The Long-Term Effect of Repeated Application of Hog Manure on Soil Productivity and on the Quality of the Environment in Semi-Arid regions of Saskatchewan.

Mike Grevers

Department of Soil Science, University of Saskatchewan, Saskatoon, SK

Introduction

Hog production in Saskatchewan is expected to increase to over 3 million hogs by the year 2005, which is triple the current production. High volume hog operations are planned across Saskatchewan; however, concerns about the disposal of large volumes of hog manure have resulted in some communities objecting to the establishment of these operations in their area.

Manure applied to the soil is a generally accepted practice for improving soil fertility and for improving soil quality. In general, manure has been found to increase soil organic matter, improve soil fertility, improve soil structure (Chater and Gasser, 1970; Sommerfeldt et al. 1988), and increase crop production (Grevers and Schoenau, 1997; Sommerfeld and Chang, 1985). Repeated applications of high volumes of manure, however, have led to concerns regarding the possibility of exceeding the capacity of the soil-plant system to absorb and re-cycle the nutrients supplied through the manure. Hog manure contains significant quantities of plant nutrients such as nitrogen, and large volumes of soil-applied hog manure may result in excessive levels of nitrate-nitrogen in the soil and possible groundwater contamination by nitrate leaching. Furthermore, hog manure contains salts such as sodium, and small quantities of heavy metals such as cadmium. The general public is concerned that large volumes of hog manure, some as high as 15,000 gallons per acre, when applied repeatedly, may deteriorate the quality of local soils, reduce crop production and lead to pollution of the environment in general (Chang et al. 1990; Larson, 1991a,b).

The long-term impact of hog manure applications on the quality of the soil and that of the environment is not known. Larney et al. (1993) caution that the residual effect of long-term manure applications needs to be evaluated. For optimal application rates of hog manure in Saskatchewan, improved knowledge is essential regarding the long-term effect of hog manure application on salinity, acidity, soil density, aggregation, soil strength, crop quality and on crop production. Furthermore, the influence of hog manure on environmental quality, such as heavy metal contamination and nitrate pollution is not clear. Projects to address these issues are currently underway in the Black soil zone. However, information is also needed on manure effects in the drier Dark Brown and Brown soil zones.

The objectives of this study are: 1) to determine the long-term effect of repeated applications of hog manure on soil quality and on crop production in the Brown and Dark Brown soil zones, 2) to identify soil types most suitable for the long-term application of large volumes of hog manure, and 3) to determine the effect on the environment of repeated applications of soil-applied hog manure.

PROJECT DESIGN:

Field Study

A total of four sites are being established in consultation with staff from the P.F.R.A. and from the Quadra Group. Two sites will be located in the Brown soil zone and two sites will be located in the Dark Brown soil zone, one of the four sites will be an irrigated site.

The experimental design is as follows (also see the diagram on next page):

Description of field sites

Site #1 Plenty. Cooperator: Victor Hamilton. Hog Barn: Eagle Creek Hog Barn
Field Location: SW 5-33-18-W3. Soil type: Regina Association, clay to heavy clay

Site #2 Beechy. Cooperator: Robert Odermatt. Hog Barn: Beechy Hog Barn
Field Location: NW11-22-11-W3. Soil Type: Willows Association, clay to clay loam

Site #3 River Lake-Irrigated. Cooperator: Rick Loepke. Hog Barn: River Lake Hog barn
Field Location: SW20-24-5-W3. Soil type: Birsay Association, sandy loam

Site #4 River Lake-Dry-Land. Cooperator: Rick Loepke. Hog Barn: River Lake Hog barn
Field Location: SW18-24-5-W3. Soil type: Birsay Association, sandy loam

Three replicated blocks at each of the sites

Five levels of hog manure/fertilizer application rates

- Control (no hog manure or fertilizer)
- 5,000 gallons per acre of hog manure soil injected
- 10,000 gallons per acre of hog manure soil injected
- Low rate of fertilizer (100% of soil test recommendations for N & P)
- High rate of fertilizer (200% of soil test recommendations for N & P)

Six levels of repeated application rates.

- a one-time application only
- 2 successive annual applications,
- 3 successive annual applications,
- 4 successive annual applications,
- applied once every two years,
- applied once every 3 years

<u>Analysis of hog manure</u>

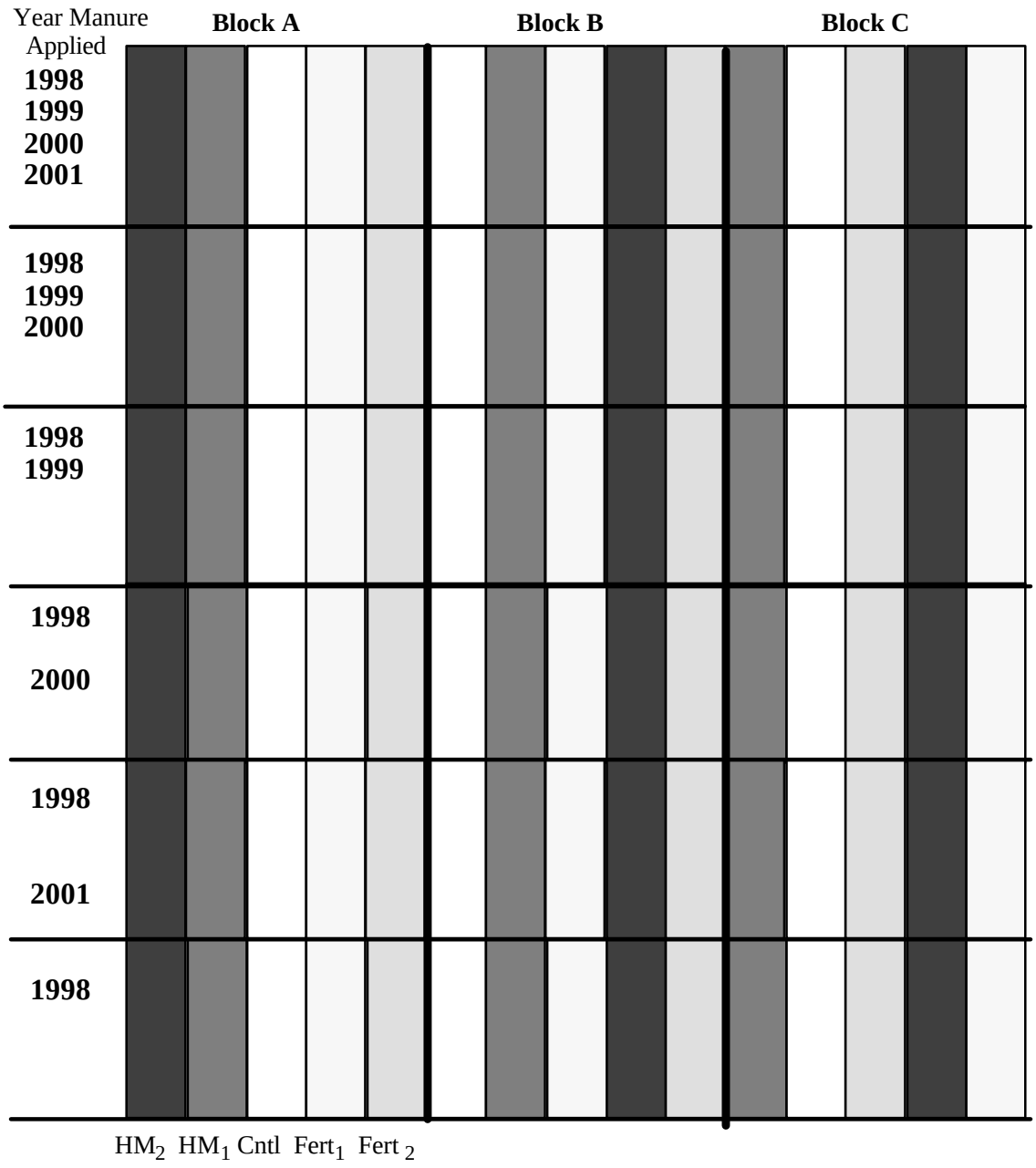
During the application of the hog manure samples will be collected from the applicator. The samples will be transported to the Univ. of Sask. where they will be stored at 4^{o} C for subsequent analysis of chemical characteristics etc.

<u>Soil analysis</u>

Each of the sites will be surveyed extensively, and a detailed characterization of the soils will be obtained. Soil samples will be collected from the top 60 cm, and transported to the University of Saskatchewan where they will be dried, ground and analyzed for soil chemical and physical properties. In the spring, soil water content, soil strength and soil density will be sampled in the field. In the final year of the project soil samples will be collected from below the root zone (~3m) and analyzed for nitrates etc.

Plant and yield analysis.

Crop biomass samples will be collected by square meter sampling prior to harvest. The samples will be transported to the Univ. of Sask., where they will be dried, weighed, and threshed. Total and grain weights will be determined and the grain samples will be analyzed for protein content.



Manure Treatments: HM_1: 5,000 gallons per acre of Hog Manure
HM_2: 10,000 gallons per acre of Hog manure
Cntl: Control: no Hog Manure and no Fertilizer
$Fert_1$: Chemical Fertilizer at low rate
$Fert_2$: Chemical Fertilizer at high rate

Rotations: years indicate when manure is applied

Plot dimensions: Main Plot: 300' x 600' = 180,000 ft^2 = 4.1 acres
Replicate Blocks: 3 replicate blocks. Each block consists of 5 manure/fertilizer treatments x 6 annual applications.
Sub-plots: width 15 feet wide + 5 foot border (20 ft for plot width)
length: 75 feet + 25 feet border for a total of 100 feet

Table 1. Nutrient content of hog manure

	Plenty	Beechy	Riverhurst	Plenty	Beechy	Riverhurst
Nutrient	lbs per 1000 gallons			lbs per 6,000 gallons		
Nitrogen	31	38	34	186	228	204
Phosphorus	1.6	3.2	3.0	10	19	18
Ammonium-N	25	30	25	150	180	150

3. Plant protein content and total N in the crop in 2001

3.1 At the Plenty site (Table 4), protein percentage for wheat ranged from 15% to 20%:

a) all of the manure treatments increased protein levels
b) there were few differences amongst manure treatments on protein percentage
a) there were significant difference amongst manure treatments on N content in the grain and straw. In general N content increased as the amount of manure applied increased

3.2 At the Beechy site (Table 5), protein percentage for Durum averaged around 19%. There were no significant differences due to any of the treatments on either grain protein percentage or on N content in the straw and grain.

3.3 At the Riverhurst - Irrigated site (Table 6), protein percentage for barley ranged from 10% to 15%:

a) most of the manure treatments increased protein levels
b) there were few differences amongst manure treatments on protein percentage
c) there were significant difference amongst manure treatments on N content in the grain and straw. In general N content increased as the amount of manure applied increased

4. Soil Nitrogen levels in the fall of 2001

4.1 At the Plenty site (Table 7), there were significant residual effects of hog manure applications on plant available N levels, and excessively high levels at the high rates, especially when repeated. Specifically with respect to hog manure applications:

a) one single application at the low rate in 1999 increased soil N levels by 16 kg/ha
b) one single application at the high rate in 1999 increased soil N levels by 223 kg/ha
c) two applications at the low rate increased soil N levels by an average of 155 kg/ha
d) three successive applications at the low rate increased soil N levels by 381 kg/ha
e) two applications at the high rate increased soil N levels by an average of 408 kg/ha
f) three successive applications at the high rate increased soil N levels by 943 kg/ha

With respect to urea fertilizer applications:

g) three successive applications at the low rate increased soil N levels by 12 kg/ha
h) three successive applications at the high rate increased soil N levels by 79 kg/ha

With respect to type of N (nitrate vs. ammonium):

i) in all plots the ammonium-N concentration in the 0-60 cm ranged from 22 to 41 kg/ha. The accumulation of N in the plots was therefore mainly in terms of increased nitrate-N levels

With respect to depth increments

j) in most of the plots the concentration of available N was greater in the 0-30 cm depth than in the 30-60 cm depth.

4.2 At the Beechy site (Table 8), there were significant residual effects of hog manure applications on plant available N levels, excessive levels at the high rates, especially when repeated. Specifically with respect to hog manure applications:

a) one single application at the low rate in 1999 increased soil N levels by 30 kg/ha
b) one single application at the high rate in 1999 increased soil N levels by 122 kg/ha
c) two applications at the low rate increased soil N levels by an average of 93 kg/ha
d) three successive applications at the low rate increased soil N levels by 305 kg/ha
e) two applications at the high rate increased soil N levels by an average of 328 kg/ha
f) three successive applications at the high rate increased soil N levels by 727 kg/ha

With respect to urea fertilizer applications:

k) three successive applications at the low rate increased soil N levels by 38 kg/ha
l) three successive applications at the high rate increased soil N levels by 93 kg/ha

With respect to type of N (nitrate vs. ammonium):

m) in all plots the ammonium-N concentration in the 0-60 cm ranged from 24 to 36 kg/ha. The accumulation of N in the plots was therefore mainly in terms of increased nitrate-N levels

With respect to depth increments

n) in some of the plots the concentration of available N was greater in the 30-60 cm depth than in the 0-30 cm depth, thus indicating movement of soil N to greater depth

4.3 At the Riverhurst - Irrigated site (Table 9), there were significant residual effects of hog manure applications on plant available N levels, excessive levels at the high rates, especially when repeated. Specifically with respect to hog manure applications:

1. one single application at the low rate in 1999 did not increase soil N levels
2. one single application at the high rate in 1999 increased soil N levels by 67 kg/ha
3. two applications at the low rate increased soil N levels by an average of 41 kg/ha
4. three successive applications at the low rate increased soil N levels by 133 kg/ha
5. two applications at the high rate increased soil N levels by an average of 158 kg/ha
6. three successive applications at the high rate increased soil N levels by 286 kg/ha

With respect to urea fertilizer applications:

7. three successive applications at the low rate did not increase soil N levels
8. three successive applications at the high rate increased soil N levels by 19 kg/ha

With respect to type of N (nitrate vs. ammonium):

9. in all plots the ammonium-N concentration in the 0-60 cm ranged from 10 to 27 kg/ha. The accumulation of N in the plots was therefore mainly in terms of increased nitrate-N levels

With respect to depth increments

10. in all of the plots with high N concentrations the concentration of available N was greater in the 30-60 cm depth than in the 0-30 cm depth, thus indicating significant movement of soil N to greater depth

4.4 At the Riverhurst – Dry land site (Table 10), there were significant residual effects of hog manure applications on plant available N levels, excessive levels at the high rates, especially when repeated. Specifically with respect to hog manure applications:

a) one single application at the low rate in 1999 increased soil N levels by 26 kg/ha
b) one single application at the high rate in 1999 increased soil N levels by 129 kg/ha
c) two applications at the low rate increased soil N levels by an average of 103 kg/ha
d) three successive applications at the low rate increased soil N levels by 163 kg/ha
e) two applications at the high rate increased soil N levels by an average of 277 kg/ha
f) three successive applications at the high rate increased soil N levels by 350 kg/ha

With respect to urea fertilizer applications:

g) three successive applications at the low rate increased soil N levels by 35 kg/ha
h) three successive applications at the high rate increased soil N levels by 122 kg/ha

With respect to type of N (nitrate vs. ammonium):

i) in all plots the ammonium-N concentration in the 0-60 cm ranged from 10 to 16 kg/ha. The accumulation of N in the plots was therefore mainly in terms of increased nitrate-N levels

With respect to depth increments
in all of the plots the concentration of available N was greater in the 0-30 cm depth than in the 30-60 cm depth

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Table 1. Available soil nutrient levels in the fall of 2000 – Beechy and Plenty sites

Treatment	N(0-30)	N(30-60)	N(0-60)	N(60-90)
	---------- kg/ha ----------			
		Beechy		
Control	24_{c}	23_{d}	47_{c}	40_{b}
U1 X-0	22_{c}	20_{d}	43_{c}	
U1 X-X	21_{c}	24_{d}	44_{c}	
U2 X-0	21_{c}	24_{d}	45_{c}	
U2 X-X	24_{c}	28_{d}	52_{c}	47_{b}
HM1 X-0	30_{c}	27_{d}	58_{c}	
HM1 X-X	94_{b}	80_{c}	174_{b}	
HM2 X-0	56_{bc}	117_{bc}	173_{b}	
HM2 X-X	316_{a}	298_{a}	614_{a}	217_{a}
		Plenty		
Control	22_{c}	24_{c}	46_{c}	44_{b}
U1 X-0	25_{c}	21_{c}	46_{c}	
U1 X-X	24_{c}	22_{c}	46_{c}	
U2 X-0	26_{c}	21_{c}	47_{c}	
U2 X-X	45_{c}	21_{c}	66_{c}	41_{b}
HM1 X-0	44_{c}	36_{c}	80_{c}	
HM1 X-X	211_{b}	70_{b}	281_{b}	
HM2 X-0	207_{b}	94_{ab}	301_{b}	
HM2 X-X	302_{a}	105_{a}	407_{a}	97_{a}

N(0-30), N(30-60), N(0-60), and N(60-90) refer to plant available nutrient levels (NO_3- N) in the 0-30 cm, 30-60 cm, 0-60 cm and 60-90 cm depths
HM1 and HM2 indicate low (1) and high rate (2) of manure applied
U1 and U2 refer to low (1) and high rate (2) of urea fertilizer applied
X-0 and X-X refer to a single application (1998/1999) and a repeated application (1998/1999 and 1999/2000).
Treatment means followed by a different letter are significantly different ($P_{0.05}$)

Table 2. Available soil nutrient levels in the fall of 2000 – Riverhurst sites

Treatment	N(0-30)	N(30-60)	N(0-60)	N(60-90)
	---------- kg/ha ----------			
	Riverhurst - Irrigated			
Control	23_{b}	10_{c}	33_{d}	9
U1 X-0	24_{b}	10_{c}	35_{cd}	
U1 X-X	25_{b}	13_{c}	37_{cd}	
U2 X-0	27_{b}	12_{c}	39_{cd}	
U2 X-X	32_{b}	17_{c}	48_{cd}	14
HM1 X-0	33_{b}	19_{c}	52_{cd}	
HM1 X-X	60_{b}	59_{bc}	118_{c}	
HM2 X-0	56_{b}	97_{b}	153_{b}	
HM2 X-X	233_{a}	239_{a}	472_{a}	27
	Riverhurst - Dryland			
Control	23_{b}	17_{b}	40_{bc}	16_{b}
U1 X-0	20_{b}	14_{b}	34_{bc}	
U1 X-X	25_{b}	18_{b}	43_{bc}	
U2 X-0	17_{b}	13_{b}	30_{c}	
U2 X-X	54_{b}	25_{b}	79_{bc}	19_{b}
HM1 X-0	30_{b}	15_{b}	45_{bc}	
HM1 X-X	66_{b}	28_{b}	94_{b}	
HM2 X-0	66_{b}	25_{b}	91_{bc}	
HM2 X-X	234_{a}	100_{a}	334_{a}	24_{a}

N(0-30), N(30-60), N(0-60), and N(60-90) refer to plant available nutrient levels (NO_3- N) in the 0-30 cm, 30-60 cm, 0-60 cm and 60-90 cm depths

HM1 and HM2 indicate low (1) and high rate (2) of manure applied

U1 and U2 refer to low (1) and high rate (2) of urea fertilizer applied

X-0 and X-X refer to a single application (1998/1999) and a repeated application (1998/1999 and 1999/2000).

Treatment means followed by a different letter are significantly different ($P_{0.05}$