Impact of Repeated Applications of Liquid Swine Manure and Biogas Production By-Products on Soils and Crops

Schoenau, J.J.[1], T.N. King[1], and S.S. Malhi[2]
[1]Department of Soil Science, University of Saskatchewan; [2]Agriculture and Agri-Food Canada, Melfort Research Station

Jeff Schoenau

SUMMARY

Short and long-term application of fresh and processed liquid swine manure, to Saskatchewan soils, at agronomic rates of nutrients that balance crop removal over time contribute to significant yield and protein benefits in the crop while minimizing nutrient loading and risk of escape to soils and water.

INTRODUCTION

IIn the spring of 2007, a new experiment was set up near Dixon, Saskatchewan to look at crop response to swine manure biodigestate that is produced from biogas production, in comparison to conventional liquid swine manure and urea fertilizer. Three rates of digestate and liquid hog manure (1,500, 3,000 and 6,000 gallons per acre) were applied along with three rates of urea: 50, 100 and 200 lbs N/acre. On long-term (since 1997) swine manure monitoring experiments at Dixon, fifteen treatments of liquid swine manure were applied by the Prairie Agricultural Machinery Institute (PAMI), continuing the sequence applied for the previous ten years. At the Melfort long-term liquid swine manure injection site, five treatments involving different rates and sequences of liquid swine manure were applied, with and without sulfur fertilizer as in the previous seven years. Assessments of grain and straw yield, nutrient concentrations, soil nutrients and properties were made on plant and soil samples collected every fall in 2007, 2008 and 2009 to determine how manure applications affected crop growth and soil properties.

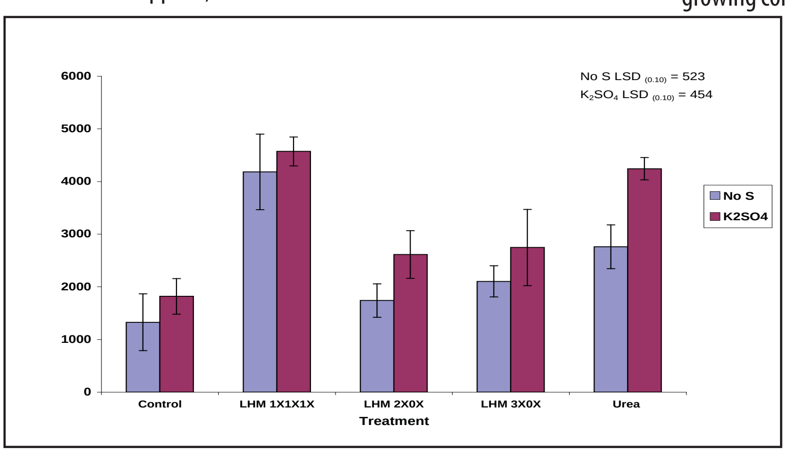

Figure 1. Barley grain yield (Melfort 2007) response to injected liquid hog manure (LHM) in 1X1X1X (3300 gallons per acre every year including 2007), 2X0X (6600 gpa in 2006, no manure 2007) and 3X (9900 gpa in 2006, no manure 2007) treatment sequences, with and without supplemental sulfur fertilizer.

RESULTS AND DISCUSSION

Crop Yield

Significant yield responses to swine manure application were observed in 2007. An example of crop response to swine manure treatments is shown for the Melfort study site (Figure 1). At the Dixon site, there appeared to be little difference in behavior of the manure digestate compared to the conventional liquid manure in terms of yield responses observed. Annual applications of ~ 3,000 gallons per acre, 62-89 N/acre (~ 34,000 litres/ha, 70-100 kg total N/ha) as liquid hog manure and biodigestate resulted in maximum yield at all sites. This supports the concept that rates of addition of liquid swine manure in the order of 3,000 – 4,000 gallons per acre per year is the "agronomic or 1X rate". Higher rates of application (6,000 gpa or 2X) made in the previous year showed good carryover into the next year. In 2007, the highest rates of application (4X agronomic rate) generally had reduced yield compared to the 2X and 1X rates.

> *" Rates of raw liquid swine manure or biodigestate of 3,000-4,000 gallons per acre (~75-100 lbs N / acre /yr) per year provided optimum yields"*

In 2008 a strong yield response of canola to manure application was noted at all sites. Annual applications of swine manure at 2X and 4X rates tended to produce the highest yields, likely reflecting better growing conditions than in 2007 and also the greater nutrient requirements of canola as compared to the oats and barley grown at the sites in 2007. Application at the 4X rate (13,200 gpa) every year results in excessive soil nitrate levels. As in previous years, there was no difference in agronomic effect of the biodigestate liquid swine manure compared to the raw liquid manure. As well, the addition of the nitrification inhibitor to liquid swine manure had no significant effect on yield. Injection of liquid swine manure produced superior yields compared to broadcast and incorporation. Liquid swine manure appears to supply close to sufficient amounts of phosphorus and sulfur, as response of the liquid manure treatments to supplemental P and S was muted in 2008.

In 2009, close to maximum yield of oat was obtained at rates of ~3,000 gpa of raw liquid swine manure and biodigestate. As in previous years, there appeared to be little difference in the agronomic performance of biodigestate from manure biogas production versus raw liquid swine manure when considered on a per kg of nutrient added basis. At the long-term liquid swine manure trial, the barley yield was maximized at the 4X annual rate, reflecting good growing conditions and high yield potential at the site. Consistent with results of previous years there was no response to addition of supplemental P fertilizer on the swine manure plots, and no response to addition of nitrification inhibitor. Treatments with skipped applications of nutrient the two previous years did not yield as high when manure was added in 2009. It appears that rates of addition of approximately 100 kg liquid swine manure - N/ha 90 lb N/ac (~ 3,000-5,000 gallons per acre per year) will maximize production over time in these soils without creating issues of nutrient loading. The results at Melfort long-term swine trial support this, as near maximum yield was observed at these rates. Application at double 1X rate every second year (6,000 – 10,000 gpa every second year) did not result in as high an oat yield in the second year 2009, pointing towards lower efficiency of total nutrient recovery in the "double up" approach. Some benefit was observed from the commercial S fertilizer application treatment made in 2008. In the 2009 oat crop it showed up in the urea treatments and also in the high rate liquid manure treatment and only for the elemental S form. Generally it appears that some benefit may be observed from fertilization with supplemental fertilizer S on liquid swine manured soils, but the variability in effects regarding crop, form and rates in which benefits are observed makes the benefits difficult to predict.

Soils

Generally, available N levels in the soil in the fall after harvest increased with increasing rate of liquid swine manure. Salinity was not significantly affected except at the 4X (13,200 gpa) annual application rate at the Dixon long-term site where, for example in 2008, it was elevated to 2.2 mS/cm, and in 2009 it was elevated to 1.3 mS/cm. Repeated application of liquid swine manure at these high rates may create potential salinity concerns for crop growth, and also resulted in greatly elevated nitrate (>200 kg /ha, 178 lb/ac) in the 0-30cm and 30-60cm depths, as did the 4X rate of urea. The content of nitrate in the 60-90cm and 90-120 cm depths was assessed in the Dixon long-term site in the fall of 2009 and revealed that only the 4X annual application of swine manure and urea had elevated concentrations of nitrate at these depths, with 60-100 kg NO_3-N present in each depth increment compared to less than 10 kg/ha for the rest of the treatments. The 1X liquid swine manure rate (~3,000-4,000 gpa) does not result in soil nitrate or phosphate loading.

Accumulation of soil extractable P was not evident in either the raw liquid hog manure treatments or the biodigestate after three years of application. Reflecting the low P content of the liquid swine manure source used at the long-term site, soil extractable P levels were relatively unaffected by liquid manure application. The broadcast and incorporation treatment at Dixon had significantly lower nitrate than injected, again supporting that along with lower crop N recovery, N losses from the system are greater with broadcast and incorporate versus injection.

The application of swine manure either on a long-term or short-term basis did not affect soil organic carbon or soil sodicity values to any great extent, but there was a trend to higher organic carbon corresponding with manure application. A long period of animal manure application seems necessary to produce significant increases in soil organic carbon in these soils. Manure application tended to increase soil strength slightly but not significantly in the long-term manure trials.

The application of swine manure either on a long-term or short-term basis did not affect soil organic carbon or soil sodicity values to any great extent, but there was a trend to higher organic carbon corresponding with manure application. A long period of animal manure application seems necessary to produce significant increases in soil organic carbon in these soils. Manure application tended to increase soil strength slightly but not significantly in the long-term manure trials.

CONCLUSION

Rates of raw liquid swine manure or biodigestate of 3,000-4,000 gallons per acre (~75-100 lbs N / acre /yr) per year gave optimum yields of the oats and canola grown over the three years and did not result in excessive soil nutrient loading. As anticipated, application of swine manure at these rates over three years had little impact on soil properties like pH, salinity and organic carbon compared to the urea fertilized treatments and the unfertilized control. In the long-term (>10 yrs) liquid swine manure trials, application rates of 3,000 – 4,000 gallons per acre every year (~75 – 100 lbs N / acre / yr) gave near optimal yields for the crops examined (oats, canola, barley) and were not associated with any loading of nitrate or phosphate in the soil. As such, these rates of application are again confirmed as the "agronomic" optimum. Double these rates applied every second year also gave good yield response in the year of application, and provided significant residual benefits in the second year after application. However, especially in the moister environment encountered at Melfort, yields in the second year following application were not equivalent to the annual application rate, suggesting that larger applications intended to carry through for subsequent years may not be as efficient. High rates of liquid swine manure applied annually re 2X (~6,600 gpa) and especially 4X (13,200 gpa) often did not produce significant yield benefit above the 1X rate and lead to accumulation of excessive quantities of nitrate in the soil profile (0-60cm) and beneath. Furthermore, 4X rates of liquid swine manure and urea increased soil salinity slightly. Owing to the relatively low phosphorus content of the liquid swine manure used in this study, levels of soil test extractable P were only elevated significantly in the 4X rates.

ACKNOWLEDGEMENTS

Strategic funding provided by Saskatchewan Agriculture Development Fund and Sask Pork.