

# Effect of Variability in Cattle Manure Application on Soil Nutrients and Crop Yield

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## Introduction

An assessment of the effects of non-uniform distribution of solid cattle manure (SCM) is necessary, as the impact of non-uniform distribution on plant yields and soil nutrients has not been well documented in Western Canada. Equipment used in Western Canada to apply SCM such as box spreaders can have coefficient of variation (C.V.) for uniformity of distribution that can range from 30 to 110 % (Landry et al., 2011). Lorimor (2000) observed that a spinner type distribution system typically had a C.V. of 50% when spreading poultry manure. Thirion and Chabot (2008) reported that that land application using modern applicators produced highly variable uniformity in manure distribution.

A precision solid manure applicator was developed as a joint venture between the University of Saskatchewan and Prairie Agricultural Machinery Institute (PAMI) which is capable of consistently applying solid and semi-solid organic animal manure at a coefficient of variation of less than 10% (Landry et al., 2011). Organic amendments aid in reducing fertilizer expenditures and serve to supplement or replace inorganic fertilizers with the added benefit of providing small amounts of micronutrients and adding organic matter to the soil. In order for organic amendments to be measured for their agronomic benefits to crops, the distribution of the product manure should be assessed for their impact on important agronomic parameters like yield.

No data currently exists relevant to Saskatchewan conditions to provide a quantitative basis for the evaluation of the impact of applying SCM to agricultural land with varying uniformity of application. The objective of the research is to examine the effect of two year's application of SCM as affected by the uniformity of manure application on crop yield and soil nutrient load distribution and run off.

## Materials and Methods

### Field Trial

The uniformity of manure application experiment was set up as a randomized complete block design on a Black Chernozem soil about 2 km east of Humboldt, Saskatchewan.

The SCM uniformity trial was established in spring 2011 and continued in 2012 on a annually cultivated farm field. The soil at this site belongs to the Cudworth Association and is a Black Chernozem formed in calcareous silty, lacustrine parent materials and having a loam surface texture (Saskatchewan Soil Survey, 1989). The soil pH is 7.1 and the electrical conductivity is less than  $0.1 \mu\text{S m}^{-1}$ . The SCM uniformity trial at Dixon consists of 14 treatments that were replicated four times in blocks arranged in a north to south direction (Table 1).

**Table 1.** Treatment applications for manure coefficient of variation study.

Treatment	Coefficient of Variation	Urea Fertilizer Application
0 T ha <sup>-1</sup>	0%	No application
20 T ha <sup>-1</sup>	10 %	No application
60 T ha <sup>-1</sup>	10%	No application
20 T ha <sup>-1</sup>	50%	No application
60 T ha <sup>-1</sup>	50%	No application
20 T ha <sup>-1</sup>	110%	No application
60 T ha <sup>-1</sup>	110%	No application
20 T ha <sup>-1</sup>	10 %	banded urea 46-0-0 fertilizer 80 kg N ha <sup>-1</sup>
60 T ha <sup>-1</sup>	10%	banded urea 46-0-0 fertilizer 80 kg N ha <sup>-1</sup>
20 T ha <sup>-1</sup>	50%	banded urea 46-0-0 fertilizer 80 kg N ha <sup>-1</sup>
60 T ha <sup>-1</sup>	50%	banded urea 46-0-0 fertilizer 80 kg N ha <sup>-1</sup>
20 T ha <sup>-1</sup>	110%	banded urea 46-0-0 fertilizer 80 kg N ha <sup>-1</sup>
60 T ha <sup>-1</sup>	110%	banded urea 46-0-0 fertilizer 80 kg N ha <sup>-1</sup>

The size of the treatment plots in the SCM uniformity trial is 10 ft (3.05 m) by 20 ft (6.10 m). The control (no manure or commercial fertilizer applied) consisted of disturbing the soil with the SCM banding unit PAMI solid manure applicator. Two application rates of SCM were applied, a low rate of  $9 \text{ t ac}^{-1}$  ( $20 \text{ t ha}^{-1}$ ) and a high rate of  $27 \text{ t ac}^{-1}$  ( $60 \text{ t ha}^{-1}$ ). These same rates were applied to the same treatment plots in the spring (early May) of each year: 2011 and 2012. The low rate of SCM application is considered to be equal to  $150 \text{ lb total N ac}^{-1}$  ( $170 \text{ kg total N ha}^{-1}$ ) and  $450 \text{ lb total N ac}^{-1}$  ( $510 \text{ kg total N ha}^{-1}$ ) for the high rate based on manure N analyses. Three C.V. rates were used: Low C.V.  $\leq 10\%$ , Mid C.V.  $\leq 50\%$  and High C.V.  $\leq 110\%$  (Table 1). Prior to SCM application, commercial urea (46-0-0) fertilizer was applied at a rate of  $71 \text{ lb N ac}^{-1}$  ( $80 \text{ kg N ha}^{-1}$ ) using a small plot drill to half of the plots. Solid cattle manure was applied using PAMI's precision manure land applicator machine as described in Lague et al. (2006) and the plots were seeded after SCM application to oats (*Avena sativa*) in 2011 and barley (*Hordeum vulgare*) in 2012.

In the fall of 2011 and fall of 2012, the plots were harvested to collect plant biomass samples. In the intensively sampled blocks, two parallel transects, each of 10 ft (3.05 m) in length per plot, were established located in a east-west direction within the plot. Six  $2.7 \text{ ft}^2$  (one-quarter meter) square plant samples were harvested from each transect in the plot, with a total of 12 plant samples. Plant samples were dried, weighed for total plant

biomass and thrashed to separate the grain from the total plant material. The grain sample was weighed to determine grain and straw biomass weights.

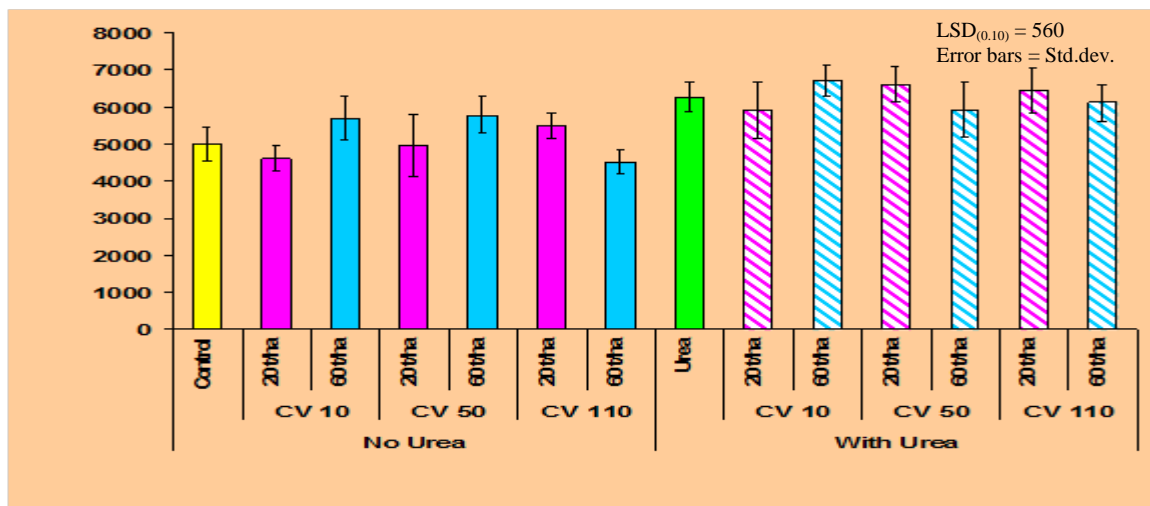
Soil samples were obtained post-harvest from each plot in late September 2011 and 2012. In the intensively samples blocks, soil samples were taken at 0-10 cm depth along both previously described transects at the same locations used for plant sampling, with a total of 12 soil samples per plot. Samples were analyzed for soil NO<sub>3</sub>-N and PO<sub>4</sub>-P concentration using a Technicon automated colorimetry analyzer.

## Results and Discussion

### 2011 Crop Results

In the blocks that were intensively sampled, the highest overall total plant biomass was with the addition of urea fertilizer that aided in achieving significantly ( $p \leq 0.10$ ) higher total biomass compared to the unfertilized treatments, with the exception of the Mid C.V. high SCM rate treatments (Figure 1).

The high SCM rate Low and Mid C.V. treatments were found to have slightly higher grain yields compared to the low SCM rate Low and Mid C.V. treatments (Figure 1). Addition of urea fertilizer to the High C.V. high SCM rate yielded significantly more grain yield compared to the unfertilized High C.V. high SCM rate treatment.

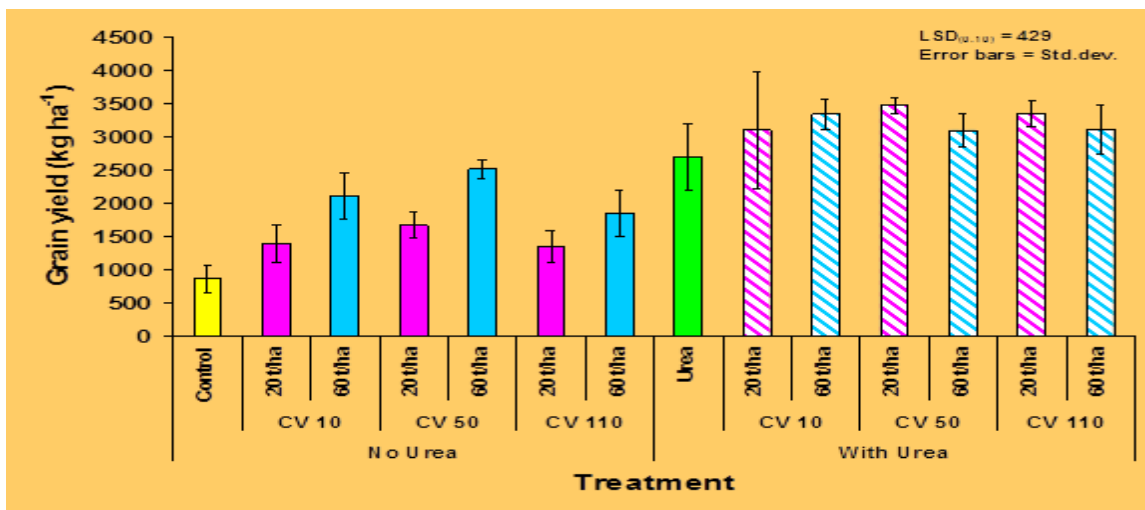


**Figure 1.** Oat grain yield fall in fall 2011.

Sampling in this manner did reveal the High C.V. high SCM rate to have the lowest yield, suggesting that high variability in manure application may have the most adverse effect when it occurs at a high rate of application. This effect may be related to nitrogen availability, as the addition of urea to the High C.V. high SCM rate resulted in a large significant yield increase.

## 2012 Crop Results

In the intensively sampled blocks, the increase in SCM from 20 to 60 t ha<sup>-1</sup> led to significant ( $p \leq 0.10$ ) increases in barley grain yield in the Low and Mid C.V. treatments, without the addition of urea fertilizer (Figure 2). The Low C.V. high SCM rate treatment produced 2100 kg ha<sup>-1</sup> grain yield and was significantly ( $p \leq 0.10$ ) greater than the 1395 kg ha<sup>-1</sup> produced in the low rate (Figure 2). The Mid C.V. high SCM rate treatment produced 2500 kg ha<sup>-1</sup> and was significantly higher than the 1675 kg ha<sup>-1</sup> produced in the Mid C.V. low SCM rate. The addition of urea fertilizer to all manure treatments increased barley grain yield to over 3000 kg ha<sup>-1</sup>, compared to the manure alone treatments, however there was no significant differences between the urea added treatments (Figure 2). The Mid C.V. low SCM rate plus urea fertilizer produced the highest overall grain yield at 3400 kg ha<sup>-1</sup> and was significantly ( $p \leq 0.10$ ) different from manure alone.



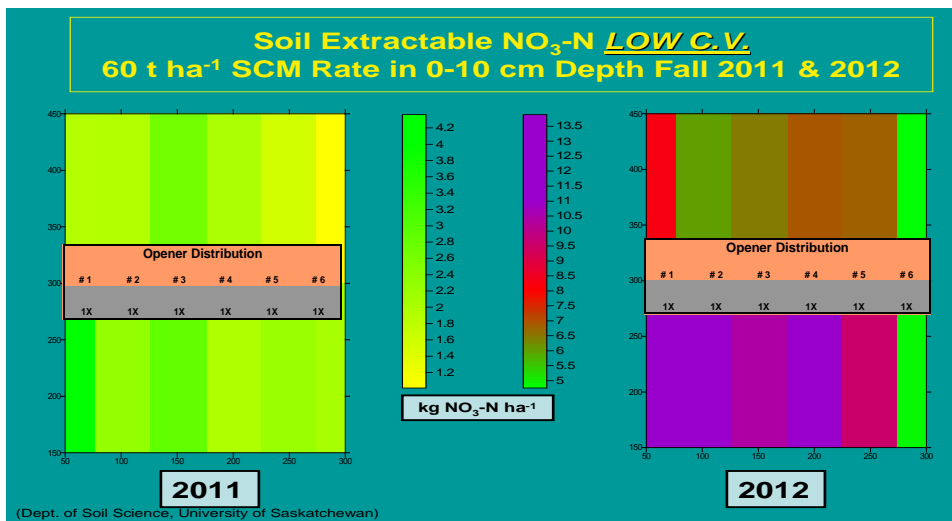
**Figure 2.** Barley grain yield in fall 2012.

In the blocks that were intensively sampled, the Mid C.V. high SCM rate was found to have a significantly ( $p \leq 0.10$ ) higher barley grain yield (2500 kg ha<sup>-1</sup>) compared to the Low, Mid, and High C.V. treatments low SCM rates (Figure 2). The High C.V. at both the low and high SCM rates produced less overall grain yield compared to the Low and Mid C.V. at low and high SCM rates, showing the detrimental effect of the High C.V. on grain yield as was evident in the first year of the study (Figure 2). This again suggests that high variability in manure application may have a more adverse effect when it occurs at a high rate of application. Overall effects were not as large as those observed from manure rate and supplementation with urea.

The addition of urea fertilizer to all three C.V. levels and two SCM rates significantly increased barley grain yield compared to the manure only treatments. However, the grain yields obtained with the addition of urea did not significantly differ between any of the three C.V. and/or manure SCM rate treatments. Grain yields were relatively similar at 3000-3500 kg ha<sup>-1</sup> between the urea added treatments (Figure 2). Addition of urea tended to diminish the effects of non-uniformity of application.

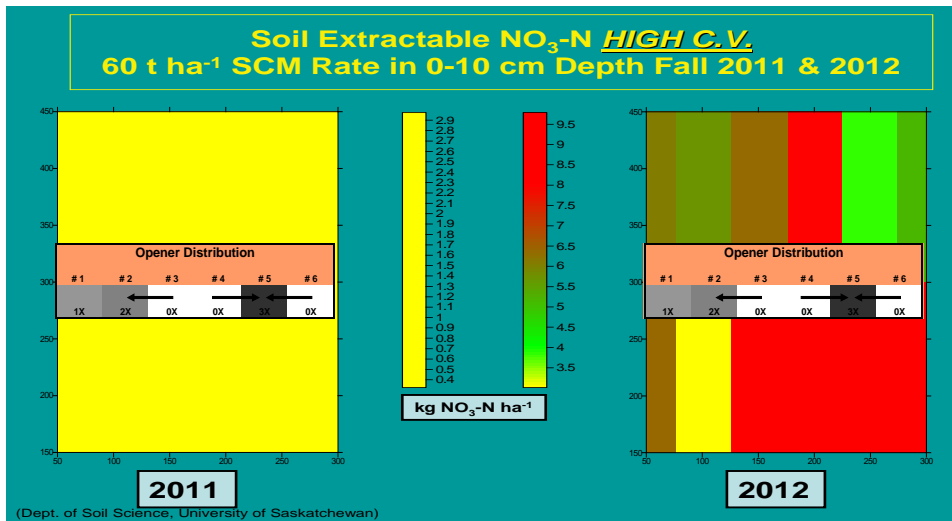
## Soil Nutrients Results

In 2011, application of SCM at a Low C.V.  $60 \text{ t ha}^{-1}$  resulted in little soil extractable  $\text{NO}_3\text{-N}$  differences in the 0-10 cm depth in the treatment plot (Figure 3). Each position in the treatment plot had the same amount of SCM applied as per the Low C.V. treatment. Soil extractable  $\text{NO}_3\text{-N}$  ranged from 1 to  $4 \text{ kg ha}^{-1}$  in fall 2011 (Figure 3). In fall 2012 soil samples, soil extractable  $\text{NO}_3\text{-N}$  levels increased in the Low C.V. High SCM rate treatment plot in all sampling positions (Figure 3). Soil extractable  $\text{NO}_3\text{-N}$  ranged from 5 to  $13 \text{ kg ha}^{-1}$  in fall 2012 (Figure 3). The parallel transects had slightly different levels in soil  $\text{NO}_3\text{-N}$ . Soil  $\text{NO}_3\text{-N}$  levels were  $9\text{-}13 \text{ kg ha}^{-1}$  in transect one while soil  $\text{NO}_3\text{-N}$  levels were  $6\text{-}8 \text{ kg ha}^{-1}$ .



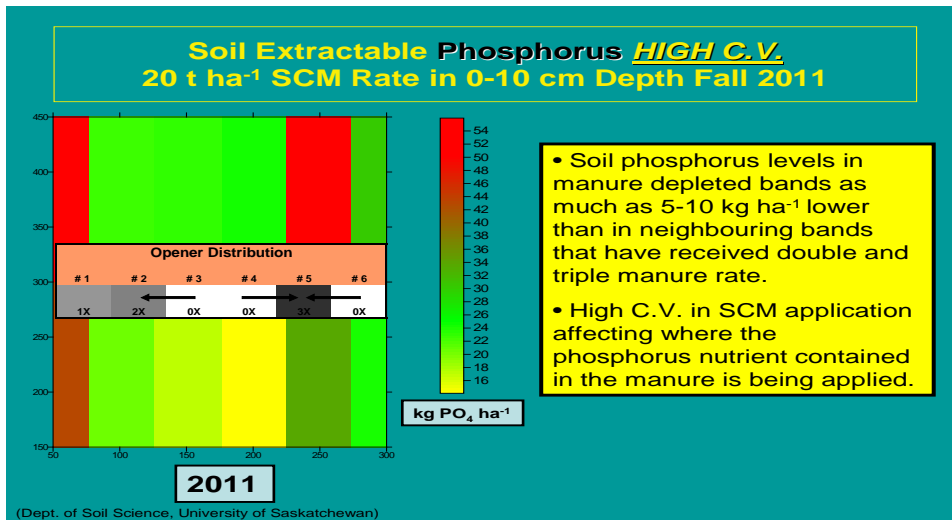
**Figure 3.** Soil extractable nitrate-nitrogen low coefficient of variation  $60 \text{ t ha}^{-1}$  solid cattle manure rate in 0-10 cm Depth fall 2011 & 2012.

In 2011, application of SCM at a High C.V.  $60 \text{ t ha}^{-1}$  resulted in very little soil extractable  $\text{NO}_3\text{-N}$  differences in the 0-10 cm depth in the treatment plot (Figure 4). Each position in the treatment plot had the same amount of SCM applied as per the Low C.V. treatment. Soil extractable  $\text{NO}_3\text{-N}$  ranged from  $0.4$  to  $3 \text{ kg ha}^{-1}$  in fall 2011 (Figure 4). In fall 2012 soil samples, soil extractable  $\text{NO}_3\text{-N}$  levels increased in the Low C.V. High SCM rate treatment plot in all sampling positions from  $3.5$  to  $9.5 \text{ kg ha}^{-1}$  in fall 2012 (Figure 4). Unlike fall 2011 where there were virtually no differences in soil extractable  $\text{NO}_3\text{-N}$  in the High C.V. treatment plot, in fall 2012 more differences in soil  $\text{NO}_3\text{-N}$  were evident. However, the relationship between the soil  $\text{NO}_3\text{-N}$  levels and where the SCM product was applied in the treatment plot area was not closely related. In the manure depleted bands along the first transect, soil  $\text{NO}_3\text{-N}$  levels were found to be similar when compared to the plot areas that received triple the amount of manure (Figure 4). This could be due to the  $\text{NO}_3\text{-N}$  nutrient being more mobile and moving across and downward in the soil profile.



**Figure 4.** Soil extractable nitrate-nitrogen high coefficient of variation 60 t ha<sup>-1</sup> solid cattle manure rate in 0-10 cm Depth fall 2011 & 2012.

Soil phosphorus levels in manure depleted bands were as much as 5-10 kg ha<sup>-1</sup> lower than in neighboring bands that received double and triple the manure rate in the High C.V. 20 t ha<sup>-1</sup> SCM rate in post-harvest 0-10 cm depth samples from fall 2011 (Figure 5).



**Figure 5.** Soil extractable phosphorus high coefficient of variation 20 t ha<sup>-1</sup> SCM Rate in 0-10 cm Depth fall 2011.

The High C.V. was affecting where the phosphorus nutrient contained in the manure was being applied. Unlike the lack of a clear relationship between placement of manure and levels of NO<sub>3</sub>-N, the adjoining manure depleted strips showed a decrease in phosphorus compared to strips that received more SCM demonstrating that non-uniform application of the manure product resulted in field position differences in the phosphorus nutrient (Figure 5).

## **Conclusion**

Overall there were some small, significant differences in grain yield amongst the three different C.V. treatments at the high SCM rate in the intensively sampled blocks. The Low and Mid C.V. treatments at the low SCM application rate achieved similar grain yield results and were significantly higher than the High C.V. high SCM rate treatments. Non-uniform manure application at high rate had a detrimental effect on yield.

Uniformity effects were diminished when urea was added along with the manure.

Addition of urea fertilizer to the treatments boosted grain yield production in most of the C.V. and rate treatments compared to manure alone, reflecting low N availability from the manure source in the initial years of application. Placement of SCM at a non-uniform C.V. had more of an effect on post-harvest obtained sample soil available P as opposed to  $\text{NO}_3\text{-N}$ . Where SCM was piled, more soil P accumulated compared to manure depleted zones in the treatment plots.

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