Manitoba Beef Producers Solid Cattle Manure Research Project
Executive Summaries of Final Reports Submitted to the Manitoba Beef Producers

Part 1. Survey of Management Practices for Solid Cattle Manure by Beef Producers in Manitoba

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A survey to document solid cattle manure handling by beef producers in Manitoba was conducted. Questionnaires were sent to producers in Manitoba's five main beef producing regions namely, Central, East/Southeast, Interlake, Northwest, and Southwest regions. The survey identified regional differences in calving, feeding practices, and manure handling.

The two most substantial conclusions from the survey are:

1) There is a wide range of cattle manure management practices within Manitoba, including manure management strategies that vary with herd size, overwintering practices and geographic region. Therefore, research and recommendations for environmentally and economically sustainable manure management practices must account for this variability.

2) A substantial proportion of cattle producers do not currently test manure for nutrient content and do not test their soils before manure application. Some of the reasons for this low adoption rate may be the challenges associated with acquiring representative samples and analyses for solid manure, getting reliable information about the relatively low availability of nutrients from solid manure, and controlling the rate and uniformity of solid manure application. Therefore, more effort is required to improve the development and adoption of these types of nutrient management practices for solid cattle manure.

Part 2. Field Studies of Solid Cattle Manure as a Nutrient Source in Annual Crop and Perennial Forage Crop Systems

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Manure generated from cattle operations in Manitoba is often applied to land, representing a wide range of soil types and uses. More information on nutrient release from soil applied cattle manure is needed to optimize the use of manure in improving soil fertility and minimizing the risk to the environment. Therefore, a series of field studies were initiated to (1) examine the agronomic and environmental availability of nutrients in solid cattle manure as influenced by parameters such as crop, soil, and application rate, (2) ensure optimum utilization of solid manure as a nutrient source for crop production while at the same time preserving soil and water quality.

Perennial forage study - One set of field studies was established near Lake Francis, MB to evaluate effects of cattle manure in a perennial grass forage system. In this study the agronomic effects of solid cattle manure on forage yield, quality and nutrient uptake were evaluated over two two-year periods, 2007/2008 and 2008/2009, following manure applications in the fall of 2006 and fall of 2007, respectively. In addition, nutrient concentrations in soil were monitored to evaluate the risk of excessive depletion or accumulation of nutrients. Three rates of "available N" -- 0, 75 and 150 kg N per hectare (0, 68 and 135 lb N per acre) -- were applied

as urea or manure in the 2007/2008 pair of site years. The same treatments were repeated in different plots in the 2008/2009 pair of site years. The concentration of "available N" for cattle manure was estimated by analyzing the manure for ammonium and organic N, then using the Manure Application Rate Calculator (MARC 2005) developed by Manitoba Agriculture, Food and Rural Initiatives (MAFRI 2005).

Results of the perennial forage study are summarized as follows:

- Forage yield responses to cattle manure and urea fertilizer were controlled mainly by the rate of available N applied. Manure and urea generally provided similar increases in forage dry matter yield in the two years after application.

- From a quality perspective, forage protein concentrations were not affected by nutrient source or rate, probably because increases in yield offset the increased availability of N, resulting in similar protein concentrations across nutrient treatments. As expected, given that manure contains P and K while urea does not, P and K concentrations in forage increased with manure application rate but not with urea. The increases in forage K concentrations from manure were greater than increases in forage Ca and Mg concentrations, resulting in increases in the grass tetany risk index.

- Plant uptake of N at midsummer haying and late season regrowth increased only in the first year after nutrient application and only with the high rate of urea. Effects of the treatments on the total estimated plant available N from the various treatments followed the same pattern as N uptake. The estimated plant availability of N from urea fertilizer tended to be greater than that for the equivalent manure treatment during the first year after application, while the trend was opposite during the second year after application. Therefore, the overall average estimates of plant available N from the equivalent manure and urea fertilizer treatments were similar for the entire two year period after application. Plant uptake of P was unaffected by the nutrient treatments, whereas plant uptake of K was increased by manure application at both rates.

- Fall residual soil nitrate concentrations were increased to a small degree by high rates of manure or urea application. However, these increases occurred only in the top 30 cm of soil and all nitrate concentrations in the top 60 cm of soil remained far below thresholds for environmental concern. Application of manure increased Olsen extractable P concentrations in the top 15 cm of soil and modified Kelowna extractable K concentrations in the 0-15 cm and 15-30 cm depths.

- Overall, the availability of N from cattle manure to the perennial forage crop tended to be lower than for an equivalent application of urea fertilizer during the first year after application, but superior to urea in the second year. Therefore, the overall availability of N from the equivalent manure and urea treatments was similar over the two year period. Application of a high rate of "available N" as manure or urea did not result in accumulations of fall residual nitrate that would generate environmental concerns. However, applications of manure resulted in elevated concentrations of soil test P and K in surface soil, as well as elevated concentrations of K and greater risk of grass tetany in forage.

Annual cropping studies - The second set of field studies focused on the response of spring wheat to applications of solid cattle manure. These annual cropping sites were established at two sites, one site near Argyle, MB and one site near Brandon, MB. As in the perennial forage study, the agronomic effects of cattle manure on wheat yield, quality and nutrient uptake were evaluated over a 1, 2 and 3 year period after the manure was applied. Nutrient concentrations in soil were monitored to evaluate the environmental risks of excess nutrient accumulations. In addition, an experiment with several rates of urea fertilizer added to manured and unmanured plots was conducted to separate and quantify nitrogen benefits and non-nitrogen benefits of applying solid cattle manure to an annual crop. Lastly, three successive annual applications of manure at rates of 68 and 135 lb "available" N per acre were applied to measure the nutrient uptake and environmental sustainability associated with frequent and substantial applications of cattle manure.

Results for the three studies with cattle manure application to annual crops are summarized as follows:

Study 1: Availability of nutrients from cattle manure

- The short term N benefits of solid cattle manure for annual crop production appear to be substantially less than those predicted by the current formula for estimating "available N" in manure. Generally both manure and urea N application increased spring wheat biomass, yield and N uptake compared to the unamended controls. However, within the first year of application, grain yield increases and N uptake from cattle manure applied at 75 kg "available N" per ha were 33% less and 43% less, respectively, than those from urea applied at the equivalent rate, indicating that the current formula for calculating N availability from manure is overestimating the N availability from solid cattle manure. Furthermore, the beneficial effects of manure were evident only during the first year after manure application, even though the crop responded to applications of additional urea N in the second year after manure application.

- Phosphorus uptake by wheat was generally not affected by manure application, probably due to application of phosphate fertilizer at planting in all treatments.

- With regards to soil nutrients, cattle manure presents little risk of accumulating excessive concentrations of residual nitrate, but does pose a risk of building up P and K in soil. Fall residual soil nitrate generally increased with manure application, particularly in the 0-60 cm depth. However, at the rates of manure and urea that were applied, all of the soil nitrate concentrations remained well below thresholds for Manitoba's environmental regulations. Manure application increased Olsen extractable soil P during the first year after application, but not in the second year. Kelowna extractable soil K also increased with manure application, but only at the Brandon site and only in the first year after application. There was no evidence of movement of applied nutrients below 15 cm for P and K or below 60 cm for N.

2: Sustainability of repeated annual applications of cattle manure

- Over the three successive years of cattle manure application totaling 225 and 450 kg "available" N per hectare with the two manure treatments, only 11% and 16% respectively of the "available" N added was recovered in the soil and plants. Hence, the current MAFRI developed guidelines for determining solid manure application rates (i.e., solid manure is equal to its ammonium-N plus 25% of its organic N) may not supply enough N for crops.

- Both application rates for manure increased Olsen-extractable soil P significantly in the 0-15 cm soil layer, with approximately 33% of the surplus P recovered by Olsen extraction at Argyle and 10% of the surplus P recovered by Olsen extraction at Brandon. Therefore, repeated annual applications of manure at high rates to meet crop N requirements will eventually result in excessive accumulation of P in the soil, which is a major environmental concern for water quality.

Study 3: Measure the N vs. non-N benefits of cattle manure

In most cases, the "optimum fertilizer rate method" used in this study was not able to distinguish between the nitrogen and non-nitrogen benefits of manure. Responses to supplemental urea N in the manured and unmanured plots were too subtle and/or inconsistent to generate reliable N response curves for the two manure treatments, except for one site year. The only site year where reliable response curves could be generated was at Argyle in 2007, where the economic N value of the manure was estimated at 44 kg N ha^{-1} in terms of urea fertilizer equivalents, which is 40% less than the 75 kg "available N" ha^{-1} at which the manure was applied.

Overall Conclusions from the Field Studies Regarding Agronomic and Environmental Nutrient Availability from Solid Cattle Manure and Implications for Optimum Utilization

Nitrogen - The availability of N from solid cattle manure is often substantially less than that predicted by the current formula used in Manitoba, probably due to the high carbon content from bedding material. However, the availability of N from cattle manure is also inconsistent, varying from situation to situation (e.g., with less availability than urea fertilizer over one two year cycle of perennial forage production, but greater availability than urea in another cycle). Therefore, more work is needed to refine our estimates of N availability for crop production. However, the environmental risk of accumulating or leaching excess soil nitrates from solid cattle manure application is relatively low.

Phosphorus - By comparison to the low availability of N, the availability of P from solid cattle manure is relatively high, increasing Olsen soil test P when applied at rates that exceed crop removal, especially where applied repeatedly. This increase in soil test P is beneficial to crop nutrition in low P soils, but can result in accumulation of P at concentrations that pose a significant risk to water quality, especially in areas where solid manure is frequently applied at rates targeted at supplying crop N requirements.

Potassium - The availability of K from solid cattle manure is also high, compared to N. Although accumulation of high concentrations of K in soil poses little or no risk to crop production or environmental health, application of manure K increases K concentrations in straw and forage, increasing the risk of nutritional imbalances such as grass tetany in cattle. Therefore, manure K management is an important factor to consider when applying manure onto land that is used for feeding livestock.