Characterization of Solid Beef Manure

A Study Funded by:
The Manitoba Cattle Producers Association
Manitoba Agriculture, Food and Rural Initiatives

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Background:

Manure management planning is an integral part of any sustainable livestock production system. The requirement for livestock producers to prepare manure management plans has increased considerably in recent years. Since 1998, livestock operations that are 400 animal units in size or greater have been required to submit plans to Manitoba Conservation under the Livestock Manure and Mortalities Management Regulation (MR42/98). Last March, this requirement was extended to operations that are 300 animal units in size or greater.

There are 4 basic steps in developing a manure management plan:

1. Establishing crop nutrient requirements based on realistic crop yield targets.
2. Crediting the nutrients that are available from the soil using soil sampling and analyses.
3. Determining manure nutrient availabilities.
4. Calculating a manure application rate for each field and crop to be grown.

In order to estimate manure nutrient availabilities, the nutrient content of the manure must be determined. This can be done through manure nutrient analyses or by using average “book” values for a given manure type. One concern with average “book” values is that they may not reflect the actual nutrient content of the manure to be land applied. This is because the variability in manure nutrient analyses can be extensive. For this reason, manure analyses are recommended for manure management planning. It should be noted, however, that solid beef manure is extremely heterogeneous and representative samples can be very difficult to take. A sample that is not representative of the manure to be land applied may be just as inaccurate as, or worse than, a “book” value.

In addition to the heterogeneity of solid beef manure, it is also not a balanced fertilizer. As such, manure application rates can only target one nutrient. The current recommended practice is to apply manure based on the N requirements of the crop. This often over-applies P which has now become an issue of environmental concern.

Objectives:

The objectives of this study are to:

1. Determine the macro-nutrient content of solid beef manure in Manitoba.
2. Determine the variability of the macro-nutrients in solid beef manure.
3. Generate a database of nutrient analyses that can be used to create "book" values for manure management planning.
4. Evaluate manure application rates based on N and P_2O_5.

Methods:

In the fall of 2004, 93 samples of solid beef manure were taken by MAFRI regional staff from beef cattle operations throughout agro-Manitoba. The samples were shipped to Norwest Labs (Saskatoon, Saskatchewan) for analysis of:

Moisture
Total Kjeldahl Nitrogen
Ammonium Nitrogen
Total Phosphorus
Total Potassium
Total Sulphur
Electrical Conductivity
Total Carbon

Operation information, such as the type of operation, amount of bedding used, type of storage, age of manure etc. was also collected at the time the samples were taken.

The nutrient data were analysed in Microsoft Excel. The average, maximum and minimum values were calculated for each parameter. As average, maximum and minimum values do not provide a full picture of the distribution of the data, frequency histograms were also created for various parameters and management scenarios.

Results and Discussion:

Nitrogen Content

The average, maximum and minimum values for total nitrogen (N), ammonium N and available N are provided in Table 1.

Table 1. Nitrogen in Solid Beef Manure

	Total Nitrogen (N)	Ammonium N	Available N*
	(lb/ton)	(lb/ton)	(lb/ton)
Average	10.57	1.53	3.79
Max	16.90	8.50	9.63
Min	5.40	0.00	1.73

Available N* was calculated to be:

Available N = (Organic N) x 0.25 + (Ammonium N – volatilization losses)
where Organic N = Total N – Ammonium N
Available N = (Total N – Ammonium N) x 0.25 + Ammonium N x (1 – 0.25)

This assumes that 25% of the organic N in the solid beef manure is mineralized following application and that about 25% of the ammonium is lost through volatilization. The actual volatilization losses will depend on the method of manure application, time until incorporation and the weather conditions at the time the manure is applied (Table 2).

Total N ranged from 5.4 to 16.9 lb/ton with an average value of 10.57 lb/ton. The distribution of the total N data is provided in Figure 1. The majority of samples had total N contents between 8 and 16 lb/ton.

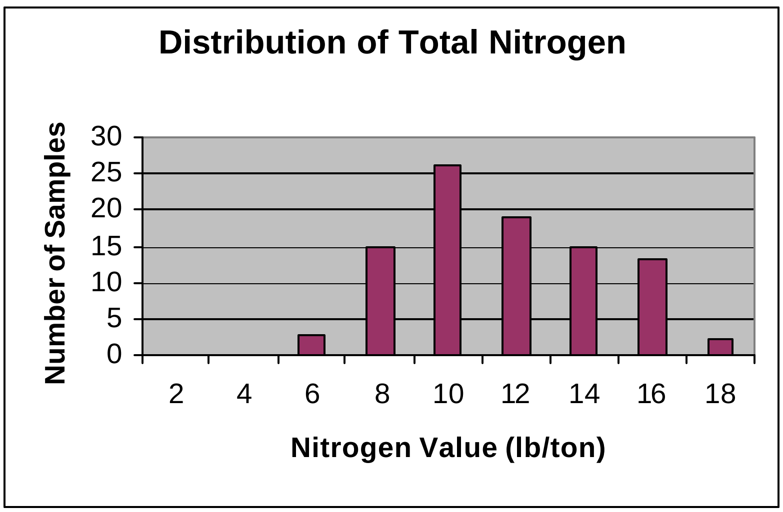

Figure 1. Distribution of Total Nitrogen in Solid Beef Manure.

The ammonium content of solid beef manure is low relative to other manures such as liquid swine manure and poultry manure. The Ammonium N ranged from 0.0 to 8.5 lb/ton with an average value of 1.53 lb/ton. The distribution of the total N data is provided in Figure 2. The majority of samples had ammonium contents below 3 lb/ton.

The available N content of the solid beef manure ranged from 1.73 to 9.63 lb/ton with an average value of 3.79 lb/ton. The distribution of the total N data is provided in Figure 2. Seventy-four % of the samples had available N contents between 3 and 5 lb/ton.

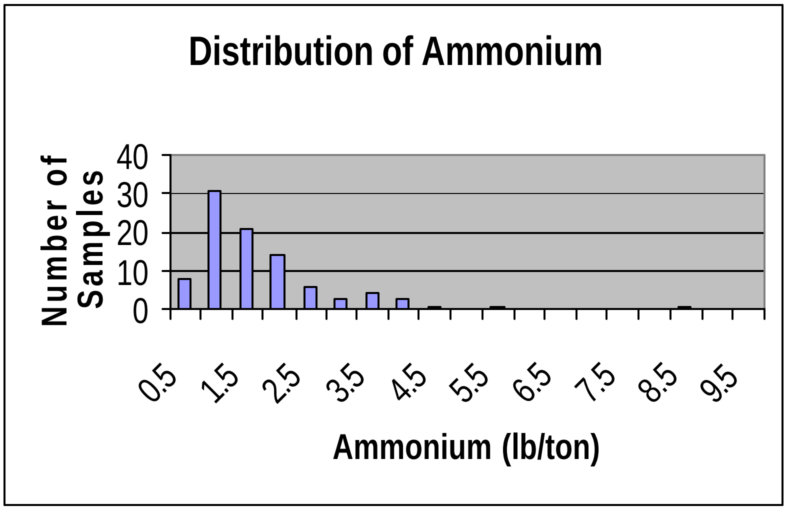

Figure 2. Distribution of Ammonium Nitrogen in Solid Beef Manure.

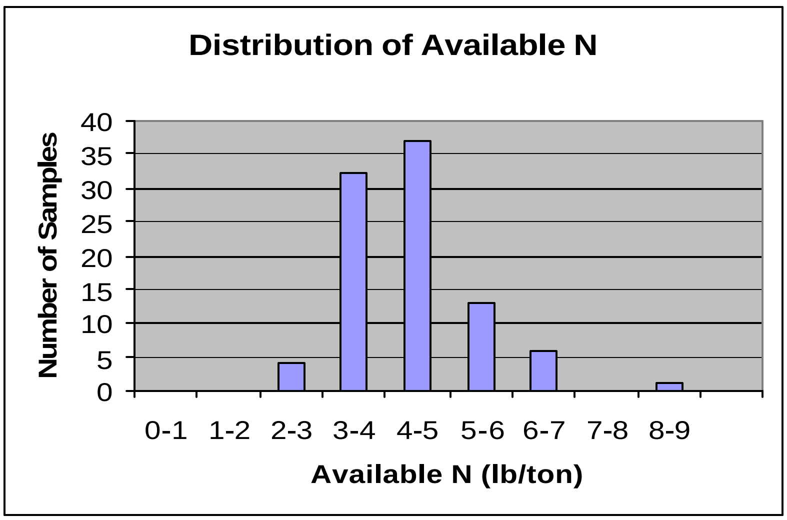

Figure 3. Distribution of Available Nitrogen in Solid Beef Manure.

Nitrogen Application Rates

The available N in the manure is used to calculate the rate of manure to apply to achieve a target N application rate. In the following example (Figure 4), a target N application rate of 70 lb/acre and a volatilization loss of 25 % are assumed.

The variability in the solid beef manure analyses became very apparent when the manure application rate required to supply 70 lb/acre was calculated. On average, 22 ton/acre were required, however, the rates ranged from 9 to 44 tons/acre. Most of the rates fell between 15 and 30 ton/acre.

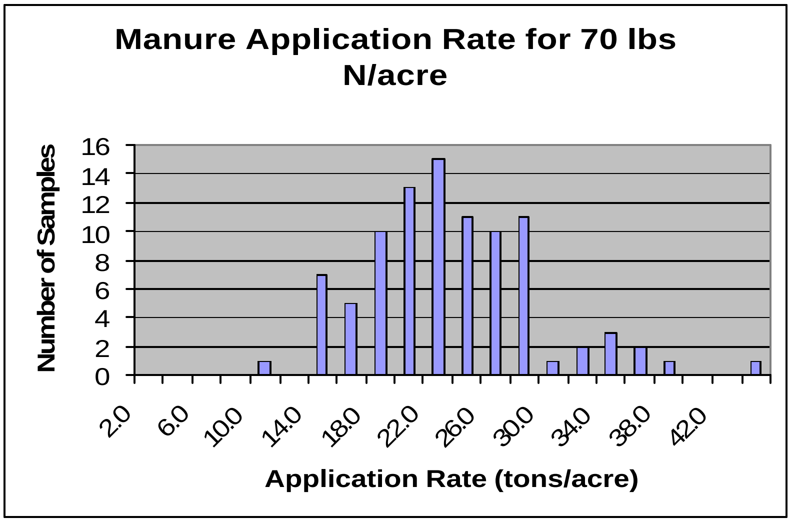

Figure 4. Solid Beef Manure Application Rates to Supply 70 lb N/acre.

Phosphorus, Potassium and Sulphur Content

The average, maximum and minimum values for total phosphorus (P), potassium (K) and sulphur (S) are provided in Table 3. Total P ranged from 0.6 to 7.00 lb/ton with an average value of 2.04 lb/ton. The distribution of the total P data is provided in Figure 5.

Table 3. Phosphorus, Potassium and Sulphur in Solid Beef Manure

	Total Phosphorus (P)	**Total Potassium (K)**	**Total Sulphur (S)**
	(lb/ton)	**(lb/ton)**	**(lb/ton)**
Average	2.04	10.45	1.80
Max	7.00	37.20	8.90
Min	0.60	3.30	0.10

P_2O_5 Application Rates

When manure is applied based on the N, P is also applied. Although the P that is applied at an N-based rate may be more or less than the crop requires, most often it is in excess of the crop P removal. If this is repeated on an annual basis, it will result in a build-up of soil test P. A build-up of soil test P can increase the risk of P mobilization and transport to surface water.

Figure 6 demonstrates the rate of P_2O_5 that would be applied with a single application of manure at 70 lb available N/acre.

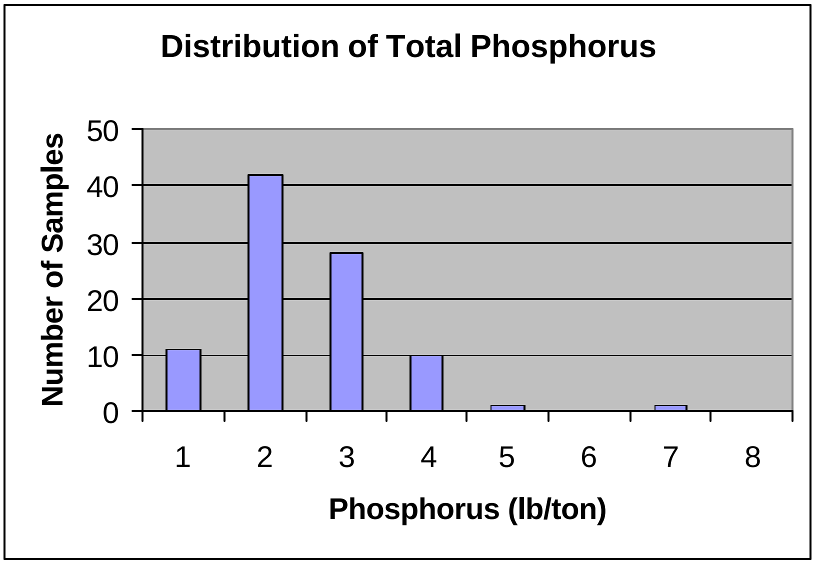

Figure 5. Distribution of Total Phosphorus (P) in Solid Beef Manure

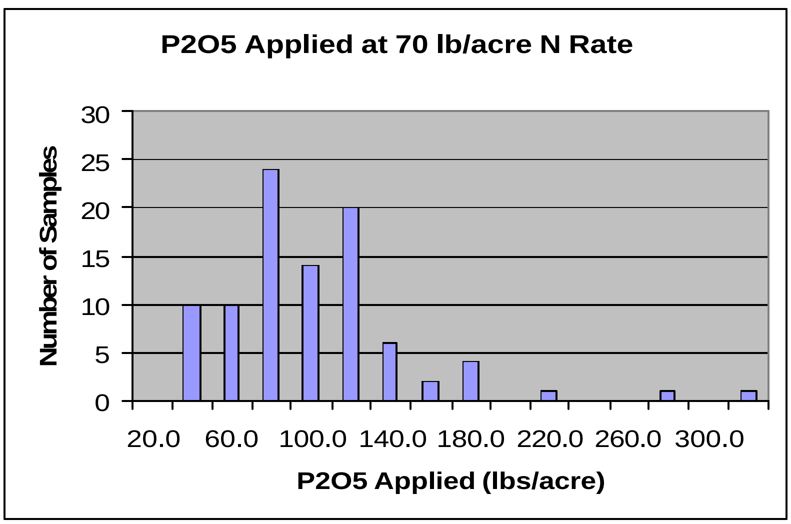

Figure 6. Rate of P_2O_5 Applied when manure is applied at 70 lb available N per acre.

In general, annual and hay crops remove about 30 lbs P_2O_5 per acre per year and 5 tons of alfalfa removes about 60 lbs P_2O_5. A single N-based manure application rate of 70 lb/acre supplied more P_2O_5 than an annual crop can remove (i.e. >30 lb/acre) 97% of the time and more P_2O_5 than high-yielding alfalfa can remove (i.e. >60 lb/acre) 82% of the time. Forty-two % of the manures supplied over 100 lb P_2O_5 at the 70 lb N per acre rate of application.

Annual applications that target 70 lb N per acre (15 to 30 tons manure per acre) to the same fields would result in soil test P build-up most of the time. However, applications at these rates every 2-4 years, as is common in the industry, could significantly slow or eliminate soil test P buildup and may require additional N and P fertilization to achieve optimum yields.

Recent concern over Lake Winnipeg water quality and the contribution of P to the lake from agriculture has prompted Government to revisit the recommendation to apply manure solely based on nitrogen. One option for the management of manure P and the build-up of soil test P is to

- allow N-based manure management within the agronomic soil test range for P;
- allow no more than 2X crop removal of P_2O_5 to be applied at moderate to high levels of soil test P; and
- allow no more than 1X crop removal of P_2O_5 to be applied at very high levels of soil test P.

The implications of these management changes on manure application rates is outlined below.

Figure 7 shows the distribution of manure application rates based on 30 lb P_2O_5 per acre. Application rates that supply only 30 lb P_2O_5 per acre ranged from 2 to 22 tons/acre. Rates of application below 10 or 12 ton/acre may be economically or technically impractical. It may be more practical to apply the manure bi-annually at twice the annual P crop removal rate (60 lb/acre). This is equivalent to the P removal rate for high yielding alfalfa. Figures 8 shows the distribution of manure application rates based on 60 lb P_2O_5 per acre.

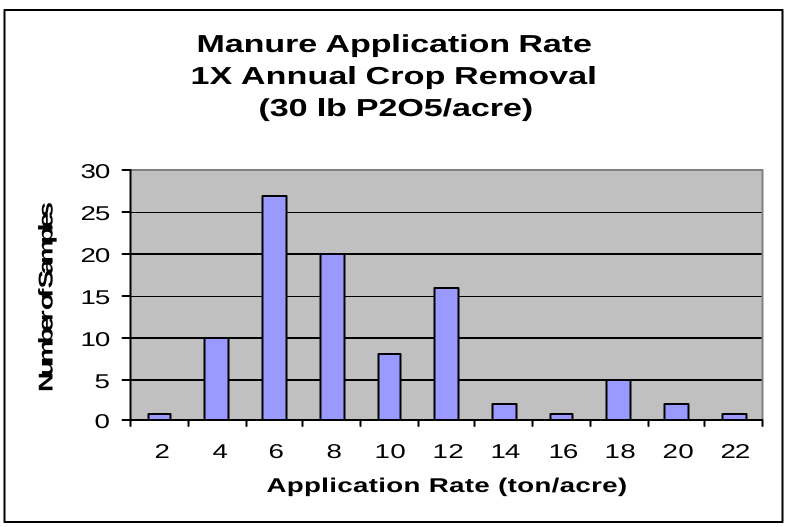

Figure 7. Distribution of manure application rates at 30 lb P_2O_5 per acre

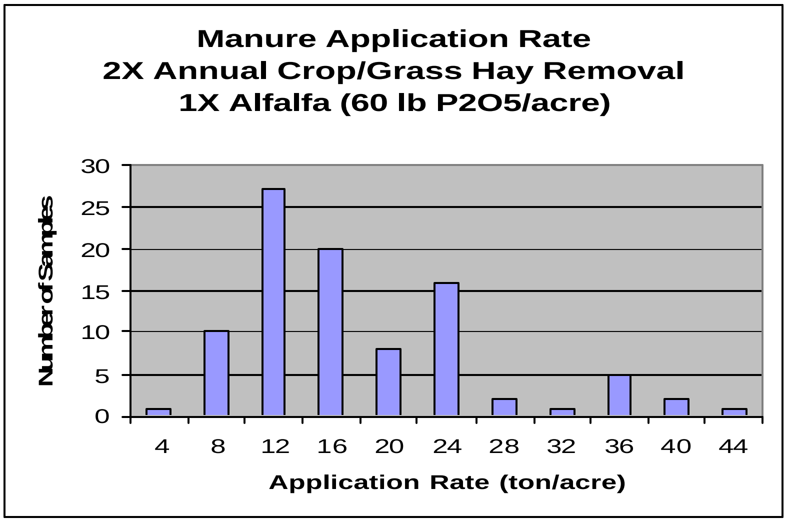

Figure 8. Distribution of manure application rates at 60 lb P_2O_5 per acre.

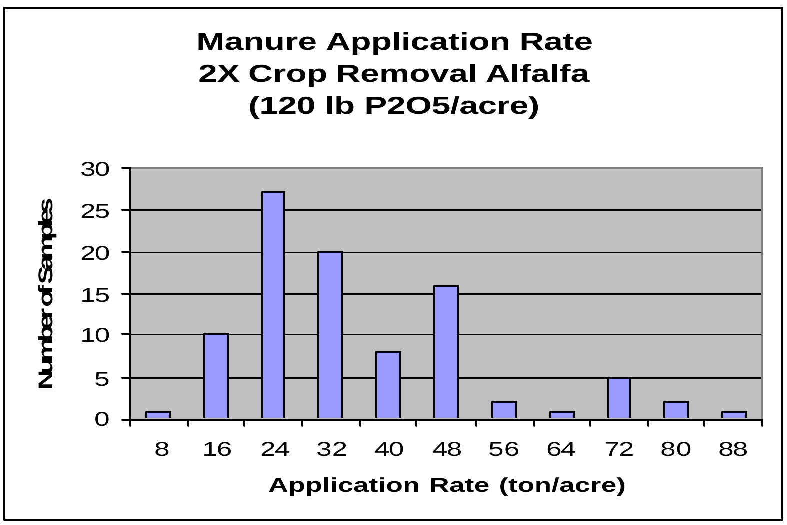

Figure 9. Distribution of manure application rates at 120 lb P_2O_5 per acre

Nitrogen:Phosphorus Ratios

The imbalance of N and P in manure is often explained by the N:P ratio of manure being much lower than the N:P removal ratio of crops. The N:P ratio of manure is calculated as:

Total N: Total P

Figure 10 shows that the bulk of the N:P ratios for solid beef manure ranged from 3:1 to 9:1. The N:P ratio of cattle manure has been reported in the literature to be in the range of 1:1 to 6:1. The average N:P removal ratios of crops range from 4.3:1 to 9.7:1 (A. Johnston, 2005. pers. comm.).

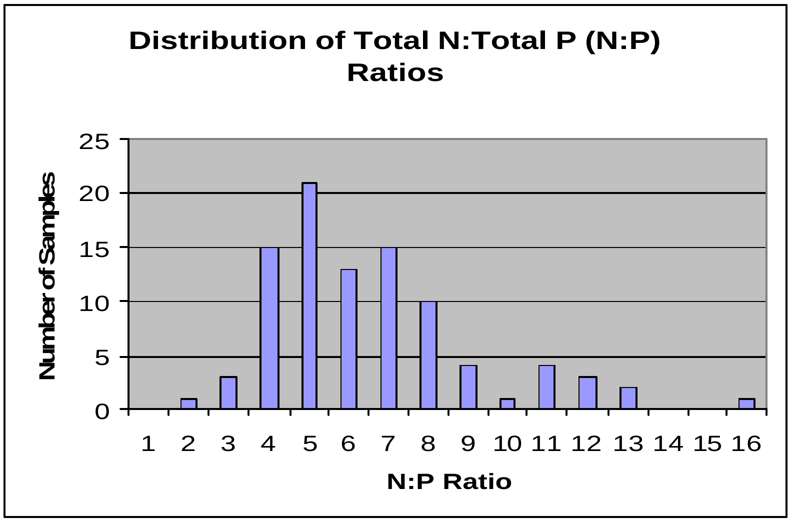

Figure 10. Distribution of N:P Ratios for Solid Beef Manure

This data indicates that the N:P ratios for solid beef manure are within the same range as the N:P uptake ratios for crop removal and is not consistent with the literature.

The imbalance between the N:P ratios of manure and crops is more apparent when the ratio of *available* N: P in the manure is considered. This makes more sense when one considers that the manure application rate calculation is based on the available N in the manure and not the total N. Figure 11 shows that the available N:P ratio for most solid beef manure samples ranged from about 1:1 to 3.5:1, which is lower than the N:P removal ratio for crops.

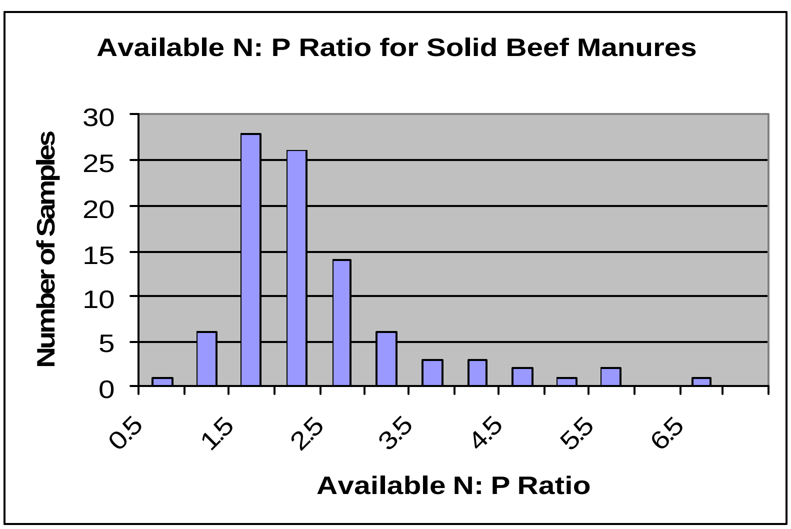

Figure 11. Available N: P Ratio for Solid Beef Manure

Carbon Content and Carbon:Nitrogen Ratios

For the purposes of calculating a manure application rate, the available N in manure is calculated as:

Available N = 0.25 x Organic N + (Ammonium N – Volatilization losses)

This function assumes that 25% of the organic N in manure is mineralized (i.e. made plant-available) in the first year following application. It has worked quite well for liquid pig manure. Solid beef manure, however, can contain a considerable amount of straw bedding. This bedding increases the C:N ratio of the manure which can dramatically alter the amount and rate of organic N that will be mineralized. Manures that have very high bedding contents, or are mostly straw, will actually immobilize (i.e. tie up) N from the soil following application and it may take months or years before the N is released.

Table 4 contains the average, maximum and minimum C and N contents and C:N ratios of the solid beef manure. The C:N ratios ranged from 7.1 to 27.6 with an average ratio of 14.6.

Table 4. Carbon and C:N Ratios for Solid Beef Manure

	Total Carbon (C) (% wet weight)	**Total N (N) (% wet weight)**	**C:N Ratio**
Average	7.34	0.53	14.59
Max	11.40	0.85	27.62
Min	3.54	0.27	7.08

Figure 4 shows the distribution of the C:N ratios for the 93 manure samples. The C:N ratio of many of the samples falls between 15:1 and 20:1 – a critical range for determining whether or not the organic N in the manure will be mineralized (lower C:N ratios) or immobilized (higher C:N ratios).

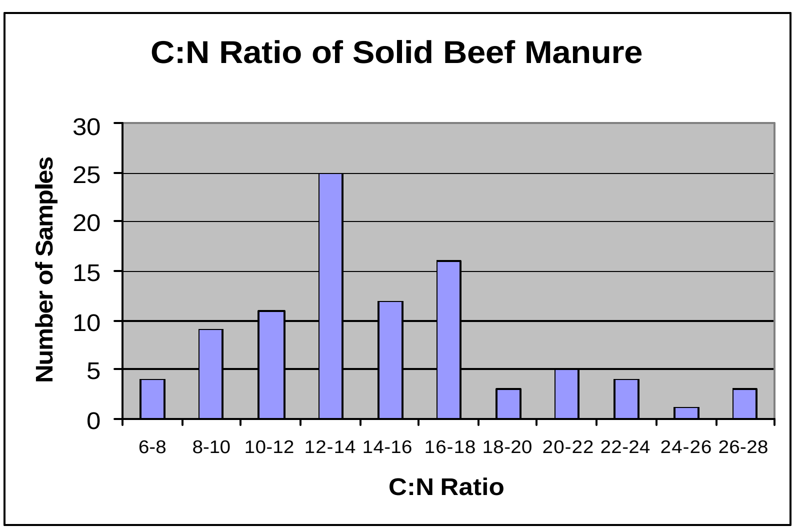

Figure 12. Distribution of C:N Ratios for Solid Beef Manure

Field research is required to determine if:

1. there is a critical C:N ratio for manure at which the N is immobilized rather than mineralized; and
2. how much of the organic N is mineralized in the year following manure application

Electrical Conductivity

Manure and soil contain the salts of ammonium, calcium, magnesium, potassium and sodium. When manure is applied to soil, varying amounts of salts are also applied depending on the salt content of the manure which can be estimated by electrical conductivity. Table 5 contains the maximum, minimum and average electrical conductivities for the solid beef manure samples.

In areas where there is adequate precipitation and drainage, these salts are normally leached through the soil profile and do not create a problem for crop production. However, in areas with borderline saline soils and low annual precipitation, manure additions may cause a salt build-up in excess of crop tolerance (Tri-Provincial Manure Application and Use Guidelines, 2004).

Table 5. Electrical Conductivity

	Electrical Conductivity
Average	6.32
Max	18.70
Min	1.70

Manure management should take into consideration soil salinity, particularly in areas with borderline saline soils and low annual precipitation. Soil salinity can also be estimated in the lab using electrical conductivity.

Conclusions:

The data from this study can be used to generate average “book” values for solid beef manure, however, the value of these estimates will depend on how closely the manure to be land applied reflects “average” solid beef manure.

Analysis of the manure to be land applied is always recommended. Unfortunately, this practice is not without its own limitations and risks. Solid beef manure is extremely heterogeneous and the macro-nutrient content is highly variable. Consequently, it is very difficult to obtain a single “representative” manure sample. A sample that does not represent the manure may be no more reliable than an “average” book value.

The most reliable method to establish the nutrient value of solid beef manure may be a number of samples from a single operation taken within one spreading season or over a number of spreading seasons. These samples could be used to create a farm-specific manure database from which the variability of the operation's manure could be established and on-farm "book" values could be generated.

The data from this study indicates that applications of solid beef manure that target the N requirements of the crop will result in the application of more P than the crop can use. Repeated, annual applications at these rates would cause a build-up of soil test P. Periodic (1 in 2 year to 1 in 4 year) applications at these rates, however, could eliminate soil test P buildup and may warrant the application of additional commercial fertilizer.

The agronomic nutrient availability of solid beef manure was not addressed in this study. Additional research is required to determine how much of the organic N is solid beef manure is mineralized in the crop year following manure application and whether or not the C:N ratio of the manure can be used to improve the mineralization estimate on a case-by-case basis. In addition, if P restrictions are placed on manure application that affect the agronomic value of the manure, P availability estimates should also be determined.