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Abstract

A growth chamber study was conducted on two Saskatchewan soils to assess the effect of application of different types of animal manure with different C:N ratios on canola yield and nitrogen uptake. Treatments consisted of 13 different manure amendments with large variance of C:N ratio added at a rate of 100 mg N kg^{-1}. Addition of the solid manure amendments in two soils generally did not result in large increases in canola yield and N uptake, except for two amendments with a C:N of about 7. Generally, cattle manures had little impact on short-term release of available N if the organic C:N ratio was in the range of 13-15 and tended to decrease N availability in the short-term if the organic C:N ratio was over 15. The N supply rate measured by anion exchange membrane was quite well correlated with plant N uptake differences obtained among the treatments.

Introduction

As N in solid animal manure is mainly in organic form, crop availability of N in manure is generally lower than N from inorganic fertilizer because of the slow release of organically bound N and the volatilization of NH_3 from surface-applied manure (Beauchamp, 1983; Klauser and Gust, 1981). Thus, the rate and timing of manure application as a source of available N should be based on N-releasing capacity, which should fulfill crop N requirements and avoid leaching of excess N below the root zone. The amount of N potentially mineralized from manures is an important variable to be considered when recommending the appropriate rate to apply to meet N needs for optimal crop production (Logan, 1990).

N mineralization is a microbiological process in which C:N ratio in the organic amendment is an important factor affecting the rate of mineralization. Manure C: N ratio was recently shown to account for 40% of the variation in amount of N mineralized from the manure (Chadwick et al., 2000). A large variance in C:N ratio can be expected in different sources of manure and manure products (e.g. compost) because of differences in animal species, feed, bedding material, age and handling. (Overcash et al., 1983).

If we understand the N release from manure in soils and how the N mineralization is related to C:N ratio, a parameter that is relatively easy to measure, a more appropriate rate and time of application maybe made. The objectives of the current study were: (1) to examine the effect of application of different type of animal manure with different C:N ratios on canola yield and nitrogen uptake; (2) to assess N supply in manured soil to determine the pattern of available N release over time; and (3) to determine the N mineralization in manured soil and its relationship to C:N ratio of the manures.

Materials and Methods

Growth Chamber Study

The effect of manure amendments on soil N availability and crop response was examined in a pot experiment performed in a controlled environment. Two soils were selected from the Central Butte and Dixon areas in Saskatchewan (Table 1). The soils were sampled from the surface layer (0 to 15 cm), and then air-dried, crushed and sieved (< 4 mm). Thirteen different organic waste amendments representing a large range in C/N ratio were used in this study. Among these were ten cattle manures collected from farms in Saskatchewan. Two pelletized hog manures, with and without supplemental fertilizer in the pellets, were used from Quebec, and a compost was used from the Agricultural Research and Development Centre, Ohio State University beef barns on Wagner Farm, Wooster, Ohio. The sources and concentrations of C and N are shown in Table 2.

Table 1. Some characteristics of soils used in the experiment

Soil Association	Texture	pH	EC dS m^{-1}	Total C g kg^{-1}	Total N g kg^{-1}	C:N	NH_4-N	NO_3-N
							---- mg kg^{-1}-----	
Blaine Lake	Clay loam	7.9	0.19	23.2	1.77	13.1	0.85	0.72
Haverhill	Sandy loam	7.6	0.19	11.0	0.84	13.1	0.36	0.66

Fertilizer urea was used as an inorganic N source to compare to the manures. All the manures and urea were applied to the two soils at rates of 100 mg of total N per kg of soil. A control without any addition was also included, giving a total of fifteen treatments. All the treatments were replicated three times with 775 g soil in each pot. Plants were grown to maturity and seeds and straw were harvested. Severe sulfur deficiency was observed in the urea treatment of both soils.

Control soils and amended soils were brought to 70% of field capacity and equilibrated for 96 hours. No additions of other nutrients were made in any of the treatments. Approximately 10 seeds of canola were sown into each pot and thinned to 3 plants after emergence. The growth chamber temperature was 25°C during the day and 12°C at night. Soil moisture was kept at 90% of field capacity in all the treatments. The pots were completely randomized and rotated each week. When plants reached the desired stage, the plants were harvested. Seeds and straw were separated, dried at 50°C, and weighed for dry matter yield determination. The samples were then ground and digested in a sulfuric acid-hydrogen peroxide mixture using a temperature-controlled digestion block (Thomas et al., 1967) followed by automated colorimetry for NO_3-N and NH_4-N. Plant N uptake is expressed as milligrams of N taken up per pot of soil.

Table 2. Carbon and N contents of the manure amendments used in the study (fresh weight basis)

Organic Manure	Location	Organic C	Organic N	Inorganic N	C:N ratio
		----- $g\ kg^{-1}$ ------			
Cow-calf penning - pack surface (CPS)	Central Butte	172	12	0.04	14.4
Stockpiled 4 yr old manure, surface (S4S)	Central Butte	157	14	0.09	11.3
Stockpiled 4 yr old manure, 10 cm depth (S4P)	Central Butte	163	13	0.13	12.7
Feedlot pen, straw bedding (FB)	Central Butte	411	19	0.09	21.7
Feedlot pen, pack (FP)	Central Butte	374	24	0.08	15.6
Broiler poultry manure (BP)	Saskatoon	243	32	0.92	7.6
Feedlot penning (FYt)	Yorkton	267	17	0.10	15.8
Feedlot penning (FPm)	Poundmaker	215	17	0.08	12.7
Feedlot penning (FA1)	Alberta 1	338	26	0.09	13.0
Feedlot penning (FA2)	Alberta 2	273	18	0.03	15.2
Pelletized hog manure (fertilized) (DEC)	Quebec	242	37	4.26	6.6
Pelletized hog manure (unamended) (LIOR)	Quebec	383	33	0.66	11.5
Compost (from steers bedded on straw)[z] (CP)	Ohio	243	28	0.20	8.7

[z]The steers are bedded on straw for the winter and when they clean out the barns, the manure/straw mix is hauled to another farm where it is put in windrows and aged/composted for 2 months.

Assessment of Nitrogen Supply Power

In order to make more efficient use of manure N, we require a better understanding of the dynamics of N release from organic forms in the manured soils. Thus, a lab incubation system was applied for assessing continuous release of nitrogen from the manured soil over a similar period of canola growth under controlled condition. Anion and cation resin membrane probes (PRS™ Western Ag Innovations, Saskatoon) were directly inserted into 200 g of soil in plastic vials to sorb NO_3-N and NH_4-N in the soil. Probes were inserted and allowed to remain in the soil for 4 days, 7 days, and 4 successive 14 day intervals. Membrane probes were inserted in the same slot each time immediately after the previous probes in soil were retrieved, allowing a total of 67 days of cumulative nutrient supply to be recorded. After the probes were removed from soils and washed free of adhering soil, the probes were eluted in 0.5 *M* HCl for an hour, respectively, to desorb the nutrient ions into HCl solution. The concentrations of N (nitrate and ammonium) in the extracts were determined by colorimetry using autoanalyzer. A detailed description of this technology is reported by Qian and Schoenau (1995) and Qian et al (1996).

Results and Discussion

Canola Yield and N Uptake as Affected by Addition of Manure

Both total (seed + straw) and straw yields were significantly ($p < 0.001$) increased in both soils amended with poultry manure and DEC (Tables 3 and 4). These were the amendments with the lowest organic C:N ratios and highest content of inorganic N (Table 2). Other amendments produced lower and sometimes non-significant yield increases. The feedlot pen straw bedding, with the highest C:N ratio (21.7) had similar yield and nitrogen uptake to the unamended control, indicating that manure amendment of this type and composition is likely to have little short term effect on increasing available N when added to soil. Solid manure has less effect in inducing a yield response in the year of application than liquid slurry as there is less immediately available inorganic N (Schoenau et al., 2000). In this study, the solid manure inorganic N comprises less than 1% of the total N, except for poultry manure and DEC. Manures contain different proportions of N fractions, and the high proportion of N in the organic form in solid cattle manure slows the rate of release (Chadwick et al., 2000). Comparing the two soils, we observed significant higher yields in the Blaine Lake soil than in the Haverhill soil in 6 treatments and in the control. This difference is attributed to higher N mineralization in the Blaine Lake soil as a result of its higher organic matter content (Table 1).

Nitrogen uptake by canola shows a similar trend to the yield production. A significant ($p < 0.001$) increase in N uptake by canola was also observed in the DEC and poultry manure in both soils. DEC is produced by pelletizing hog manure with N fertilizer. Higher inorganic N content (11.5%) resulted from N fertilizer addition during the pelletization and relatively easy decomposition of manure organic N would contribute to increased N availability for plant uptake. Although poultry manure has a much lower content of mineral N (2.9%) than DEC, it had second lowest C:N ratio (7.1) among the all the manures used (Table 2) and the organic fraction in poultry manure is considered the most readily mineralizable among poultry, hog and cattle manures (Chadwick et al., 2000).

N uptake by canola in other treatments is not as greatly influenced by manure amendments as DEC and poultry manure. However, significant effect ($p < 0.05$) were observed in other treatments, such as the stockpiled 4 year old manure taken inside the pile (S4P). Factors affecting N availability and uptake include amount of mineral N content, readily mineralizable versus stable organic N content, C:N ratio, as well as other nutrients in the different manure products. Chadwick et al. (2000) concluded that there is no single chemical parameter which could quantitatively predict N mineralization. Factors other than N content and C:N ratio in the manures were clearly influencing mineralization rates even under carefully controlled experimental conditions. Less significant impact or no impact on N uptake by plants in many of the manure treatments may be because the two soils had no history of manure use and the application amount was low (100 $\mu g\ N\ g^{-1}$).

Table 3. Effect of manure addition on canola yield and N uptake in Haverhill soil

Treatments	Yield (g)		Uptake (mg pot^{-1})	
	Seed+Straw	Straw	Seed+Straw	Straw
Cow-calf penning - pack surface (CPS)	1.58a	1.46a	14.3a	9.3ab
Stockpiled 4 yr. old, surface (S4S)	1.84ab	1.64a	21.1ab	7.5a
Stockpiled 4 yr. old, 10 cm depth (S4P)	1.86ab	1.66ab	19.2ab	10.2b
Feedlot pen, straw bedding (FB)	1.60a	1.48a	11.9a	6.8a
Feedlot pen, pack (FP)	2.22b	1.95b	18.9a	9.4ab
Broiler poultry manure (BP)	4.58c	4.42c	26.2b	19.3c
Feedlot penning (FYt)	2.11b	1.85b	19.3ab	8.7ab
Feedlot penning (FPm)	2.00b	1.70ab	18.0a	6.2a
Feedlot penning (FA1)	1.74ab	1.62ab	16.3a	7.8a
Feedlot penning (FA2)	2.16b	1.91b	19.0ab	7.3a
Pelletized hg manure (DEC)	4.60c	4.36c	49.1c	39.5d
Pelletized hog manure (LIOR)	2.24b	2.03b	33.2bc	19.8c
Compost (CP)	1.57a	1.40a	20.9ab	10.4b
Control	1.43a	1.30a	12.1a	6.4a

Values followed by the same letter in each column are not significantly different ($p = 0.05$) according to Duncan's new multiple range test.

The N stored in the seeds represented an average of 44.5% and 61.5% of total N uptake by canola for Haverhill and Blaine Lake soils, respectively. Higher concentration of N in the seeds indicates a late supply of available N from organic N mineralization in the manure treatments. Late N would be allocated to the seed rather than straw (Qian and Schoenau, 2000).

Good correlations were observed between canola yield and N uptake by canola ($r = 0.78^{**}$ and 0.92^{*}, respectively, for Haverhill and Blaine Lake soils), indicating that available N as affected by the organic amendments was a main factor determining the yield.

Table 4. Effect of manure addition on canola yield and N uptake in Blaine Lake soil

Treatments	Yield (g)		Uptake (mg pot^{-1})	
	Seed+Straw	Straw	Seed+Straw	Straw
Cow-calf penning - pack surface (CPS)	2.10a	1.69a	22.9a	7.1a
Stockpiled 4 yr. old, surface (S4S)	2.75b	2.35b	21.0a	6.6a
Stockpiled 4 yr. old, 10 cm depth (S4P)	2.66b	2.39b	21.6a	11.9bc
Feedlot pen, straw bedding (FB)	2.05a	1.75a	20.0a	8.1ab
Feedlot pen, pack (FP)	2.50ab	2.21ab	29.3b	8.6ab
Broiler poultry manure (BP)	4.58c	4.18c	33.0c	17.0d
Feedlot penning (FYt)	2.36ab	2.03ab	20.6a	7.1a
Feedlot penning (FPm)	2.60ab	2.24ab	24.4ab	6.4a
Feedlot penning (FA1)	2.46ab	2.10ab	23.8ab	9.8ab
Feedlot penning (FA2)	2.38ab	2.20ab	19.4a	10.7b
Pelletized hog manure (DEC)	5.73c	4.78c	45.8d	13.1c
Pelletized hog manure (LIOR)	2.29ab	2.00ab	26.0b	8.1a
Compost (CP)	2.08a	1.81a	17.8a	7.3a
Control	2.14a	1.83a	18.2a	6.6a

Values followed by the same letter in each column are not significantly different (p = 0.05) according to Duncan's new multiple range test.

Relationship between Organic N Mineralization and C:N ratio

In our study, the mineral N content in the manures only accounted for less than 1% of the total N with a couple of samples only as large as 2-3% of total N. In a study on N mineralization in manured soils, Chadwick et al. (2000) used so-called "ammonium-free manure" by removing NH_4-N artificially. However, they found that there was still NH_4-N left, which comprised at 1% of total N for cattle manure, 2% of total N for hog manure, and 3% of total N for poultry manure. With only a small percentage of mineral N in the manures, mineral N content in the manures can be considered to be negligible. Thus, the total N in the manures was considered equivalent to organic N in the calculation of N mineralization in the study.

In order to estimate the organic N mineralization contribution from the added manure amendment, the N uptake by canola grown on the controls was subtracted from the total N uptake by canola grown on the different manure amendments. Total organic N mineralization calculated in this manner and its relationship with C:N ratio in the manures are shown in Fig. 1.

Better correlation between C:N ratio in the manure and N mineralization rate was observed in Haverhill soil. Haverhill is a sandy loam which may provide better conditions for N mineralization than Blaine Lake soil. Research found that N mineralization in coarse-textured soils is more rapid than in fine-textured soils (Van Veen et al., 1985; Hassink, 1994). As well lower inherent N mineralization in the Haverhill soil due to low organic matter content would have a lower masking effect on the manure amendment effects.

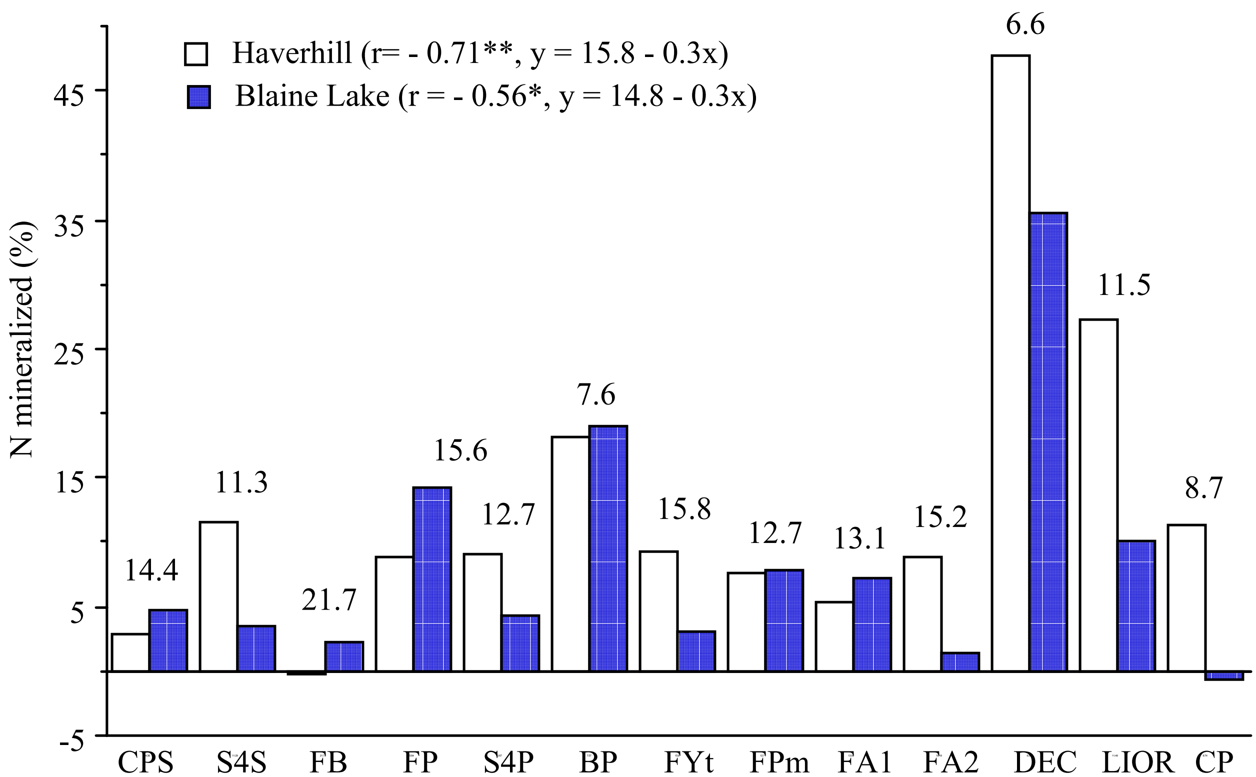

Fig. 1. Relationship between manure C:N and % of manure amendment N mineralized during 75 days of canola growth

Available Soil N Supply Over Time as Affected by Manure and Urea Application

The release of available N (NH_4 and NO_3) over the 67 day period was significantly higher (p > 0.001) in poultry manure- and DEC-amended soils than in the controls. Significantly higher (p > 0.05) release of organic N was also observed in soils amended with S4S and S4P (stockpiled, aged manure) which also had relatively lower C:N ratios. Soils amended with manure with the C:N ratio at the range of 13 to 15 had little impact on nitrogen release. A lower

N supply rate than the control was measured in certain treatments where manure C:N ratio was over 15. It was also observed that soils amended with compost had lower N supply rate than control. Selective patterns of available N release over the 67 days of incubation for both Haverhill and Blaine Lake are presented in Fig. 2. Chadwick et al. (2000) suggested that manure C: N ratio was a major factor influencing N mineralization in the manure-amended soils. Inorganic N release and accumulation was also different between the two soils. The Blaine Lake soil generally had higher N release than Haverhill (Fig. 2), probably due to its higher organic N content.

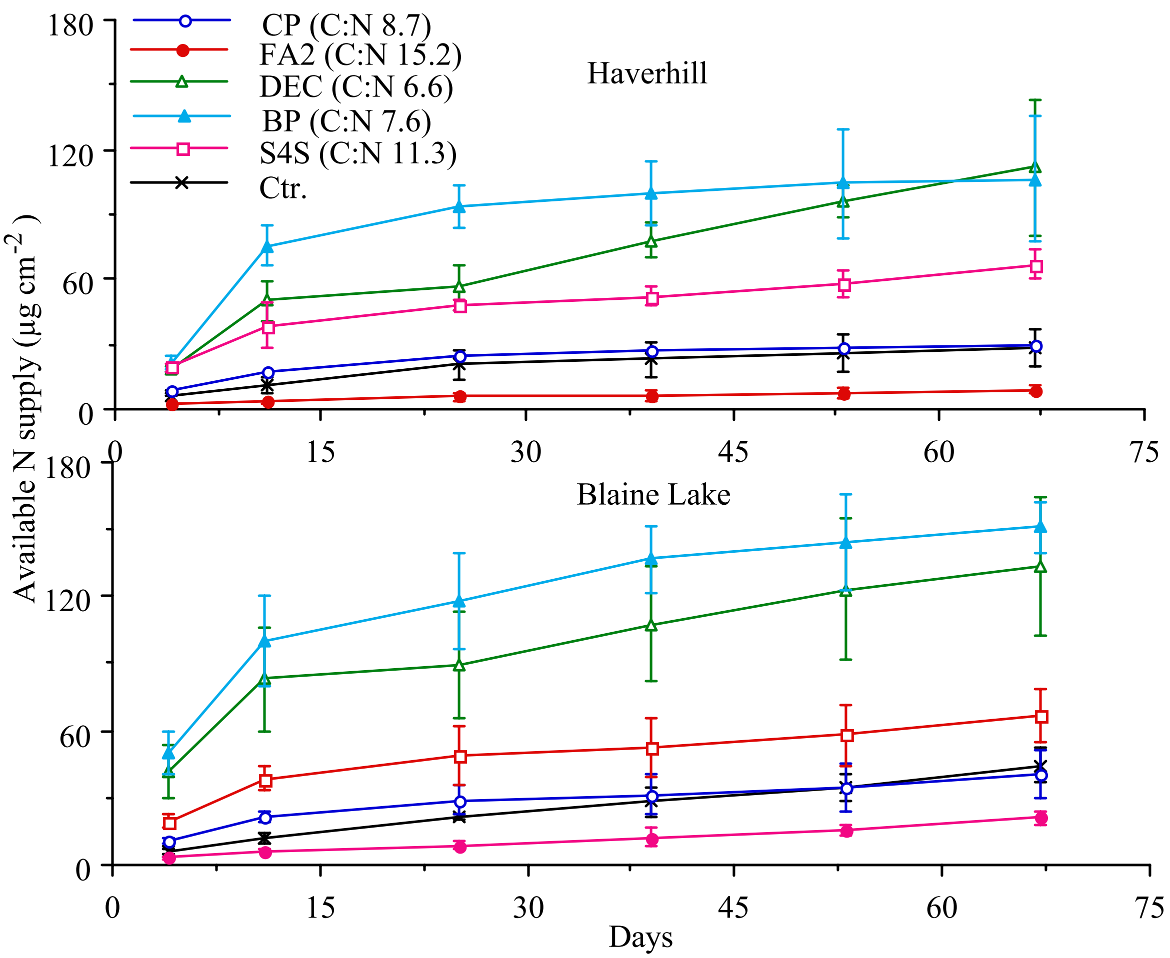

Fig. 2. Cumulative available N supply over time as determined by summing amounts of NH_4-N and NO_3-N released and sorbed onto PRS™ during successive burial periods over 67 days. Vertical bars indicate the standard deviation of the mean (n = 3).

Relationship between available N supply and total N uptake by canola

Significant relationship was observed between available N supply rate in manure-amended soils and total N uptake by canola (Table 5) with better correlation in Blaine Lake soil. An increase in r value was achieved by including a longer time span of N supply measured by accumulation on the membrane probe, especially in Haverhill soil, indicating that the continuous contribution of N mineralized is important in influencing plant uptake in manure soils.

Table 5. Linear regression between N uptake by canola and available N supply over time in two soils used.

Time (days)	Correlation coefficient (r)	
	Haverhill	Blaine Lake
4	0.42	0.68**
11	0.47	0.78**
25	0.56*	0.76**
39	0.64*	0.77**
53	0.69**	0.80**
67	0.73**	0.80**

Asterisks * and ** following correlation coefficients indicate statistically significant correlations, $P < 0.05$ and $p < 0.01$ respectively.

Conclusion

Addition of the solid manure amendments in two soils generally did not result in large increases in canola yield and N uptake, with exception of poultry manure which has larger content of easily mineralized organic N fraction ,and DEC which has fertilizer N mixed with it. Soil N mineralization after amendment with manure is influenced by several factors. However, manure C:N ratio does play a significant role as a significant correlation between manure C:N ratio and N mineralization was found for the manure-amended soils. Generally, cattle manures had little impact on short-term release of available N if the organic C:N ratio was in the range of 13-15 and tended to decrease N availability in the short-term if the organic C:N ratio is over 15. The N supply rate measured by anion exchange membrane was quite well correlated with plant N uptake differences obtained among the treatments. Longer periods of supply rate measurement in the soils resulted in better correlation with plant N uptake.

Acknowledgments

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