Effect of Uniformity of Land Application of Solid Cattle Manure on Crop Yield and Soil Nitrate

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ABSTRACT

Equipment used in Western Canada to apply solid cattle manure (SCM) are known to exhibit uneven uniformity of distribution of material. For organic bio-solid manures to be a viable supplement or alternative to chemical fertilizers, it is essential that the uniformity of distribution of the product be measured by the effect that occurs on soil components and crop yields. A precise field scale solid manure applicator has been developed at the University of Saskatchewan and Prairie Agricultural Machinery Institute that is capable of precise surface and subsurface application of solid organic manure. 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. Addition of urea fertilizer to the treatments boosted grain yield production in most of the C.V. and rate treatments, however most of these increases were found to be not significantly different from urea only fertilized treatment plots. The addition of urea fertilizer in most of the treatments increased soil NO_3-N compared to the non-urea fertilized treatments. There was however, no significant difference in soil NO_3-N amongst the three C.V. treatments without the addition of urea fertilizer. The lack of large manure impacts is likely related to low release of available nutrient in the year in application.

INTRODUCTION

An assessment of the effects of non uniform distribution of solid cattle manure (SCM) is necessary to examine the impact of non-uniform distribution on plant yields and soil nutrients. 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., 2006). 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 measured for their agronomic benefits to crops, the distribution of the product manure should be measured by the agronomic effects of the uniformity of distribution. 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 one year's application of SCM as affected by the uniformity of manure application on crop yield and soil nutrient load distribution.

MATERIALS AND METHODS

The uniformity of land application of manure trials was set up as a randomized complete block design on a Black Chernozem soil at Dixon, Saskatchewan. The SCM uniformity trial was established in spring 2011 on a annually cultivated farm field situated at GPS coordinates: 13 486714E 5785258N. 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 8 and the electrical conductivity is less than 0.1 µS m^{-1}. Organic carbon was measured at 2.4 %, soil extractable NO_3-N was 30 kg ha^{-1} and soil extractable phosphate was measured at 30 kg ha^{-1}. Solid cattle manure used for the uniformity trial contained 38 % water, 0.9 % total N and 8 % of the total N was ammonium. At the low or 20 tonnes ha^{-1} SCM application rate, the manure would supply 170 kg total N with 14 kg of that total N being ammonium. 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^{-1}	0%	No application
20 T ha^{-1}	10 %	No application
60 T ha^{-1}	10%	No application
20 T ha^{-1}	50%	No application
60 T ha^{-1}	50%	No application
20 T ha^{-1}	110%	No application
60 T ha^{-1}	110%	No application
20 T ha^{-1}	10 %	banded urea 46-0-0 fertilizer 80 kg N ha^{-1}
60 T ha^{-1}	10%	banded urea 46-0-0 fertilizer 80 kg N ha^{-1}
20 T ha^{-1}	50%	banded urea 46-0-0 fertilizer 80 kg N ha^{-1}
60 T ha^{-1}	50%	banded urea 46-0-0 fertilizer 80 kg N ha^{-1}
20 T ha^{-1}	110%	banded urea 46-0-0 fertilizer 80 kg N ha^{-1}
60 T ha^{-1}	110%	banded urea 46-0-0 fertilizer 80 kg N ha^{-1}

The plot size of 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 t ac^{-1} (20 t ha^{-1}) and a high rate of27 t ac^{-1} (60 t ha^{-1}). The low rate of SCM application is considered to be equal to 150 lb total N ac^{-1} (170 kg total N ha^{-1})and 450 lb total N ac^{-1} (510 kg total N ha^{-1}) for the high rate. Three C.V. rates were used: Low C.V. = 10%, Mid C.V. = 50% and High C.V. = 110% (Table 1). Prior to SCM application, commercial urea (46-0-0) fertilizer applied at a rate of 71 lb N ac^{-1} (80 kg N ha^{-1}) using a small plot drill was applied 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 the fall of 2011, the plots were harvested to collect plant biomass samples. In the plant intensively sampled blocks, two parallel transects, each 10 ft (3.05 m) in length per plot were established located in a east-west direction within the plot. Six 2.7 ft^2 (one-quarter meter) square plant samples were harvested from each transect in the plot, totaling 12 plant samples. In the less intensively samples blocks, two square meter plant samples were harvested at random locations within each plot. 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 at post-harvest from each plot in late September 2011. In the intensively samples blocks, soil samples were taken at 3.9 in (0-10 cm) depth along both transects from the plant sampled sections established for plant sampling totaling 12 soil samples per plot. In the less intensively sampled blocks, two 3.9 in (0-10 cm) soil samples were taken at random locations within each plot. Samples were analyzed for soil NO_3-N concentration using a Technicon automated colorimetry analyzer.

RESULTS AND DISCUSSION

Plant Sampling

Rate Effect

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

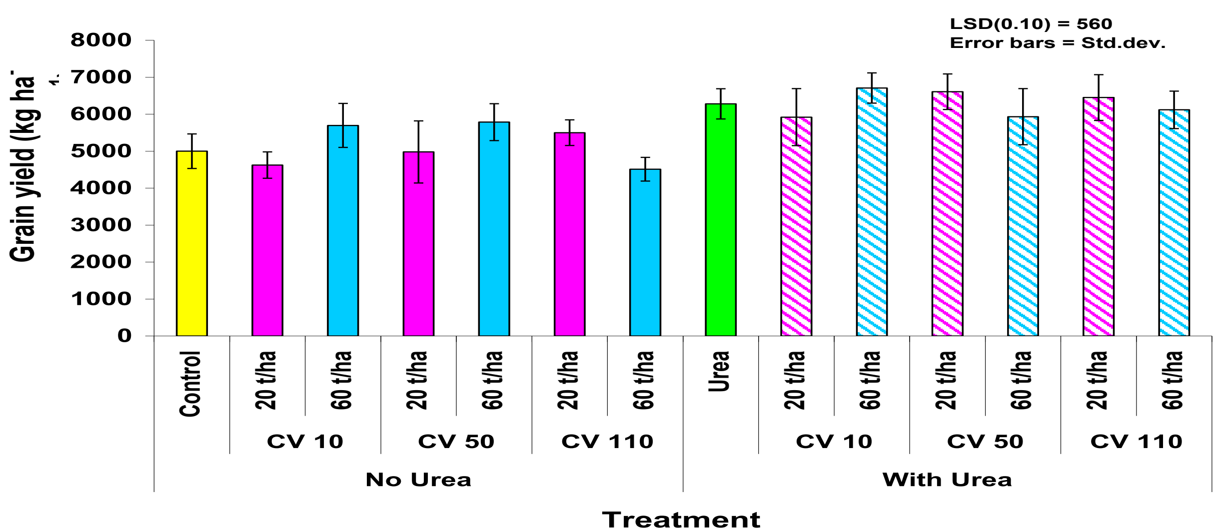

Figure 1. Oat grain yield in intensively sampled blocks in Fall 2011.

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. 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.

Coefficient of Variation (CV) Effect

The addition of urea fertilizer to the Low C.V. high SCM rate, High C.V. low SCM rate treatments and the Mid C.V. low SCM rate treatment achieved the highest total plant biomass (Figure 1). The Low C.V. high SCM rate and Mid C.V. high SCM rate treatments were found to have significantly ($p=0.10$) higher grain yield compared to the High C.V. high SCM rate treatment (Figure 1).

Soil Sampling

Rate Effect

In the blocks that were intensively soil sampled, only the Mid CV high SCM rate treatment increased soil NO3-N compared to the other non-urea fertilized treatments (Figure 2). The addition of urea fertilizer increased soil N with some significant ($p=0.10$) differences between the urea fertilized and non-urea fertilized treatments. Highest overall soil NO_3-N was observed with the addition of urea in combination with the Mid CV high rate of SCM manure and in addition to the High CV low rate of SCM manure (Figure 2).

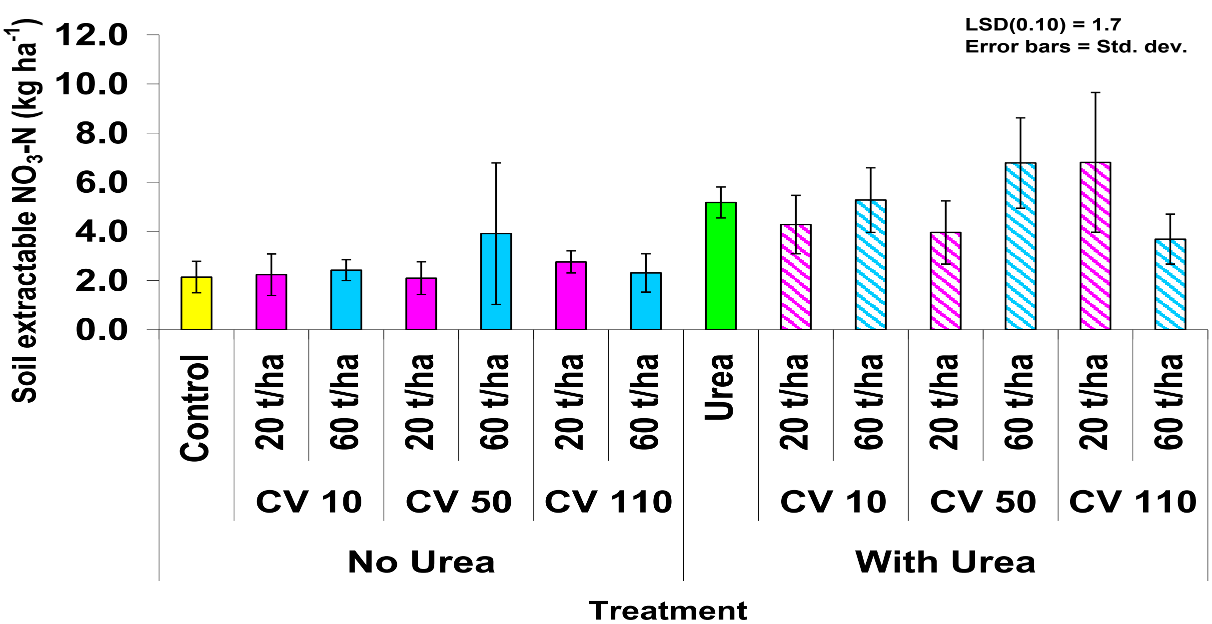

Figure 2. Soil residual nitrate-nitrogen in 0-10 cm depth in Fall 2011.

Coefficient of Variation (CV) Effect
In the blocks that were intensively soil sampled, there was little differences in soil residual NO_3-N in treatments in the less intensively sampled blocks without the addition of urea fertilizer with varying C.V.'s, except the Mid C.V. high rate of SCM application (Figure 2). Although soil residual NO_3-N was elevated, this increase was not significantly ($p=0.10$) different from the other treatments.

CONCLUSIONS

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. Addition of urea fertilizer to the treatments boosted grain yield production in most of the C.V. and rate treatments, however most of these increases were found to be not significantly different from urea only fertilized treatment plots. As with the yield effect there were some small significant differences in soil residual NO_3-N amongst the three different C.V. treatments in the intensively sampled blocks. Addition of urea fertilizer significantly increased soil residual NO_3-N in the Low C.V. low and high rate SCM treatments. There was however, no significant difference in soil residual NO_3-N amongst the three C.V. treatments without the addition of urea fertilizer. A negative impact of manure application with high variability at high rates is noted that may be related to nitrogen availability. The lack of large manure impacts is likely related to low release of available nutrient in the year in application.

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