Effects of four annual applications of manure on Black Chernozemic soils

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Assefa, B.A., Schoenau, J.J. and Grevers, M.C.J. 2004. **Effects of four annual applications of manure on Black Chernozemic soils.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **46**: 6.39-6.46. The influence of four annual applications of cattle and hog manure on soil pH, electrical conductivity (EC), sodium adsorption ratio (SAR), organic carbon, bulk density, aggregation, aggregate stability, crust strength, and water infiltration was investigated at two field sites, Burr and Dixon, in Saskatchewan under canola-wheat-barley-canola crop rotation. The average annual precipitation of these sites over the 4-year period was 400 mm. Manure application rates were 7.6, 15.2, and 30.4 Mg/ha (dry basis) for the cattle manure and 37.5, 75.1, and 150.2 m^3/ha for the hog manure. Cattle manure increased the EC of the Dixon soil from 0.30 to 1.60 dS/m and the aggregate stability of the Burr soil from 0.75 to 0.84. Hog manure reduced the pH of the Burr soil from 8.0 to 7.6 and the crust strength from 3 to 0 kPa. Cattle and hog manure increased the SAR by 148 – 354% and decreased the bulk density and aggregate size by 8 - 9% and 30 - 40%, respectively, but did not significantly affect the total organic carbon content. Cumulative water infiltration tended to increase with manure application but the increase was not significant. Overall, the effect of manure application on the soil chemical and physical properties after four annual applications were relatively small and variable suggesting that several years of repeated application may be required to produce changes in soil properties that would significantly influence soil productivity. **Keywords:** manure, soil properties, salinity, sodicity, long-term.

L'impact de quatre épandages annuels de fumier de bovins et de lisier de porcs sur le pH du sol, la conductivité électrique (CE), le ratio d'adsorption du sodium (RAS), le carbone organique, la masse volumique, l'agrégation, la stabilité des agrégats, la dureté de la croûte et l'infiltration de l'eau a été étudié au champ sur deux sites : Burr et Dixon en Saskatchewan sous une rotation colza – blé – orge – colza. Les taux d'épandage étaient de 7,6; 15,2 et 30,4 Mg/ha (base sèche) pour le fumier de bovins et de 37,5; 75,1 et 150,2 m^3/ha pour le lisier de porcs. Le fumier de bovins a augmenté la CE du sol de Dixon de 0,30 to 1,60 dS/m et la stabilité des agrégats du sol de Burr de 0,75 à 0,84. Le lisier de porcs a réduit le pH du sol de Burr de 8 à 7,6 et la dureté de la croûte de 3 à 0 kPa. Le fumier de bovins et le lisier de porcs ont augmenté le RAS de 148 – 354% et diminué la densité volumique et la taille des agrégats de 8 – 9% et 30 – 40% respectivement, mais n'ont pas affecté significativement le contenu total en carbone organique. L'infiltration d'eau cumulative augmentait avec l'épandage mais cette augmentation n'était pas significative. En général, l'effet de l'épandage sur les propriétés chimiques et physiques des sols après quatre épandages annuels était relativement minime et variable suggérant qu'un épandage répété sur plusieurs années peut être nécessaire pour produire des changements des propriétés du sol qui pourraient influencer significativement la productivité des sols. **Mots clés**: fumier, lisier, propriété des sols, salinité, sodicité, long terme.

INTRODUCTION

Livestock production, particularly intensive hog operations, is expanding in the Canadian Prairies. Manure, if managed and used properly, is a good source of nutrients for crop production (Campbell et al. 1986; Freeze and Sommerfeldt 1985). By contributing to the soil organic matter content, it can improve the physical condition of the soil (Sommerfeldt et al. 1988; Hillel 1980). Applying manure to the soil can also have advantages such as enhancing recycling of nutrients and acting as a low-cost source of nutrients. However, repeated applications of large volumes of manure may deteriorate certain soil quality attributes that may reduce crop production over the long-term (Larson 1991; Chang et al. 1990). For example, manure applications add considerable amounts of sodium salts to the soil that could cause soil structure deterioration.

Besides nutrient levels in the soil, manure addition can affect soil chemical properties such as organic matter content, pH, electrical conductivity (EC), and sodium adsorption ratio (SAR). Many studies have investigated the effects of manure applications on soil chemical properties. For example, several annual applications of manure increased the organic matter content of the top (0 - 0.15 m) soil (Chang et al. 1991; Sommerfeldt et al. 1988; Mugwira 1979; Mathers and Stewart 1974). In some cases, manure application increased soil pH (Whalen et al. 2000; Eghball 1999; Iyamuremye et al. 1996; King et al. 1990; Mugwira 1979) whereas in other cases it decreased soil pH (Chang et al. 1990, 1991; King et al. 1990). Increases in soil electrical conductivity (EC) and sodium adsorption ratio (SAR) due to manure application have also been documented (Chang et al. 1990, 1991).

Manure not only affects the chemical properties of soils but also the physical properties. For example, Campbell et al. (1986) reported that soils that received repeated applications of cattle manure were more friable to the feel and less compact under the foot than those of the unmanured plots. Hoyt and Rice (1977) suggested that barnyard manure when applied to farmland could improve soil structure. Unger and Stewart (1974) and Meek et al. (1982) have shown that manure increased water-holding capacity and decreased evaporation rate.

Mathers et al. (1977) reported that cattle feedlot manure applications to soils increased water infiltration into the soils. Mathers and Stewart (1980) observed a decrease in soil bulk density and an increase in the saturated hydraulic conductivity of the soil following repeated cattle manure applications over an eleven-year period. Nuttall (1970) found from a pot experiment that additions of manure decreased crust strength and increased the emergence of rapeseed (*Brassica napus* L.).

While other jurisdictions such as Brown Chernozemic soils in southern Alberta have received considerable attention as to the effects of repeated manure application on soil properties, previous research on the impacts of manure addition in the Black soil zone of Western Canada has mainly addressed crop responses to applied manure nutrients (Mooleki et al. 2001, 2002, 2004) and has not specifically addressed the impact of manure on other chemical and physical attributes of soil quality such as aggregation, crusting, and water infiltration. The research described in this paper addresses this gap by determining the effects of repeated (4 years) cattle and hog manure applications on selected soil chemical and physical properties: pH, salinity, sodicity, organic matter, bulk density, aggregation, aggregate stability, crust strength, and water infiltration at two field research sites in the Black soil zone in Saskatchewan. These properties are important attributes that affect the quality of soil for crop production.

MATERIALS and METHODS

Site description

Two field research sites, Burr and Dixon, were used in this experiment. Both sites are located near the town of Humboldt in the Black soil zone in Saskatchewan. These sites were part of an on-going study started in the fall of 1996 to examine crop and soil responses to cattle and hog manure applications at varying rates and methods of application. The responses of crops (yield, nutrient recovery) and soil nutrients (soil N) to the repeated annual applications of manure over the four years (1997-2000) have been documented (Mooleki et al. 2001, 2002, 2004). The current study reports on the effects of the repeated (4 years) annual applications of manure on the soil physical and chemical properties at both sites. The average (1997-2000, inclusively) annual precipitation of the sites was 400 mm (Environment Canada 2004). Detailed growing season weather data for each of the four years were provided by Mooleki et al. (2002).

The soil at the Burr site is classified as Meota Association with a sandy loam texture underlain by a gravel lens of variable depth with significant sub-surface salinity. The soil at the Dixon site is classified as Cudworth Association with a predominantly loamy surface texture. Both sites received hog and cattle manure applications annually during the 4-year period (1997 – 2000, inclusively). Prior to that, there was no recorded history of manure application on the sites.

Experimental design and treatments

A randomized complete block experimental design was used at both sites. Separate blocks were used for the cattle manure treatments and the hog manure treatments. At both sites, the treatments were randomly assigned to each plot within the different blocks, except in the first block of replicates where they were laid down consecutively for the purpose of demonstration. Both sites had similar plot layout and plot sizes (3.05 m by 30.50 m) for the hog manure trials. For the cattle manure trials, the sites had similar plot layout but differing plot sizes (3.05 m by 2.44 m at the Burr site and 3.05 m by 3.05 m at the Dixon site). There was about a 1-m wide unseeded edge between successive plots at both sites to avoid cross interaction. The liquid hog manure was injected to a depth of 0.1 m using a heavy-duty cultivator applicator (0.3 m sweep-type-openers) attached to a nurse tank. The cattle manure was spread manually and incorporated using a rotary tiller. Manure application was performed in the preceding fall of each growing season except in 1997 when manure was applied in the spring of that year due to early freeze up in the fall of 1996. The manure application rates for these selected treatments are shown in Table 1. The low rate applications, which translate to about 100 kg N ha^{-1} y^{-1}, represent agronomic recommended rates while the medium and high rates were two and four times the low rates, respectively. The control treatment refers to no manure application. More details on the application rates are provided in Mooleki et al. (2002, 2004).

Table 1. Annual application rates of cattle and hog manure at Burr and Dixon sites.

Treatments	Cattle manure* (Mg/ha)	Hog manure (m^3/ha)
Control	0.0	0.0
Low rate	7.6	37.5
Medium rate	15.2	75.1
High rate	30.4	150.2

* Cattle manure rates are on a dry weight basis.

Soil sampling

Soil sampling for chemical analysis (three cores per plot) was performed to a depth of 0.3 m. This sampling was done in the spring of 2000 using a punch truck equipped with a 0.1 m diameter soil coring tube. Three other sets of samples, each from three random locations per plot, were collected separately in the summer of 2000 for determination of soil physical properties. Soil sampling for bulk density was done to a depth of 0.15 m using PVC cores of 0.1 m diameter by 0.15 m length. The PVC core was driven into the ground using a hammer and a piece of wood. The soil around the core was removed using a shovel and the core was taken out of the ground. Another set of bulk soil samples was collected by hand using a shovel to a depth of 0.15 m for the determination of soil aggregation and aggregate stability. The third set of soil samples was collected using a trowel to a depth of 0.05 m for the determination of soil crust strength.

Soil chemical analyses

The soil samples collected for the chemical analysis were air dried and ground to less than 2 mm size prior to any of the analyses. The pH was determined using a PHM 82 standard pH meter and the electrical conductivity was measured using a CDM 83 conductivity meter on a 1:2 soil water extract (Rhoades 1982; McKeague 1976). Organic carbon content in the soils was determined using a LECO CR-12 carbon determinator set at 840°C (Wang and Anderson 1998).

Sodium adsorption ratio (SAR) was determined on saturated paste extracts using measurements of concentrations of Na, Mg, and Ca in the extracts using an atomic absorption spectrometer (Perkin Elmer Model 3100). The concentrations (ppm) of the Na, Ca, and Mg were converted to milliequivalents per liter (me/L) prior to the SAR calculation. The SAR was calculated using Eq. 1.

$$SAR = \frac{\left[Na^{+}\right]}{\sqrt{\frac{\left[Ca^{2+}\right]+\left[Mg^{2+}\right]}{2}}} \quad (1)$$

where $[Na^{+}]$, $[Ca^{2+}]$, and $[Mg^{2+}]$ are ionic concentrations (me/L) of Na, Ca, and Mg, respectively.

Soil physical analyses

The soil samples collected for bulk density determination were weighed and sub-samples were dried in an oven for 24 hours at 105°C to determine the water content. Soil volume was calculated from dimensions (0.1 m diameter by 0.15 m length) of the PVC cores. Then the oven dry bulk density was determined by dividing the oven-dry mass of the soil by the volume.

Soil aggregation, aggregate stability, and crust strength were determined on air-dried soil samples. For determination of aggregation, the air-dried samples were sieved into seven average aggregate size groups (0.25, 0.90, 1.94, 4.89, 12.36, 26.05, and 44.06 mm) using a motorized sieving machine. Mean Weight Diameter (*MWD*) was then determined to study the nature of soil aggregation. The *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 (Eq. 2).

$$MWD = \sum_{i=1}^{n} \bar{x}_i w_i \quad (2)$$

The summation is carried out over all *n* size fractions including the one that passes through the finest sieve (Kemper and Chepil 1965). The less than 2 mm size fractions (0.25, 0.90, and 1.94 mm) were thoroughly mixed for aggregate stability determination. Aggregate stability was determined with a Spectronic™ 20 colorimeter using the turbidimetric method for assessing soil aggregate stability as outlined by Williams et. al. (1966).

A modulus of rupture test (Reeve 1965; Richards 1953) was performed to determine the soil crust strength. Modulus of rupture is defined as an index of the strength of materials and can be used to compare the binding strength of a structural material by determining the probable load required to break a beam of a certain material (Reeve 1965). In this study, this principle was applied to examine the surface crusting of the soils as this critically influences seedling emergence. The soil samples were air-dried prior to the modulus of rupture determination. The air-dried soil was passed through a 2-mm-round-hole sieve, thoroughly mixed, and sub-sampled into vials. Soil briquettes (from the sub-samples) were formed in special rectangular briquette moulds that were precision-made from a 9.52-mm brass strip with inside dimensions of 35 mm wide by 70 mm long.

Reeve (1965) and Richards (1953) described the apparatus used to measure the breaking force. It has a briquette-support and knife-edge assembly that makes use of two parallel bars 0.05 m apart for supporting the sample. The breaking force was supplied from a third overlying bar that is centrally located and parallel with respect to the supporting bars. A beam balance was used to apply and measure the amount of load applied to the briquette-breaking apparatus mounted on the balance platform. A jet of water was directed toward the vessel at the rate of 0.033 kg/s where it accumulated as long as the briquette remained unbroken. The upward motion of the two lower bars broke the briquette via water accumulating in a vessel hung from the balance beam. The end of the balance beam drops vertically when the briquette breaks and that action automatically stops the accumulation of water into the vessel. The breaking force is the weight of the water accumulated in the vessel.

The modulus of rupture for the rectangular soil briquette was calculated by Eq. 3.

$$S = \frac{3FL}{2bd^{2}} \quad (3)$$

where:

- S = modulus of rupture (kPa),
- F = breaking force applied at center of briquette beam span (kN),
- L = distance between the two briquette supports (m),
- b = width of briquette (m), and
- d = depth or thickness of briquette (m) (Reeve 1965).

In-situ water infiltration into the soil was measured at the Dixon site only in the fall (October) of 2000 after plot harvest. The rate of water intake by the soil was measured by a method of flooding, also known as the double ring infiltrometer method (Bertrand 1965). The infiltrometer consisted of a set of two concentric cylinders (inside and outside) driven into the ground. The inside and the outside cylinders had internal diameters of 200 and 300 mm, respectively, a height of 150 mm, and a thickness of 1 mm. They were simultaneously driven into the ground, the smaller ring inside the larger ring, to a depth of about 50 mm, using a hammer and a wooden block. Transparent plastic rulers were taped to the inside wall of the smaller cylinder for measuring water height in the cylinder.

Both the inside and the outside cylinders were simultaneously filled with tap water from tanks in the morning and left until the afternoon. Late in the afternoon (approximately 6 h later) the cylinders were refilled with water from the same source again to a height of around 100 mm. The drop in the height of the water from the inside cylinder was recorded in one minute increment intervals by taking readings from the ruler to determine infiltration rate. This is a method of determining water entry into soil referred to as falling head ponded infiltration (Philip 1992). The water poured into the outside cylinder was assumed to act as a buffer protecting against radial flow of water from the inner cylinder.

Statistical analysis

The data (except that of infiltration) were analyzed using SAS GLM procedures, and SAS™ Statistical Software Version 8 (SAS 1999). For many soil properties, especially physical properties, the variability is high so a 0.10 level of significance was chosen instead of 0.05. Treatment means, with least significant differences (LSD) at the 0.10 level of significance, were calculated to compare the different treatments using a one-way analysis of variance (ANOVA) suitable for a randomized complete block design (RCBD). For comparison of the water infiltration data, the cumulative water infiltrations were calculated along with the standard errors and plotted against time. The cumulative water infiltration curves were considered not to be significant where error bars overlapped.

Table 2. Soil physical properties at the Burr cattle manure site in samples taken in the summer of 2000.

Treatment	Bulk density (Mg/m^3)	Aggregate size *MWD* (mm)	Aggregate stability	Crust strength** (kPa)
Control	1.38 a*	19.7 a	0.75 a	0 a
Low (7.6 Mg/ha)	1.39 a	16.3 a	0.78 a	2 a
Medium (15.2 Mg/ha)	1.26 b	13.8 b	0.75 a	0 a
High (30.4 Mg/ha)	1.28 a	16.6 a	0.84 b	0 a

* Values followed by the same letter in each column are not significantly different (P=0.10).

** Crust strength was determined in the 0-0.05 m depth: other properties were determined in the 0-0.15 m depth.

RESULTS and DISCUSSION

Burr – cattle manure

Soil chemical properties There were no significant (P = 0.10) differences in the soil pH (range: 7.6 – 7.8) between any of the treatments and the control (data not shown). Chang et al. (1990) documented decreases in soil pH following long-term (11 years) application of feedlot manure, leading to a suggestion that the soil might eventually become more acidic with continued manure applications. In contrast, Hoyt and Rice (1977) reported cattle manure to have a buffering effect against decrease in soil pH. Sommerfeldt et al. (1973) observed that soils of a field under irrigation that had been manured annually at near recommended rate (70 Mg/ha) for over 40 years did not become acidic.

There were no significant (P = 0.10) differences in the electrical conductivity (range: 0.64 –1.88 dS/m) between any of the treatments (data not shown). Chang et al. (1990) showed a linear increase in EC with time due to repeated (eleven) annual applications of cattle feedlot manure in southern Alberta. They indicated that even under irrigated conditions, with a higher leaching rate than that of the non-irrigated, the applied water was not sufficient to wash down all the soluble salts from the soil profile. In the Burr cattle manure trial, the SAR (1.66) of the medium rate treatment was slightly but significantly (P = 0.10) higher than that of the control (0.67) and low rate (0.74) treatments. The difference in SAR between the medium (1.66) and high rate (1.30) treatments was not significant. Chang et al. (1990) suggested that there is a potential for soils to become sodic as a result of repeated cattle feedlot manure applications. Chang et al. (1991) and McCalla (1974) also documented substantial increases in soil salinity and sodicity in other studies when manure was applied repeatedly over several years.

There were no significant (P = 0.10) differences in the organic carbon content (range: 2.99 – 3.30%) between any of the treatments (data not shown). However, several researchers have reported increases in organic matter content of soils following manure applications for several years. For example, Mathers and Stewart (1980, 1984) and Hoyt and Rice (1977) reported that cattle feedlot and barnyard manure applied for eleven and six successive years, respectively, increased soil organic matter. Three annual applications of cattle feedlot manure at the rate of 224 Mg/ha raised the organic matter content of Pullman clay loam soil from 1.5 to 3.5% (Mathers and Stewart 1974). These rates of addition are much higher than those used in the current study. Similarly, Mugwira (1979) observed an increase in the organic matter content from 2.2 to 3.2% due to three annual applications of dairy cattle manure to a silty clay loam soil. Most of the increases in soil organic matter that the above authors reported occurred in the top 0 - 0.15 m depth of the soils. The reason for the lack of a significant increase in the soil organic carbon content at the Burr cattle manure site could be that the amount of manure organic C added over four years was not large enough to result in significant differences between the treated and control plots in the 0 - 0.3 m depth samples used in this study. Higher microbial activity associated with the high organic matter content of these Black soils may also accelerate the decomposition of manure carbon.

Soil physical properties The bulk density of the soil (0 - 0.15 m) at the medium rate treatment was significantly (P=0.10) lower than that in the control (Table 2). Mathers and Stewart (1984) also reported that manure incorporation decreased soil bulk density. The authors attributed their observation to the effect of manure on increasing the organic matter content of the soil. Cattle manure is of lower density than soil and the effect of manure incorporation into soils would be reduction in the bulk density of the soil.

The aggregate size (*MWD*) was lower in the three cattle manure treatments than in the control. However, only the medium rate manure treatment was significantly (P = 0.10) lower (Table 2). The reduction in the aggregate size could have been caused by some dispersion of the aggregates due to the sodium added to the soil with the manure. So and Aylmore (1995) concluded that increasing sodium results in the dispersion of soil aggregates. Aggregate stability increased significantly (P = 0.10) at the high rate of cattle manure addition (Table 2). Similarly, Elson (1941, 1943) reported increases in aggregate stability resulting from manure applications. There were no significant (P = 0.10) differences in crust strength between any of the treatments. In previous studies, So and Aylmore (1995) and Rengasamy and Olsson (1991) reported increased values of crust strength (modulus of rupture) associated with elevated sodicity. In another study conducted in a pot experiment, barnyard manure applications decreased crust strength on Luvisolic soils (Nuttall 1970).

Burr – hog manure

Soil chemical properties The pH of the soil in the high rate hog manure treatment (7.6) at Burr was significantly (P = 0.10) lower than that of the control (8.0) and the medium rate treatment (7.9). This could be because of a low buffering capacity of the soil associated with its high sand content, coupled with acidification due to nitrification of ammonium from the hog manure, as liquid hog manure has a higher proportion of its N as ammonium as compared to cattle manure (Mooleki et al. 2001). King et al. (1990) observed an increase or a decrease in soil pH depending on the application rate, in the surface (0 - 0.15 m) soil (pH 5.4) due to annual applications of hog lagoon effluent to Coastal bermudagrass for eleven years. In their study, King et al. (1990) reported that the low rate (335 kg N ha^{-1} y^{-1}) and medium rate (670 kg N ha^{-1} y^{-1})

Table 3. Soil physical properties at the Burr hog manure site in samples taken in the summer of 2000.

Treatment	Bulk density (Mg/m^3)	Aggregate size *MWD* (mm)	Aggregate stability	Crust strength** (kPa)
Control	1.34 a*	21.4 a	0.71 a	3 a
Low (37.5 m^3/ha)	1.31 a	18.3 a	0.76 a	4 a
Medium (75.1 m^3/ha)	1.23 b	16.1 a	0.72 a	0 b
High (150.2 m^3/ha)	1.28 a	12.6 b	0.74 a	0 b

* Values followed by the same letter in each column are not significantly different (P=0.10).
** Crust strength was determined in the 0-0.05 m depth: other properties were determined in the 0-0.15 m depth.

applications of the hog lagoon effluent increased the soil pH by 0.4 to 0.5 units whereas the high rate (1340 kg N $ha^{-1} y^{-1}$) annual manure application decreased the pH of the soil by 0.3 units.

Similar to the cattle manure trial, there were no significant (P = 0.10) differences in the electrical conductivity (range: 0.53 – 1.41 dS/m) between the hog manure treatments at the Burr site (data not shown). The SAR was significantly (P = 0.10) higher in the medium rate treatment (1.29) than in the control (0.40) indicating possible increases in sodicity with repeated hog manure applications, which should be monitored. There were no significant (P = 0.10) differences in organic carbon content (range: 2.75 – 3.20%) between any of the treatments (data not shown). As with the cattle manure treatments, additions were made for only four years and the inherent high level of organic matter in the soil made detection of small differences difficult. Liquid hog manure is greater than 95% water, with a low solids and organic matter content, and the amounts of organic carbon added with the liquid hog manure are very small relative to the total amount of organic carbon in the soil.

Soil physical properties The bulk density of the soil treated with hog manure was significantly (P = 0.10) lower at the medium rate treatment than the control (Table 3). Similar to the cattle manure trial, the aggregate size decreased with hog manure application at this site. This could be explained by the dispersive effect of added manure Na in the soil. There were no significant differences in aggregate stability (range: 0.71 – 0.76) between any of the treatments (data not shown). The medium and high rate applications of the hog manure decreased the crust strength as compared to the control, which might be due to elevated surface organic matter from the crop residue. Similarly, Hafez (1974) reported reduction in crusting strength due to addition of hog manure to a Capay clay soil.

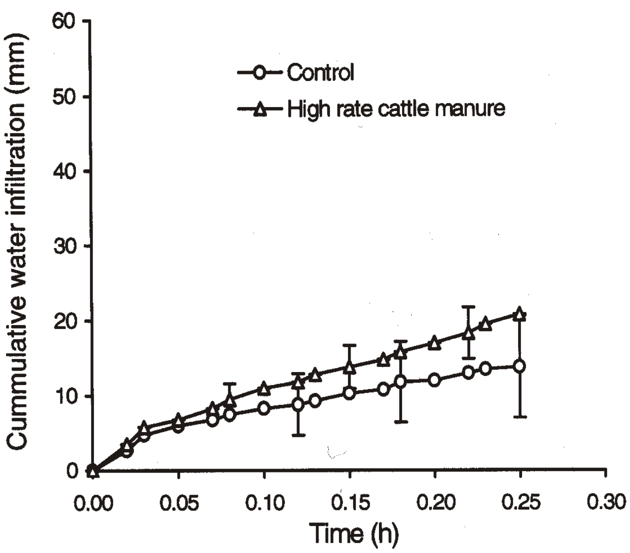

Fig. 1. Plot of cumulative water infiltration versus time at the Dixon cattle manure site. Vertical bars indicate the standard errors of the mean (n=4).

Dixon – cattle manure

Soil chemical properties Similar to the Burr cattle manure site, there were no significant (P = 0.10) differences in the soil pH (range: 7.7 – 7.9) at this site among the treatments (data not shown). The electrical conductivity of the medium rate cattle manure treatment (1.60 dS/m) was significantly (P = 0.10) higher than the control (0.30 dS/m). The SAR increased with increasing rates of cattle manure applied. The sodium adsorption ratios of the medium (0.85) and high (1.50) rate cattle manure treatments were significantly (P = 0.10) higher than the control (0.33). Although increases in EC and SAR observed after four years in this study were small, these properties should be monitored in soils receiving repeated applications of manure, especially over long time periods at higher rates. Chang et al. (1990, 1991), Pratt (1984), Mathers et al. (1977) , and Wallingford et al. (1975) also reported increases in salinity and sodicity due to repeated manure applications. There were no differences in organic matter content (range: 2.05 – 2.20%) between any of the treatments (data not shown), as observed at the Burr site.

Soil physical properties There were no significant (P = 0.10) differences in the soil bulk density (range: 1.27 – 1.29 Mg/m^3), aggregate size (range: 11.7 – 15.6 mm), aggregate stability (range: 0.68 – 0.73), and crust strength (range: 11 – 76 kPa) among any of the treatments at the Dixon cattle manure site (data not shown). However, similar to the Burr cattle manure site, there was a trend towards lower bulk density and aggregate size with manure addition.

Cattle manure addition did not significantly (P = 0.10) affect the cumulative water infiltration at this site as shown by overlapping error bars (Fig. 1). However, there was a trend toward higher infiltration in the cattle manure treatment as compared to the control. Similarly, Sommerfeldt and Chang (1987) did not find any significant effect on soil water infiltration after twelve annual applications of cattle feedlot manure.

Dixon – hog manure

Soil chemical properties There were no significant (P = 0.10) differences in the soil pH (range: 7.6 –7.6) among any of the hog manure treatments at the Dixon site (data not shown). The electrical conductivities (range: 0.32 – 0.55 dS/m) of the manure

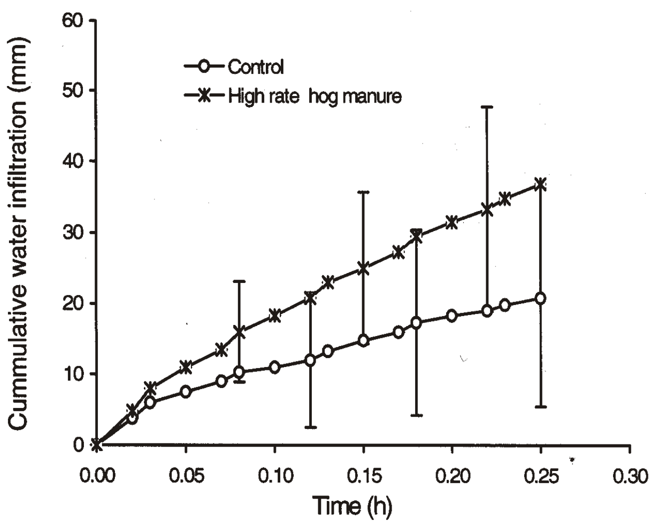

Fig. 2. Plot of cumulative water infiltration versus time at the Dixon hog manure site. Vertical bars indicate the standard errors of the mean (n=4).

treatments were also not significantly (P = 0.10) different from the control (data not shown). Although there was a general trend for the sodium adsorption ratio (range: 0.48 – 0.92) to increase with increasing rate of manure application as at Burr, at the Dixon site the differences were not statistically significant (P = 0.10) (data not shown).

Soil physical properties There were no significant (P = 0.10) differences in the soil bulk density (range: 1.32 – 1.34 Mg/m^3), aggregate size (range: 12.2 – 15.1 mm), aggregate stability (range: 0.61 – 0.67), and crust strength (range: 35 – 71 kPa) between any of the treatments at the Dixon hog manure site (data not shown). Lack of significant effects at this site might be attributed to better inherent structure and drainage in the Dixon soil as compared to the Burr soil.

Additions of hog manure did not significantly (P = 0.10) affect the cumulative water infiltration. The cumulative water infiltration curves were not significantly different as evidenced by overlapping error bars (Fig. 2). As compared to the cattle manure treatments, the hog manure treatments showed more variability in terms of cumulative water infiltration and the hog manure treatments had higher cumulative water infiltration, despite less organic matter added directly as manure. Although the cumulative water infiltration was not significantly affected due to either of the manure treatments, the plots that received the hog manure had a tendency towards higher infiltration. This may be attributed to greater crop biomass and residue (straw) produced on the hog manure plots as compared to the cattle manure plots during the past four years (Mooleki et al. 2001), as Baumhardt and Lascano (1996) reported an increase in mean cumulative infiltration associated with increasing amounts of crop residue.

CONCLUSION

Four annual applications of cattle and hog manure did not affect the pH of the soils except at the Burr hog manure site where the soil pH decreased by 5%. A trend towards increased EC of these soils became apparent following the repeated manure applications. The increase in EC, by 433%, was statistically significant at the Dixon cattle manure site. Both cattle and hog manure increased the sodium adsorption ratio (in the range of 148 – 354%) in these soils suggesting that there is a potential for increased sodicity with several applications of manure at high rates at around 400 mm average annual precipitation. The repeated applications of manure decreased the bulk density and aggregate size of the sandy loam textured soil at the Burr site by 8 – 9% and 30 – 40%, respectively, but increased the aggregate stability by 12%. There was also a trend towards decreasing aggregate size in the loamy textured soil at the Dixon site. Crust strength generally followed an increasing trend with increasing rates of manure application in the Dixon soil whereas in the Burr soil it decreased by 100%. The four annual applications of manure were not enough to significantly increase the cumulative water infiltration into the soils. However, a trend towards increased infiltration with manure application was observed.

In general, the four annual applications of manure did not have large impacts on the chemical or physical attributes of these two Black soils. It appears that the effect of manure application on soil chemical and physical properties in these soils is variable depending on soil and manure type. The trend towards increases in EC and SAR, and decreases in aggregation following the four annual applications of manure suggests that salinity and sodicity assessment should be part of a monitoring program on manured lands to ensure that soil quality and productivity are not adversely affected over the long-term by repeated manure applications.

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