# Balancing the Availability of Nutrients in Manured Soils

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## Background

Animal manures are a valuable source of plant nutrients in crop production in Western Canada. Significant yield responses to nutrients added as swine manure (Mooleki et al., 2002) and cattle manure (Mooleki et al., 2001) have been reported in field trials in Saskatchewan. Increased availability of nitrogen in manured soils is a primary factor associated with reported yield and protein increases in these studies, particularly with liquid swine manure. In some instances, part of the yield response to manure addition may be attributed to enhanced availability of other nutrients such as phosphorus (Qian and Schoenau, 2000a) when soil availability of these nutrients is limiting. Therefore, manure addition can make a significant contribution to crop nutrition by increasing the availability of many nutrients in the soil. However, the amounts, forms, availability and therefore the balance of available nutrients in the soil following manure addition is controlled to large extent by the composition of the manure. This composition is variable depending on factors such as the animal physiology, feed rations and additives, manure handling and storage as well as environmental conditions which affect nutrient retention (Lindley et al., 1988). As such, when manure is applied, nutrients are applied in the proportion or balance they are present in the manure source, which may be different than the relative proportions required by the crop to be grown.

An issue that can arise when applying manure to meet a requirement for one particular nutrient such as nitrogen, is the over-application or under-application of other nutrients. For example, repeated application of manure with a low nitrogen:phosphorus ratio can result in accumulations of excess phosphorus in the surface soil (Dormaar and Chang, 1995), particularly when the availability of nitrogen in the manure source is low and high rates of manure are added to compensate. Accumulations of large amounts of nutrient in the soil can pose environmental risk and can also interfere with crop growth and nutrition, depending on the nutrient element. On the other hand, application of manure to meet a requirement for one nutrient may result in insufficient amounts of other nutrients to optimize crop growth and utilization of all manure nutrients added. An example would be the use of a manure source with high nitrogen availability but low sulfur availability as the sole source of fertilizer for a canola crop grown on a sulfur deficient soil.

To optimize crop response and utilization of nutrients applied to fields as manure, there is a need to consider the impact of the manure addition not only on the amounts of any individual nutrient, but also on their relative proportions or balance. This balance can be adjusted quite effectively through the application of supplemental commercial fertilizer to achieve the optimum balance or ratio of available nutrients to ensure that all nutrients are used effectively to enhance crop nutrition while minimizing nutrient loading concerns. Using Saskatchewan research on trends in manure nutrient composition, crop responses to manure addition in field trials, and recently initiated research on responses to supplemental commercial fertilizer addition in these trials, the need for considering and managing nutrient balance in manured soils is explored in this paper.

**General Observations on Manure N:P and N:S Balances**

*N:P Balances:*

Plant roots absorb nitrogen in the forms of ammonium and nitrate ions, and phosphorus as orthophosphate ions. The ratio of N:P required by most crops is around 10 : 1. When expressed as a ratio of $N:P_2O_5$, this ratio is ~ 4.4 : 1. Liquid swine manure is characterized by high nitrogen availability in the year of application, with about 60 to 80% of the total N present in the available form, or becoming available over the growing season (Qian and Schoenau., 2000b). On the other hand, cattle manure and other solid manure sources are characterized by lower N availability in the year of application (~ 10 to 50%) due to a low ammonium content and the need for mineralization to convert the organic N to the plant available inorganic forms. These differences are demonstrated in the apparent recovery of N from different manure forms by canola in the year of application at a field trial site near Dixon in east-central Saskatchewan (Table 1).

**Table 1.** Yield increase and apparent recovery of nitrogen by canola from two different manure sources in the year of manure application (1997) at Dixon, SK (Charles, 1999).

| | Yield Increase Over Control (Bushels/acre) | Apparent Crop N Recovery (%) |
|---|---|---|
| Injected Liquid Swine Manure @ 120 kg total N/ha | 21 | 43 |
| Broadcast/Incorp. Cattle Manure @ 120 kg total N/ha | 2 | 5 |

The low availability of N in the year of application for the cattle manure source used in the above study, as revealed in the low yield response and low recovery, is consistent with a low proportion (only ~ 10%) of the total N in the manure present as ammonium and a high C:N ratio of the manure organic matter due to a lot of straw bedding incorporated with the manure. It has been reported that if the C:N ratio of manure is greater than about 15:1, one can expect to see limited release of available N from solid manure in the year of application (Qian and Schoenau, 2002).

The availability of N relative to the availability of P in a manure source is an important consideration with regard to P loading issues when applying manure to meet all of a crop's nitrogen requirements. Manure sources such as cattle manure and poultry manure characteristically have a high content of P relative N. The N:P ratios of the cattle penning manure used in our Saskatchewan field trials ranges around 3:1 to 4:1. Repeated application of manure sources of high C:N ratio and low N:P ratio at high rates in an attempt to supply all of the N required via the manure can result in undesirable accumulations of labile P in the soil after several years. A more appropriate strategy when using manure sources of low N availability (i.e. high C:N) and high P content is to apply at a rate according to P-based requirement and supplement with commercial N fertilizer that first year to ensure adequate N supply for cereals or oilseeds, especially if the field has no history of prior manure application. The nitrogen load in the soil over time should also be monitored as eventually the manure organic N added to the soil will start to mineralize and commercial inorganic N fertilizer rates should be reduced accordingly. The N mineralization potential of soils receiving repeated applications of manure, especially solids, will be increased (Jalil et al., 1996) and this contribution needs to be accounted for down the road. Ensuring adequate N fertility by supplementing manure with commercial N fertilizer in the initial years is anticipated to help reduce phosphorus build-up by increasing crop growth and nutrient removal.

For some animal manures, the phosphorus content relative to nitrogen may be altered through feeding strategies or feed additives. A good example of this is with swine manure, in which the phosphorus content may be reduced through the use of phytase enzyme as a feed additive or the use of low phytate feed sources. To this end, new varieties of feed grains are being developed specifically to lower the phosphorus content of the manure. Although not systematically studied, we have observed a trend towards lower phosphorus contents of swine manure in recent years in our field trial research projects across Saskatchewan. At one site in southwestern Saskatchewan, the N:P ratio increased from about 5:1 to 10:1 over a period of four years which coincided with the onset of use of phytase enzyme by the barn. As the total phosphorus content of slurries tends to be directly related to the solids content, the degree of manure agitation before application can also influence the amounts of phosphorus added to a given land area. At our field research site at Dixon, five annual applications of liquid swine manure had little effect on soil available phosphorus in the 0-6" depth, but annual applications of cattle manure caused significant increases (Qian et al., 2002).

*N:S Balances:*

Animal manures contain sulfur, and their addition to the soil can increase supplies of available sulfur for crop growth (Charles, 1999). However, because of their generally high C:S ratio, animal manures have been reported to have a variable and sometimes limited effect on increasing available sulfur (Tabatabai and Chae, 1991). At two sites in east-central Saskatchewan, swine manure was found to have a lower and more variable content of extractable sulfate than the cattle manure used in the field trials (Charles, 1999). Low availability of sulfur relative to nitrogen in liquid swine manure might be anticipated due to anaerobic conditions in the earthen manure storage unit resulting in conversion of soluble sulfates to insoluble sulfides. Using a fertilizer of low available sulfur content relative to nitrogen is of particular concern with high sulfur demanding crops like canola grown on sulfur deficient soils, with the potential for severe N:S imbalance. This was revealed in a field study with canola grown on a Gray soil near Star City, SK receiving urea or swine manure (Table 2).

**Table 2.** Canola yield and straw S concentration in 2001 on a Gray soil near Star City, SK receiving injected liquid swine manure or urea.

| *Manure* (gallons per acre) | | *2001 Canola Crop* | | |
|---|---|---|---|---|
| **2000** | **2001** | **Grain** kg/ha | **Straw** kg/ha | **Straw S** % |
| 0 | 0 | 1155 b | 3225 b | 0.41 |
| 3000 | 3000 | 1975 a | 4355 a | 0.28 |
| 6000 | 0 | 1190 b | 3850 ab | 0.27 |
| 9000 | 0 | 918 bc | 4720 a | 0.25 |
| *Urea* (kg N/ha) | | | | |
| 80 | 80 | 583 c | 4900 a | 0.19 |

Values in a column followed by the same letter are not significantly different at $P<0.05$.

The effect of adding nitrogen alone on creating a nitrogen : sulfur imbalance in the canola at this site is evident in the seed yield reduction and substantially reduced straw S concentration in the urea treatment compared to the unfertilized control. The annual application of swine manure produced the highest canola yield. Limited carryover of available nitrogen from the single larger applications (6000gpa and 9000gpa) made at the start of the 2000 season was evident in soil available N contents in spring of 2001 in these treatments that were not significantly different from the control. Spring soil sulfate contents followed the trend in soil available N and grain yield with highest values in the 3000gpa annual application treatment and lowest in the control and single larger manure application treatments. Lower N availability along with lower sulfur availability are postulated as the reason for the lower seed yields in these treatments.

To further investigate sulfur limitations at this site, sub-plots were established in the spring of 2002 with 40kgS/ha broadcast as elemental S or potassium sulfate across the treatments about two weeks prior to seeding of oats in the plots in the spring. Despite dry conditions at this site in early spring, rain in July allowed the crop to recover somewhat and a significant yield response to both manure application and sulfur fertilization was observed (Table 3).

**Table 3.** Response of oats (2002) to supplemental sulfur fertilizer (40kgS/ha) on a Gray soil near Star City, SK receiving injected liquid swine manure or urea.

| Treatment | 2002 Oat Grain Yield *kg/ha* |
|---|---|
| *Control* | |
| $K_2SO_4$ | 1682 a |
| $S^0$ | 1717 a |
| No S | 1265 a |
| *Annual Low Rate Swine Manure Application( 3000 gpa each year)* | |
| $K_2SO_4$ | 4082 a |
| $S^0$ | 3418 b |
| No S | 2359 c |
| *Single High Rate Swine Manure Application( 9000 gpa in 2000)* | |
| $K_2SO_4$ | 1581 ab |
| $S^0$ | 1905 a |
| No S | 1397 b |
| *Annual Urea Application (80 kgN/ha each year)* | |
| $K_2SO_4$ | 3611 a |
| $S^0$ | 2961 b |
| No S | 2365 c |

For each application treatment, values followed by the same letter are not significantly different at $P<0.05$.

Fertilization with potassium sulfate produced the highest oat yield in treatments that had received manure or urea fertilizer the previous fall. The response to added sulfur was reduced in the control and the single high rate application treatment made in the fall two years previously, due to low N availability. Elemental S was less effective than potassium sulfate in increasing oat yield in the urea and annually manured treatments, presumably due to only partial oxidation in the year of application, but still produced significant yield increases over the unfertilized control. This experiment will be continued in 2003 and 2004. The results so far indicate that the potential for sulfur deficiency and response to sulfur fertilization exists for crops grown on sulfur deficient soils receiving swine manure.

## Conclusion

There is opportunity to make more effective use of manure nutrients through balancing with commercial fertilizer. Important considerations identified so far are: 1) the N:P balance with respect to compensating for low N availability in solid manures through application of supplemental fertilizer nitrogen to enhance crop response and utilization of manure P, and 2) the N:S balance with respect to potential limitations of S relative to N on swine manured soils and requirements for additional fertilizer S.


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