Effect of Repeated Hog and Cattle Manure Application on Soil Quality in East Central Saskatchewan

B.A. Assefa, M.C.J. Grevers, J.J. Schoenau

Department of Soil Science, University of Saskatchewan

Key words: Long-term, Manure application, Salinity, Sodicity, Soil structure

Abstract

The effect of repeated (4 years) manure applications on some soil quality indices such as pH, EC, SAR, bulk density, and aggregation was evaluated. The study was conducted at two sites (Burr and Dixon) in the Black Soil Zone near Humboldt in east central Saskatchewan. The study was initiated in 1996 and the sites received manure annually for the last four years. Sites were soil sampled in the spring of 2000 and the above properties were analyzed. The treatments used were: check (no manure application), low rate, medium rate, and high rate manure applications based on nitrogen requirement. The responses of crops to the manure additions were documented. The results of the analysis of the chemical and physical properties of the soils following the repeated manure applications are discussed in this paper. It was observed that pH and EC were not much affected by repeated manure applications. However, there was an increasing trend in the soils' salinity and an increased sodicity (SAR) was observed. Soil bulk density decreased at the Burr sites and soil aggregation decreased at all sites. From the results obtained it was concluded that soil structure deterioration could be a concern due repeated manure applications because of considerable sodium accumulation and therefore, salinity and sodicity should be monitored in a given long-term manure application scheme.

Introduction

The general public is concerned that large volumes of manure, when applied repeatedly may deteriorate the quality of local soils and reduce crop production (Change et. al. 1990 and Larison 1991a, b). Hog manure applications add considerable amounts of sodium salts to the soil, and this could cause soil deterioration. On the other hand others envision positive effects such as improved soil quality from the addition of organic matter, recycling of nutrients, and low cost source of fertilizer. Sound manure management practice is an important component in the agricultural sector to enable capturing the economic benefits from using manure as a fertilizer resource while reducing the risk of environmental pollution. The need for extensive research to achieve such a management practice is evidenced by the amount of coverage given to the subject in literature. This study is also believed to contribute a significant amount of understanding leading to the desired achievement.

Studies have shown that manure is a valuable fertilizer and soil amendment (Campbell et al., 1986) which improves the physical conditions of the soil such as water holding capacity and structure by virtue of its contribution to the soil organic matter content (Buckman and Brady, 1960; Hillel, 1980). This dictates enhanced soil productivity and sustainable agriculture.

Sustainable agriculture considers soil and crop productivity, economics, and environment (Halvin et al., 1999). While increased productivity and viable economy is expected from manure application in agriculture, due consideration should be given to its effect on environmental quality in the short and long term. Excessive application of manure has a pollution potential (N, salts, pathogens) to soil and water (McCalla, 1974). Nitrogen, in its several forms, is of particular concern. Continued application of manure in rates based on N needs of crops may also result in P accumulation in soils which could give rise to nutrient imbalances leading to eutrophication of surface waters. The huge amount of manure production associated with large livestock operations is another problem by itself, because the manure has to be disposed of. This poses the need for sound manure management practices. Allison (1973) suggested returning manure to land as directly and efficiently as possible until better solutions of manure disposal are developed to avoid environmental pollution. Chang and Entz (1996) reported that, in Alberta, disposal of manure without pollution of the soil and water resources could be challenging.

Optimum manure management practices are subject to the varied perception among the society towards the material, which arises from its characteristics, environmental, social, and economic concerns. Manure varies in its moisture content and nutrient content. This makes it difficult to determine exactly how much of a nutrient is being applied. The amount of manure applied can also be difficult to determine particularly if a manure spreader is not calibrated. Nonetheless, its agronomic importance as a source of plant nutrients is widely accepted. Manure is cheaper than conventional fertilizer, although the hauling and spreading costs limit the use, availability, and location. It contributes to reducing the cost of production by enabling to cut back the amount of commercial fertilizer needed on land.

The purpose of this research was to determine the optimal rates and methods of manure application by studying the response of different soils and crops to different rates and methods of manure application. A study to examine soil and crop responses to different rates and methods of hog and solid feedlot cattle manure application was started in 1997 at two sites in east-central Saskatchewan in the Black Soil Zone near Humboldt and has been underway for four years. The effect of the manure addition on soil nutrient availability, uptake, and yield for these sites is well documented (Mooleki et. al. 2001). Schoenau et. al. (1999) reported that there were no significant differences in soil pH, electrical conductivity, and sodium adsorption ratio between any of the treatments at these sites in the first year of application. However, the effect of repeated manure applications on soil properties was not looked at either of the sites. The objective of this study, therefore, was to determine the longer-term impacts of repeated (4 years) applications of swine and cattle manure on some soil quality indices such as pH, electrical conductivity, sodium adsorption ratio, bulk density, and aggregation at the two sites.

Methodology

Site description

This study was conducted at two field sites, Dixon and Burr near Humboldt in the Black Soil Zone in east central Saskatchewan which were selected in the fall of 1996 and were under study since. The soil at the Dixon site is classified as Cudworth Association with a predominantly loamy surface texture. The soil at the Burr site is classified as Meota Association with sandy loam texture underlain by a gravel lens of variable depth with significant sub-surface salinity. Both sites received swine and cattle manure applications annually for the last four years since May 1997 except the Burr hog manure site, which received the first application in October 1996.

Experimental Design and Treatments

The design used at both sites was a randomized complete block design. Both sites had a similar layout and generally the plot sizes of the hog manure treatments (10 by 100 ft.) were larger in size than the cattle manure treatments (10 by 8 ft.). The liquid hog manure was injected to a depth of 10 cm using a heavy-duty cultivator applicator (30 cm sweep-type-openers) attached to a nurse tank. The cattle manure was spread manually and incorporated by using rotary tiller. The hog manure treatments were: check (no manure application), low rate (3300 g/ac), medium rate (6600 g/ac), and high rate (13200 g/ac). The cattle manure treatments include: check (no manure application), low rate (9 t/ac), medium rate (18 t/ac), and high rate (34 t/ac).

In the spring of 2000 both sites were soil sampled. Sampling was performed to a depth of 12", using a punch truck. Soil pH, electrical conductivity, and sodium adsorption ratio were determined. The sampled soils were air dried and ground to 2mm size particles prior to analysis. pH and EC were determined on a 1:2 soil to water extract while SAR was determined on a saturated paste extract. PVC cores of 10 cm diameter and 15 cm length were used to soil sample the sites for bulk density determination. The samples were oven dried over night at 105 ^{o}C and water content calculated from weight deference between the weights before and after drying. Soil volume was calculated from dimensions of the PVC cores. Then bulk density was determined on the basis of oven-dried soil. Bulk samples were collected for aggregate analysis. The samples were air dried and sieved in to 7 average aggregate size groups (0.25mm, 0.90mm, 1.94mm, 4.89mm, 12.36mm, 26.05mm, and 44.06mm). Mean Weight Diameter (MWD) was then calculated to study the nature of soil aggregation. MWD was calculated as the sum of products of the mean diameter $\bar{x}_i$ of each size fraction and the proportion of the total sample weight w_i occurring in the corresponding size fraction. Symbolically the equation is given by:

$$\text{MWD} = \sum_{i=1}^{n} \bar{x}_i w_i$$ (Youker and McGuinness, 1956)

Results and discussion

A summary of analysis of the properties of the soils at both sites is given in Tables
1-4. The statistical analysis (ANOVA) was performed using the SAS General Linear Models (GLM) procedure. The data indicated in the tables are mean values with least significant differences (LSD) at 90 % probability for each soil property and treatment.

The chemical and physical properties of the Burr cattle site are shown in Table 1. There were no significant differences in the soil pH and electrical conductivity between any of the treatments and the check. There seems to be a slightly increasing trend in both soil pH and electrical conductivity of the soil in several of the manure application treatments as compared to the check.

Significantly higher sodium adsorption ratio was observed in the medium rate treatment than the check and low rate. The difference in SAR between the medium and high rate treatments was not significant. Lower bulk density in the high and medium rate than in the check and low rate treatments was observed. The aggregate size distribution (MWD) was found to be lower in the three levels of manure treatments than in the check. But the three levels of manure treatments were not significantly different from each other. Only the medium rate manure treatment was significantly lower than the check.

The result of the soil properties analysis of the Burr hog manure is shown in Table 2. The pH of the soil in the high rate treatment was significantly lower than that of the check and the medium rate treatments. There were no significant differences in the electrical conductivity between all the treatments. There were no significant differences in SAR between the three levels of manure treatments but the medium rate was significantly higher than the check. The bulk density of the medium rate treatment was significantly lower than the rest of the treatments. The aggregate size distribution decreased with increasing rate of the hog manure but only the high rate treatment was significantly lower than the check.

The chemical and physical properties of the Dixon cattle manure site are indicated in Table 3. There were no significant differences in the soil pH, bulk density and aggregation at this site between any of the treatments. The electrical conductivity of the medium rate was significantly higher than the check, low, and high rate treatments. The sodium adsorption ratio increased with increasing rate of manure applied. The high rate sodium adsorption ratio was higher than the rest of the treatments and the medium rate treatment is higher than the check.

The chemical properties' analysis for the Dixon hog manure was summarized in Table 4. There were no significant differences in soil pH and bulk densities between any of the treatments. The electrical conductivities of the three levels of manure treatments were not significantly different from the check. Although there was a generally increasing trend in the sodium adsorption ratio with increasing rate of manure application there was no significant difference in SAR between all the treatments. Aggregation differences between the check and the rest of the treatments were not significant.

In summary pH was not much affected except that at the Burr hog manure site it was reduced which could be because of the lower buffering power of the soil to pH changes. More over as compared to the cattle manure applications there could be more acidification due to nitrification of ammonium from the hog manure. Salinity (EC) was also not much affected except at the Dixon cattle manure site where a little bit of higher value was observed at the medium rate than at the check. However, there was a slightly increasing trend overall. Both hog and cattle manure increased the SAR. Larger differences were in the cattle manure sites. Bulk density was reduced at the Burr cattle and hog manure sites but remained the same at the Dixon sites. This could be explained by the more responsiveness of the Burr site soil to manure application due to its sandy texture. By the same token the MWD (aggregation) was reduced at the Burr cattle and hog sites.

These properties are not the only ones that will be studied in the study. Other properties such as water infiltration, crust strength, and aggregate stability will be looked at. The fact that soil sampling was done in the spring of 2000, not long after the last application of the manure in the previous fall, must be noted. This may have resulted in overestimation of changes to soil properties.

Conclusion

Repeated (4 years) manure applications have resulted in some evidence of sodification and this could cause soil structure concerns. There was also a trend showing increased soil salinity levels with the repeated manure applications. The increase in sodicity suggests a potential for deterioration of soil structure following repeated manure applications to agricultural fields. This finding is in agreement with previous research findings (Chang et. al. 1991). Therefore, salinity and sodicity should be monitored in soils receiving repeated applications of manure.

Table 1. Soil properties at the Burr cattle manure site.

Treatment	MWD (mm)	Bulk density ($Mg/m^{3)}$	EC (dS/m)	pH	SAR
Check	19.7	1.4	1.00	7.7	0.67
Low	16.3	1.4	0.64	7.8	0.74
Medium	13.8	1.2	1.88	7.8	1.66
High	16.6	1.2	1.12	7.6	1.30
LSD (0.1)	5.0	0.1	1.49	0.2	0.80

Table 2. Soil properties at the Burr hog manure site.

Treatment	MWD (mm)	Bulk density ($Mg/m^{3)}$	EC (dS/m)	pH	SAR
Check	21.4	1.3	0.53	8.0	0.40
Low	18.3	1.3	0.94	7.8	0.55
Medium	16.1	1.2	1.41	7.9	1.29
High	12.6	1.3	0.55	7.6	0.86
LSD (0.1)	7.7	0.1	1.11	0.3	0.86

Table 3. Soil properties at the Dixon cattle manure site.

Treatment	MWD (mm)	Bulk density ($Mg/m^{3)}$	EC (dS/m)	pH	SAR
Check	15.6	1.3	0.30	7.7	0.33
Low	15.3	1.3	0.53	7.8	0.59
Medium	11.7	1.3	1.60	7.7	0.85
High	12.1	1.3	0.70	7.9	1.50
LSD (0.1)	4.4	0.1	0.70	0.3	0.32

Table 4. Soil properties at the Dixon hog manure site.

Treatment	MWD (mm)	Bulk density (Mg/m$^{3)}$	EC (dS/m)	pH	SAR
Check	14.4	1.3	0.50	7.6	0.48
Low	13.3	1.3	0.32	7.6	0.84
Medium	12.2	1.3	0.35	7.5	0.88
High	15.1	1.3	0.55	7.6	0.92
LSD (0.1)	2.4	0.1	0.12	0.3	0.45

References

Allison, F. E. 1973. Maintenance of soil organic matter. P.422-425. In: Chang, C. and T. Entz. 1996. Nitrate Leaching Losses under Repeated Cattle Feedlot Manure Applications in Southern Alberta. J. Environ. Qual.25: 145-153.

Buckman. H.O., and Brady, N.C. 1960. The nature and properties of soils. 6th ed. The Macmillan Company, New York. In: Sommerfeldt. T. G., and C. Chang. 1987. Soil-water properties as affected by twelve annual applications of cattle feedlot manure. Soil Sci. Soc. Am. J. 51:7-9.

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

Chang, C. and Entz, T. 1996. Nitrate Leaching Losses under Repeated Cattle Feedlot Manure Applications in Southern Alberta. J. Environ. Qual.25: 145-153.

Chang, C., Sommerfeldt, T.G., and Entz, T. 1990. Rates of soil chemical changes with eleven annual applications of cattle feedlot manure. Can. J. Soil Sci. 70:763-681.

Chang, C., Sommerfeldt, T.G., and Entz, T. 1991. Soil chemistry after eleven annual applications of cattle feedlot manure. J. Environ. Qual. 20: 475-480.

Halvin, J. L., Beaton, J. D., Tsisdale, S. L., Nelson, W. L. 1999. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 6th ed. Prentice Hall, New Jersey 07458. P 281.

Hillel, D. 1980. Applications of soil physics. Academic Press, New York.

Larson, B. G. 1991. Saskatchewan Pork Industry Manure Management Recommendations. Quadra Management Services Ltd. P 1-30.

MacCalla, T. M. 1974. Use of animal manure wastes as a soil amendment. J. Soil Water Conserv. 29: 213-216.

Mooleki, P. S., Schoenau, J. J., Hultgreen, G., Wen, G., and, Charles, J. L. Crop Response to Liquid Swine Effluent and solid cattle Manure over Four Years in East-Central Saskatchewan. Soils and Crops 2001, Feb. 22 & 23, 2001.(This issue).

Schoenau, J.J., Charles, J. L., Wen, G., Qian, P., Hultgreen, G. 1999. Effect of Hog Manure Addition on Soil Fertility and Crop Growth in East Central Saskatchewan. Proceedings of a tri-provincial conference on manure management. P 66-85.

Youker, R. E. and McGuinnes, J. L. 1957. A Short method of obtaining mean weight-diameter values of aggregate analysis of soils. Soil Scie. 83:291-294.