# Swine Manure as a Source of Plant Nutrients

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## Introduction

Swine manure can be a valuable source of nutrients needed by plants and an effective fertilizer when it is applied using appropriate rates and methods of application. Most soils in Saskatchewan can benefit from the nutrients contained within swine manure. Application of swine manure to farm fields in Saskatchewan allows a portion of the plant nutrients traditionally exported in feed grains to be recycled back through the system. However, to make the nutrient recycling system work in a sustainable manner, it is important to strive towards getting as much of the applied nutrient as possible into the crop. Doing so will maximize the economic benefit of the nutrients in the manure and reduce risk of nutrient contamination of adjacent environments. This paper addresses some of the issues surrounding the use of swine manure as a source of plant nutrients, using examples from recent and on-going research work in Saskatchewan.

## Issues Surrounding Swine Manure as a Plant Nutrient Source

### 1. Low Nutrient Content bv Weight

Liquid swine manure from earthen storage units is perhaps best perceived as a dilute, multi-nutrient solution fertilizer. Analysis of samples of liquid swine manure collected during application to research plots near Humboldt in 1996 and 1997 revealed that the effluent contained most of the nutrients required by plants. Elements measured for and detected included nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, copper, iron, zinc, manganese and boron. Manure samples were also analyzed for the presence of cadmium and lead but these two elements were not present in detectable amounts in the manure digests as measured using inductively coupled plasma emission spectroscopy.

Despite the presence of essential plant nutrients in liquid swine manure, a major challenge is that the concentrations of nutrient elements are very low per unit volume or weight compared to commercial fertilizers (Table 1). Furthermore, the relative amounts of the nutrients may not exist in the desired proportions or balance called for in a fertilizer recommendation. For example, if the ratio of N:P in the liquid effluent is around 1: 1, meeting the nitrogen recommendation could result in the application of more phosphorus than is called for in the fertilizer recommendation. This is why yearly soil analyses are needed in manured fields in order to monitor the effects of the manure application on soil nutrient supplies and balances and adjust application rates accordingly.

Table l. Comparison of typical range of concentrations of nutrients found in liquid swine manure versus a commercially prepared inorganic NPKS solution fertilizer blend (note: typical range of values for hog effluent concentrations are based on values encountered during research in Saskatchewan by the authors and others over the last three years).

| | Liquid Hog Effluent | Example Commercial Solution Fert |
|---|---|---|
| **Total N** | 15-40 lb /l000 gallons | 2000 lb /l000 gallons |
| **Inorganic N** (plant available ammonium) | 8-20 lb /l000 gallons | 2000 lb /1000 gallons |
| **Total P** | l- 20 lb /l000 gallons | 700 lb /l000 gallons |
| **Total K** | 10-30 lb /l000 gallons | 700 lb /l000 gallons |
| **Total S** | 0.1-3 lb /1000 gallons | 600 lb S /1000 gallons |
| Total Cu | 0.05 - 0.5 lb /l000 gallons | |
| Total Mn | 0.05 - 0.5 lb /l000 gallons | |
| Total Zn | 0.05 - 1 lb /l000 gallons | |
| Total Fe | 0.2 - 1 lb /l000 gallons | |

The low concentrations of nutrient in liquid swine manure means application rates in the order of a few thousand gallons per acre are typically required to meet the nutrient requirement of a crop versus perhaps ten to twenty gallons per acre for concentrated commercial fertilizer blends. The low analysis means that transportation and application costs relative to the value of the nutrient can be high, making it economically difficult to transport the manure long distances from site of production to the field for use as a fertilizer. Therefore, there is a need for technology which will increase the proportion of the total weight of the effluent made up of nutrient. This could involve deliquification and recycling of the water followed by cornposting of the solids. Fortification is another possibility. For example, some research work in Western Canada has examined combinations of elemental sulfur and hog manure as a means of raising the sulfur content of the manure and accelerating the sulfur oxidation rate (Dormer, 1997) and perhaps retaining more ammonium nitrogen in the soil (Bailey et al., 1997). Another possibility may be the ammoniation of liquid swine manure to increase available N content and attain the desired balance of nitrogen to other nutrients like phosphorus and potassium.

## 2. Variability in Nutrient Content / Composition of Liquid Swine Effluent

Nutrient levels in liquid swine manure can be variable and difficult to predict as the feed rations, handling, storage time, agitation, and pumping depth in pit all influence nutrient content and form. For this reason, it is advisable to obtain samples of effluent from the earthen storage unit after agitation and have them analyzed for nutrient content before application begins. While not perfect, this manure nutrient content information along with soil analysis and a fertilizer recommendation can be used to calculate the appropriate rates of manure and application strategy to meet the crop requirement before application begins.

Variation in application rates of total nutrient may be encountered during the application process as a result of variability in nutrient content from load to load. Much of the variability encountered during application seems to be related to degree of agitation and subsequent solids content. We have observed that the total phosphorus and micronutrient concentration in the effluent can vary widely from batch to batch during application and seems quite closely related to the solids content, with greater solids associated especially with higher total phosphorus and micronutrient concentrations. Ammonium and potassium, on the other hand, were often more uniform from load to load.

The increase in total nutrient concentration with increased solids content is not likely to produce a direct linear increase in immediately available nutrient as a significant proportion of the nutrient may be strongly bound in or on the suspended organic and mineral constituents. However, it may be possible to fine tune the application rates of total amounts of some nutrients in the field on the basis of a simple measurement of solids content.

## 3. Some Nutrient in Swine Manure is Not Immediatelv Plant Available

In the liquid swine manure samples we have analyzed in our field research studies, we have found that about 20% to 50% of the nitrogen is in the organic form, with the remainder present largely as ammonium ($NH_4$). Nitrate ($NO_3$) is present in the manure itself only in very low concentrations.

When the effluent is applied to the soil, the ammonium nitrogen is retained on negatively charged colloids. The ammonium may then be assimilated directly by roots or microbes. If the ammonium is not assimilated, it is eventually converted to nitrate by nitrifying microorganisms in the soil. The organic nitrogen applied in the manure is slowly converted (mineralized) to ammonium and nitrate by heterotrophic microorganisms in the soil. The rate at which organic nutrient forms are converted to inorganic available forms in soil is variable and difficult to predict as it depends on temperature, moisture, and soil type as they affect microbial activity. Some general estimates have been made of around 50% organic N mineralization in the year of application. In a growth chamber study (Qian and Schoenau, 1998) reported on elsewhere in these proceedings, we found that the supply rate of plant available inorganic nitrogen over an 84 day period was significantly lower in soil amended with liquid swine effluent compared to urea added at the same rate of total N. These results suggest that only a portion of the organic nitrogen added in the swine manure was converted to available nitrogen over the time period of the study.

## 4. Rates of Swine Manure Application to Meet Nutrient Requirements

The goal in maximizing fertility benefit of swine manure is to match as closely as possible the manure nutrient application rate to the crop's need and ability to use the applied nutrients. This will depend on the crop yield potential as governed by crop type, available moisture, growing season conditions and on the inherent nutrient supplying power of the soil, as all of these factors influence response to added fertilizer nutrient. Soil analysis every year to determine levels and balances of available nutrients in the soil and a corresponding fertilizer nutrient recommendation is critical in achieving this goal.

Often nitrogen is the element most limiting crop growth in fields with no prior history of manure application, so application rates based on meeting the N requirement are often the most suitable approach initially. Using the ammonium nitrogen concentration in manure and the recommended fertilizer N rate one can calculate how many gallons per acre are required to meet the requirement. One can also expect some additional available N release over the growing season from mineralization of the organic N that is added. This late supply of available nitrogen from mineralization may contribute to increase in protein content as well as yield of cereal crops grown following the addition of swine manure (Schoenau et al., 1998).

Since swine manure contains other nutrients along with nitrogen, one should calculate the amount of other nutrients being added at the manure rate used to satisfy the N requirement. Yearly monitoring of soil nutrient levels in fields to which manure is applied is essential to determine if applications are resulting in excessive quantities of certain plant nutrients such as nitrate and if imbalances in availability of certain nutrients are being created. Also one should pay attention to total salt load and sodium, especially in poorly drained soils. Yearly measurements of soil electrical conductivity and sodium adsorption ratio will help in revealing any possible problems arising. Application of manure nutrient at rates that greatly exceed the crop's ability to absorb and utilize the applied nutrient can result in buildup of excessively high soil nutrient levels over time, leading to concerns about potentially high nutrient losses from the soil as well as possible adverse crop effects such as reduced germination and lodging.

## 5. Method and Timing of Application of Swine Manure

Injection of liquid swine manure into the soil should result in less volatile amrnonia loss than surface application. Application equipment which covers the injection channel with soil will also reduce the chance of downslope movement of swine manure in the injection channels and should also reduce odor. The relative importance of denitrification losses may increase with injection, although this has received relatively little research attention under Western Canadian conditions. For a crop to be grown the following spring, late fall applications of manure should result in less chance of nutrient loss than early fall applications. If applied too early in the fall, the soil may be warm enough to result in microbial conversion of the applied ammonium to nitrate which is then susceptible to leaching or denitrification losses.

## 6. Crop Response to Nutrients Added in Swine Manure

Large yield' responses to added liquid swine manure have been observed in trials recently conducted in Saskatchewan on soils with no history of manure application. For example, one site in southern Saskatchewan in 1995 showed - 18 bu/ac yield increase in spring wheat in low slope positions from application of 8000 gpa liquid hog manure the previous fall (Dormer et al., 19%). Field trials conducted at two sites near Humboldt, Saskatchewan in 1997 evaluated canola response to injected liquid swine manure effluent at three different rates of application compared to fertilizer urea (Charles et al., 1998). The results of these trials, discussed in more detail elsewhere in these proceedings, revealed a significant yield response of the canola over the control to application of swine manure and urea (Table 2).

Table 2. 1997 canola grain yields at Dixon (Blaine Lake clay loam soil) in plots receiving different rates of spring injected liquid swine manure and banded urea

| Treatment | Canola Grain Yield kg/ha |
|---|---|
| Control (no fertilizer) | 563a |
| Swine Manure @ 3400 gpa (-63 lb/a total N, 33 lb/a $NH_4$, 6 lb/a total P) | 1358 b |
| Swine Manure @ 6800 gpa (-126 lb/a total N, 66 lb/a $NH_4$, 12 lb/a total P) | 1698 b |
| Swine Manure @ 13,600 gpa (-252 lb/a total N, 132 lb/a $NH_4$, 24 lb/a total P) | 1618 b |
| Urea @ 50 lb N / a | 1272 b |
| Urea @ 100 lb N / a | 1437 b |
| Urea @ 200 lb N / a | 1668 b |

Values followed by the same letter are not significantly different at the 5% probability level.

Overall, the low rate of swine manure addition produced a similar yield response over the control as the low rate of urea, with a slightly higher amount of total N added in the manure and a slightly lower amount of immediately available N (ammonium) in the manure. Other nutrients such as phosphorus and potassium added in the swine manure would also contribute to yield response under deficiency. The yield response curve to applied manure and fertilizer we observed at this site in 1997 suggests that an application rate of manure in the vicinity of 4000 - 5000 gpa would be sufficient to maximize yield under the conditions present at this site in 1997. In a trial at another site south of Humboldt on a sandy loam Meota soil, we observed some evidence of reduced crop germination, emergence and delay in crop development in plots receiving a high application rate of manure (- 20,000 gpa) the previous fall. This may be related to a salt effect or ammonium toxicity to the seeds and seedlings. Similar effects were observed in urea treatments at high rates of N. Injury effects are liable to be most pronounced with small seeded crops like canola, on sandy textured soils of high pH.

## Conclusions

Liquid swine manure can be a valuable plant nutrient source which is perhaps best perceived as a dilute multi-nutrient solution fertilizer blend. Its dilute nature, variability in nutrient content, and presence of nutrients in organic as well as inorganic forms poses some challenges in effective utilization as a fertilizer material. However, when it is applied using the appropriate rate, timing and method of application, it can function well as a source of nutrients in Saskatchewan cropping systems. Like most fertilizers, it is possible to get too much of a good thing. Therefore, emphasis should be placed on managing manure like one would for any other fertilizer material: using fertilizer nutrient content and soil test / fertilizer recommendation information to calculate rates of application that match the crops ability to use the nutrients applied and produce economic yield responses. Research is underway in Saskatchewan which is addressing the nature of soil and crop response to application of swine manure in order to improve our understanding of how to achieve maximum economic and environmental benefit from this resource.

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