil organic matter in temperate agroecosystems: Long-term experiments in North America. CRC Press, Boca Raton, FL.

Campbell, C. A., M. Schnitzer, J. W. B. Stewart, V. O. Biederbeck, and F. Selles. 1986. Effect of manure and P fertilizer on properties of a Black Chernozem in southern Saskatchewan. Can. J. Soil Sci. 66:601-613.

Denmead, O. T., and R. H. Shaw. 1960. The effects of soil moisture stress at different stages of growth on the development and yield of corn. Agron. J. 52:272-274.

Eghball, B. 1999. Liming effects of beef cattle feedlot manure or compost. Commun. Soil Sci. Plant Anal. 30: 2563-2570.

Eghball, B., and J. F. Power. 1999. Phosphorus- and nitrogen-based manure and compost application: Corn production and soil phosphorous. Soil Sci. Soc. Am. J. 63: 895-901.

Eghball, B., and J. E. Gilley. 2001. Phosphorus risk assessment index evaluation using runoff measurements. J. Soil Water Conserv. J. Soil Water Conserv. 56: 202-206.

Hergert, G. B., R. B. Ferguson, and C. A. Shapiro. 1995. Fertilizer suggestions for corn. NebGuide G74-174-A, Cooperative Extension, University of Nebraska.

Hornik, S.B. 1988. Use of organic amendments to increase the productivity of sand and gravel spoils: Effect on yield and composition of sweet corn. Amer. J. Alternative Agriculture. 3(4):156-162.

Hornik, S. B., and J. F. Parr. 1987. Restoring the productivity of marginal soils with organic amendments. Amer. J. Alternative Agric. 2(2):64-68.

Hutchinson, G. L., and A. R. Mosier. 1981. Improved soil cover method for field measurement of nitrous oxide fluxes. Soil Sci. Soc. Am. J. 45:311-316.

Larney, F. J., and H. H. Janzen. 1996. Restoration of productivity to a desurfaced soil with livestock manure, crop residue, and fertilizer amendments. Agron. J. 88:921-927.

Larney, F. J., and H. H. Janzen. 1997. A simulated erosion approach to assess rates of cattle manure and phosphorus fertilizer for restoring productivity to eroded soils. Agriculture Ecosystems and Environment, 65:113-126.

Littell, R. C., G. A. Milikens, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS institute. Cary, NC.

Lucas, R. E., and M. L. Vitosh. 1978. Soil organic matter dynamics. Research Report 358. Michigan State Univ. Agric. Exp. Stn., East Lansing, MI.

Sommerfeldt, T. G., and C. Chang. 1985. Changes in soil properties under annual applications of feedlot manure and different tillage practices. Soil Sci. Soc. Am. J. 49:983-987.

Weier, K. L., J. W. Doran, J. F. Power, and D. T. Walter. 1993. Denitrification and the dinitrogen/nitrous oxide ratio as affected by soil water, available carbon, and nitrate. Soil Sci. Soc. Am. J. 57: 66-72.