# Manure Nutrient Management

**Alfalfa Unable to Prevent Groundwater Contamination Under an Abandoned Barnyard on Sandy Soil**

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**Introduction**

There is substantial public concern about water quality. Many point sources of excess N and P are being controlled, yet water quality in many areas of the USA continues to deteriorate. This is especially true in much of central Wisconsin and other areas dominated by sandy soils where ground water contamination has become a serious problem.

Manure addition to soil may result in excessive P accumulation, which can threaten surface water quality and in some instances, ground water quality. Although P is generally considered immobile in soil, significant P leaching may occur after high livestock manure application rates. Increased P loading could be environmentally detrimental in areas where ground water is hydrologically connected with surface water.

Livestock have traditionally been fed in outdoor lots ('barnyards') to minimize production costs. Excessive manure accumulation occurs near feed bunks, hay bales, or watering tanks. Our hypothesis was that alfalfa would protect ground water quality at an abandoned barnyard site in Central Wisconsin, and that special non-$N_2$-fixing types of alfalfa would be more effective than standard alfalfa.

**Methods**

The experiment was located in Portage Co., Wisconsin. Dairy young stock had been fed year-round on 4 to 6 ha of Richford loamy sand (0 to 6% slope), which had been nearly devoid of vegetation for about 15 year. Soil and ground water sampling, preliminary piezometer installation, and seeding of alfalfa were initiated in summer of 1998; ground water monitoring well nests were installed in 1999. Two replicate 30 x 60 m plots of non-$N_2$-fixing alfalfa ('Ineffective Agate') in the other and two of standard $N_2$-fixing alfalfa ('Agate') were seeded in late July 1998, but stands of one replicate failed. Due to limited seed availability, this replicate was reseeded with 'Ineffective Saranac' and 'Saranac' in August 1999.

Herbage samples were obtained per plot from 1-$m^2$ sections located in areas of contrasting soil fertility at each of three alfalfa harvests per year. We used the $^{15}N$ natural abundance technique to estimate symbiotic $N_2$ fixation by $N_2$-fixing alfalfa during 2000 and 2001. Soil and ground water were sampled periodically over 3 years and analyzed for inorganic N and P.

## Results and Conclusions

At the forage yields produced at this site, we found that standard $N_2$-fixing alfalfas removed at least 200 kg N $ha^{-1}$ annually from these sandy soils. Nitrogen fixation is a facultative process: when large amounts of inorganic N are available at a site, alfalfa will fix less $N_2$ from the atmosphere. This research demonstrated how the facultative nature of symbiotic $N_2$ fixation provides an economic benefit for phytoremediation (Fig. 1). In sites that have heterogeneous accumulations of nitrate, $N_2$-fixing alfalfa will produce uniformly high yields, yet remove inorganic N efficiently, as long as other factors are optimum for alfalfa growth (water supply, nutrient levels, etc.). Non-$N_2$-fixing alfalfa did not remove as much total N as $N_2$-fixing alfalfa at this site, presumably because available N was lost by leching, thereby limiting growth and yield in the non-$N_2$-fixing plots.

Nitrate leaching to ground water was significant at this site, with all wells exceeding the 10 mg $L^{-1}$ public drinking water standard for $NO_3^-$-N. One example is shown in Fig. 2. Concentrations as high as 80 mg $L^{-1}$ $NO_3^-$-N were found in down-gradient wells in 2001. Both non-point and focused recharge leaching was apparent at this site, highlighting the need for better livestock manure handling and storage on these soils.

Further research to optimize N uptake in remediation sites should focus of companion crops like wheat, barley, or oats planted with alfalfa to provide more first-year uptake of N while alfalfa develops a deep root system, especially in soils having high hydraulic conductivity. The cereal crop can be harvested for silage at the soft dough growth stage to provide feed and to limit competition with alfalfa in midsummer. Farmers who use this forage should be aware of potentially high concentrations of $NO_3^-$ in grass forage, which may be toxic to livestock. Ensiling will reduce excess $NO_3^-$ in the stored forage, whereas conserving the forage as hay will not.

In addition, direct seeding techniques that would not require cultivation should be used where previous soil compaction will not limit root growth. Cultivation destroys near-surface compacted layers, which coincidentally increases both rapid mineralization of organic N and $NO_3^-$ leaching.

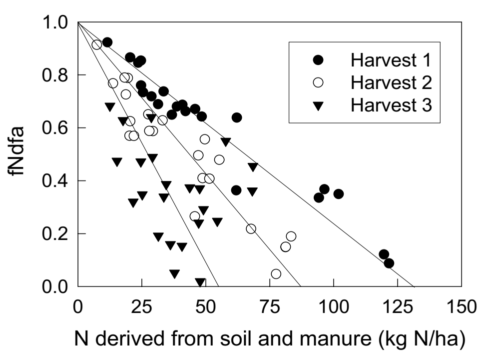


Figure 1. The fraction of N derived from the atmosphere (fNdfa) declined with increasing N derived from the soil and manure.

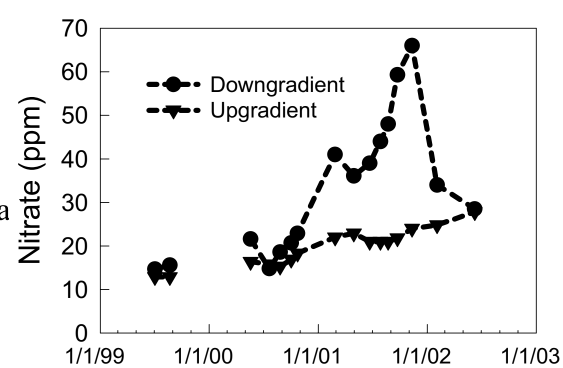


Figure 2. Ground water nitrate increased below the alfalfa plots, regardless of alfalfa type. Slow increases in nitrate in upgradient wells indicate nitrate loading from a new barnyard.

**Differential $^{15}N$ Labeling of Dairy Manure Components for Nitrogen Cycling Studies**

J.M. Powell, Z. Wu, K. Kelling, P. Cusick and G. Muñoz

**Introduction**

Approximately 70 - 80% of the nitrogen (N) consumed by a dairy cow is excreted in urine and feces. Fecal N can be divided into two pools: 1) endogenous N consisting of microbial products and micro-organisms from the rumen, the intestine and the hind gut, and N originating from the digestive tract itself; and 2) undigested feed N. When applied to soil, urine N mineralizes rapidly, followed by fecal endogenous N and fecal undigested feed N. Although undigested feed N in feces may not make a significant contribution to crop N requirements during the year following application, this component likely plays an important role in soil-crop N dynamics over the long-term, and contributes significantly to soil organic matter in manure-amended soils. The objective of this study was to differentially label urine N, fecal endogenous N, and fecal undigested feed N for the purpose of determining their short- and long-term mineralization in soils.

**Methods**

Two methods were used to differentially enrich dairy urine and fecal N components in $^{15}N$. The *forage method* involved labeling alfalfa (*Medicago sativa* L.) hay and corn (*Zea mays* L.) silage then feeding these forages to dairy cows. This technique labels urine N, fecal endogenous N and fecal undigested feed N. The *urea method* involved the direct feeding of $^{15}N$-enriched urea to cows with unlabeled forage. This technique labels urine N and fecal endogenous N. No labeled undigested feed N in feces can be expected using the *urea method* since no $^{15}N$ forage is fed. Two ruminally-fistulated non-lactating cows weighing from 440 to 520 kg were used for each labeling method. Cows were first adapted to a diet consisting of approximately 55% alfalfa hay and 45% corn silage on a dry matter basis (atom % $^{15}N$ at natural abundance) for 7d. On the last day of the adaptation period, indwelling catheters were inserted into the bladders for urine collection. $^{15}N$-enriched forage or urea was fed for 2-3 days. Feces and urine were collected separately at 4 or 8 h intervals for 8 days after the initiation of $^{15}N$ feeding.

**Results and Discussion**

In the forage labeling part of this study, highest alfalfa yields and $^{15}N$ enrichments were generally attained in the first and second harvests (Table 1). Relatively high levels of $^{15}N$ enrichment were also attained in the third harvest, even though $^{15}N$-enriched fertilizer was applied only before the first and second harvests. For the cows fed $^{15}N$-enriched forage, the pattern of $^{15}N$ excretion in urine and feces was similar for both cows during all four years of the study. $^{15}N$ concentrations in urine and feces increased to a single maximum point and decreased thereafter. Peak $^{15}N$ concentrations in urine occurred between 20 and 60h after the initiation of feeding $^{15}N$-enriched forage (Fig. 1). Peak $^{15}N$ concentrations in feces occurred between 32 and 72h, or approximately 6 to 32 h after the final offer of $^{15}N$-enriched forage (Fig. 2). The pattern of $^{15}N$ excretion in urine and feces after feeding $^{15}N$-enriched urea (data not shown) was very different from the observed pattern of $^{15}N$ excretion after feeding $^{15}N$ enriched forage. A single 100g dose of 5 atom% $^{15}N$ urea fed in 1999 resulted in a single peak of $^{15}N$ enrichment in urine (approximately 1.25 atom% $^{15}N$), which occurred at 8 h, and a single peak of $^{15}N$ enrichment in feces (approximately 0.75 atom% $^{15}N$), which occurred at 32 h. Eight doses of $^{15}N$-enriched urea fed at 4 h intervals in 2000 resulted in eight $^{15}N$ peaks (from 1.25 to 2.15

atom% $^{15}N$) in urine. Each peak was recorded within 4 h after feeding $^{15}N$-enriched urea. A single $^{15}N$ enrichment peak in feces occurred (approximately 1.25 atom% $^{15}N$) approximately 56 h after the initial offer of $^{15}N$-enriched urea. No increases in urinary or fecal $^{15}N$ concentrations were observed after the 7th or 8th dosing.

| Year of forage production | Forage type | Amount fed | Total N content | Atom % $^{15}N$ excess |
|---|---|---|---|---|
| | | kg DM | g kg$^{-1}$ | |
| 1997 | Alfalfa harvest 1 | 8.1 | 29.59 | 3.231 |
| | 2 | 5.4 | 38.45 | 3.055 |
| | 3 | 1.7 | 43.10 | 1.956 |
| | Corn silage | 12.2 | 8.92 | 6.436 |
| | **Total diet** | **27.4** | **22.97** | **3.562** |
| 1998 | Alfalfa harvest 1 | 9.3 | 23.78 | 3.643 |
| | 2 | 6.0 | 33.23 | 4.761 |
| | 3 | 2.4 | 26.83 | 3.125 |
| | Corn silage | 11.0 | 6.52 | 5.235 |
| | **Total diet** | **28.7** | **19.39** | **4.188** |
| 1999 | Alfalfa harvest 1 | 9.3 | 24.98 | 3.431 |
| | 2 | 10.8 | 29.84 | 2.919 |
| | 3 | 5.4 | 33.52 | 3.580 |
| | Corn silage | 23.2 | 8.67 | 4.689 |
| | **Total diet** | **48.7** | **19.234** | **3.554** |
| 2000 | Alfalfa harvest 1 | 15.2 | 31.70 | 1.911 |
| | 2 | 11.9 | 33.47 | 3.791 |
| | 3 | 4.2 | 41.04 | 1.171 |
| | Corn silage | 28.8 | 9.07 | 4.624 |
| | **Total diet** | **60.1** | **21.86** | **2.923** |

Table 1. Forage fed to dairy cows for $^{15}N$-labeling of manure

The undigested feed N in feces (NDIN) accounted for approximately 20-22% of the total fecal N, or 10% of the total N (urine plus feces) excreted by the cows fed the diets of this study. The homogeneous $^{15}N$ labeling of fecal N components was evaluated by comparing $^{15}N$ concentrations in fecal total N and NDIN. Fecal endogenous N [neutral detergent soluble N (NDSN)] was calculated as the difference between total fecal N and NDIN. During all study years, the labeling of NDIN appeared to be slower than NDSN during the period before maximum fecal $^{15}N$ concentrations were attained (data not shown). The proportionate mixing of feces from periods before and after peak $^{15}N$ excretions is needed to obtain uniformly labeled feces. The selection of a manure $^{15}N$ labeling technique would depend on the intended use of the $^{15}N$-labeled manure, and associated costs and labor.

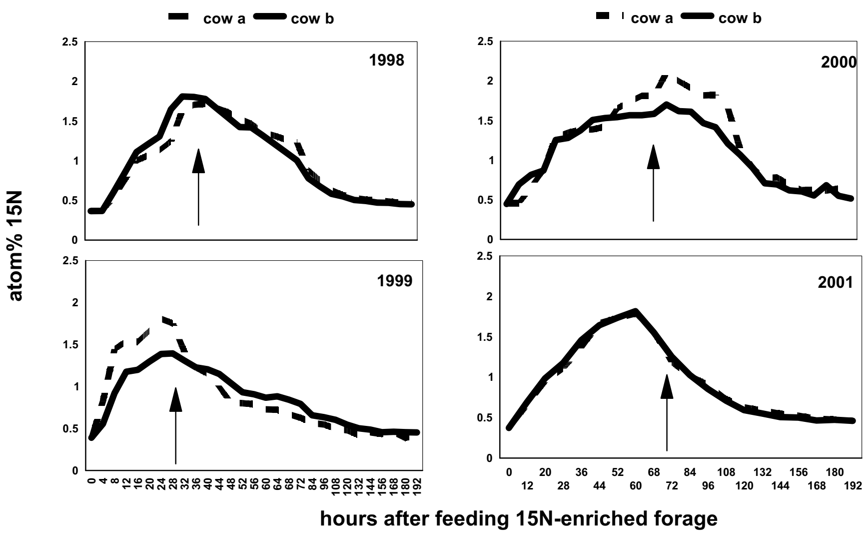


Figure 1. $^{15}N$ concentration in urine after feeding $^{15}N$-enriched forage (base of arrows point to time when last offer of $^{15}N$-enriched forage was made).

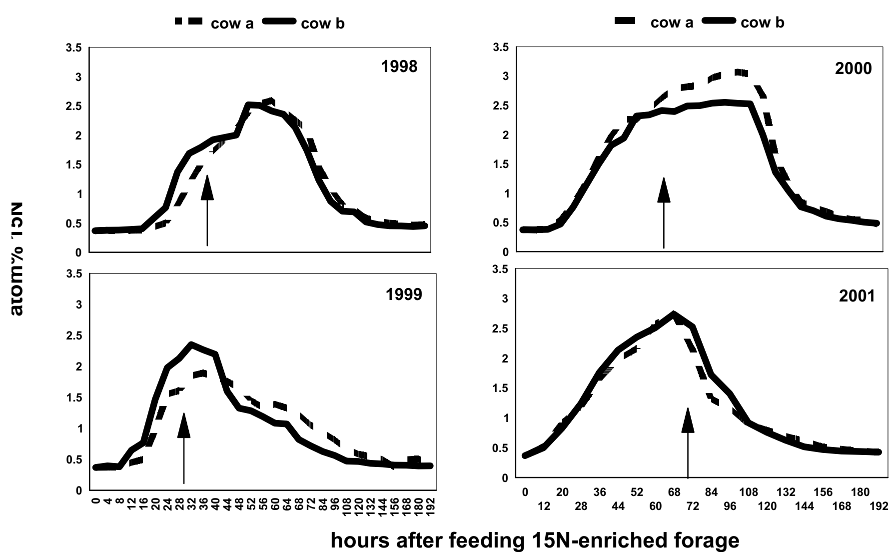


Figure 2. $^{15}N$ concentration in feces after feeding $^{15}N$-enriched forage (base of arrows point to time when last offer of $^{15}N$-enriched forage was made).

Of the total $^{15}N$ used in this study, 22 to 28% was incorporated into feces and urine using the *forage method* verses 64 to 78% using the *urea method* (Table 2). The major difference in $^{15}N$ use efficiency between the two $^{15}N$ labeling techniques was the loss of $^{15}N$ in soil when labeling forage. From 36 to 44% of applied $^{15}N$ was taken up by alfalfa and 26 to 65% taken up by corn. Lowest $^{15}N$ uptake by corn occurred in 1998 when high rainfall events following the second and third fertilizer applications likely resulted in $^{15}N$ leaching losses. Of the total $^{15}N$ fed, 51 to 64% was recovered in feces and urine from cows fed $^{15}N$-enriched forage verses 64 to 78% recovery from cows fed $^{15}N$-urea. Higher $^{15}N$ recovery using the urea method was likely due to urea's rapid incorporation into the rumen microbial biomass with excess excreted in urine. Un-recovered $^{15}N$ fed as forage or urea was incorporated into rumen microbial and body tissue.

**Conclusions**

Manure $^{15}N$ labeling provides a tool for direct measurement of N flow in various components of the feed-dairy cow-manure-soil/crop continuum. The forage method should be used to label manure for use in long-term N cycling studies so both fecal endogenous and undigested feed N components become $^{15}N$-enriched. Uniform labeling of fecal N components can be achieved by the proportionate combination of feces excreted before and after peak $^{15}N$ excrement levels are attained. The urea method is less laborious and costly and may be used to label manure for short-term studies, for example, to determine crop uptake of manure N during a single cropping season.

| Component | 1997-98 | 1998-99 | | 1999-2000 | | 2000-01 |
|---|---|---|---|---|---|---|
| | Forage method | Forage method | Urea method | Forage method | Urea method | Forage method |
| Crop input | | | | | | |
| Alfalfa | 38.54 | 53.95 | Not applicable | 53.95 | Not applicable | 72.68 |
| Corn silage | 13.42 | 14.41 | | 14.41 | | 19.81 |
| Crop output | | | | | | |
| Alfalfa | 15.52 | 19.56 | | 23.86 | | 26.32 |
| Corn silage | 7.00 | 3.75 | | 9.43 | | 12.07 |
| | | | | | | |
| Cow input | | | | | | |
| Feed | 22.52 | 24.32 | 4.85 | 33.29 | 15.56 | 38.39 |
| Cow output | | | | | | |
| Feces | 5.64 | 7.05 | 1.00 | 9.10 | 2.73 | 11.02 |
| Urine | 5.97 | 7.96 | 2.12 | 10.15 | 9.40 | 13.43 |
| | | | | | | |
| $^{15}N$ Use Efficiency† | | | | | | |
| Alfalfa | 40 | 36 | Not applicable | 44 | Not applicable | 36 |
| Corn | 52 | 26 | Not applicable | 65 | Not applicable | 61 |
| Cow | 51 | 62 | 64 | 58 | 78 | 64 |
| Overall | 22 | 22 | 64 | 28 | 78 | 26 |
| Costs‡ | $376 | $373 | $269 | $291 | $277 | $325 |

Table 2. $^{15}N$ excess (g) input-output relationships in crop and cow components.
† ($^{15}N$ excess output/$^{15}N$ excess input) x 100 for each component
‡ total cow $^{15}N$ excess output in feces and urine divided by cost of $^{15}N$.
Cost of 10 atom % ammonium sulfate was $1.66 per g, and 5 atom % urea was $4.20 per g.

## Evaluation of Dairy Manure $^{15}N$ Enrichment Methods on Short-Term Crop and Soil Nitrogen Budgets

J.M. Powell, K. Kelling, G. Muñoz and P. Cusick

### Introduction

Nitrogenous compounds artificially enriched in $^{15}N$ have been used extensively to study manure nitrogen (N) cycling in soils. These compounds have been used for (1) post-excretion labeling, which is usually accomplished by adding a $^{15}N$-enriched inorganic source, usually ammonium sulfate, to excreta, or (2) labeling feedstuffs, which are then fed to ruminant livestock (Dittert et al., 1998). Post-excretion N labeling is usually used to study ammonium-N cycling in slurry-amended soil. Whereas slurry is the most common manure type on free stall dairy operations having parlor flush systems and lined manure storage pits, semi-solid manure consisting of feces, urine and straw bedding is the most important manure type on small dairy operations (Jackson-Smith et al., 1997).

Two methods for differentially enriching dairy manure N components in $^{15}N$ have been recently proposed (see **Differential $^{15}N$ labeling of dairy manure components for nitrogen cycling studies, pp. 90)**. The *forage method* involves the labeling and feeding of $^{15}N$-enriched forage to dairy cows to label urine N, fecal endogenous N and fecal undigested feed N (Mason and Frederiksen, 1979). The *urea method* involves feeding $^{15}N$-enriched urea directly to dairy cows to label urine N and fecal endogenous N. No fecal undigested feed N is labeled using the *urea method* since no $^{15}N$-enriched forage is fed. The objective of this study was to determine corn $^{15}N$ uptake and the amount and forms of soil $^{15}N$ in field plots amended with $^{15}N$-enriched manure derived from the forage and urea labeling methods.

### Methods

In 1999 and 2000 manure derived from the *forage method* and *urea method* were surface applied to a Plano silt loam (fine-silty, mixed, mesic, Typic Argiudolls) in field plots 1.5 m wide x 2.3 m long containing three corn (*Zea mays* L.) rows. Corn was grown for two years after each manure application. In fall 2000, soil samples were taken from each plot to 90-cm depth in 30-cm increments and analyzed for $^{15}N$ enrichment of soil total N and nitrate N.

### Results and Discussion

Corn $^{15}N$ uptake during the first year after manure application was not significantly affected by method of manure $^{15}N$ enrichment or year of application (Table 1). Of the total manure $^{15}N$ applied, 14 to 18% was accounted for in corn harvested the cropping season after manure application. Average residual $^{15}N$ uptake by corn in 2001 (8% of original manure $^{15}N$ applied) was significantly greater than residual $^{15}N$ uptake in 2000 (4%). Total (first year plus second year residual) $^{15}N$ uptake ranged from 18 to 25% with no significant differences due to manure $^{15}N$ enrichment method or year of application. Relative manure $^{15}N$ uptake by corn in our study corresponded well to crop $^{15}N$ uptake calculated by others (Sørensen and Jensen, 1998; Jensen et al., 1999).

| Harvest year | Manure type | 1st year $^{15}N$ uptake | 2nd year $^{15}N$ uptake | Total $^{15}N$ uptake |
|---|---|---|---|---|
| | | --------------% of manure $^{15}N$ applied-------------- | | |
| 1999 | Forage | (6)† 14.0 | NA | NA |
| | Urea | (6) 15.9 | NA | NA |
| 2000 | Forage | (4) 14.8 | (6) 4.3 | (6) 18.3 |
| | Urea | (4) 17.5 | (6) 4.0 | (6) 19.9 |
| 2001 | Forage | NA | (4) 8.4 | (4) 23.2 |
| | Urea | NA | (4) 7.4 | (4) 24.9 |
| Mean | | 15.4 | 5.6 | 21.1 |
| p-values | | | | |
| manure type | | .530 | .683 | .687 |
| Year | | .737 | .025 | .248 |
| type*year | | .928 | .838 | .997 |

Table 1. $^{15}N$ uptake by corn the first and second year after application of forage- or urea-labeled dairy manure. (Number in parentheses refers to the number of microplots used in calculation. For example, the 6 forage- and urea-manure plots used in 1999 to calculate 1st year uptake were the same 6 plots used in 2000 to calculate residual uptake).

Soil $^{15}NO_3$–N increases due to manure $^{15}N$ enrichment method ranged from approximately 2 to 20 kg $ha^{-1}$ (Figure 1). Both the lowest and highest $NO_3$–N levels were found in plots amended with urea manure (UM) in 1999 and 2000, respectively. Except for plots amended with UM in 2000, most (72 to 98%) $NO_3$–N was found in the upper 30 cm of soil indicating little nitrate leaching under the conditions of this study. Nitrate-N in the plots amended with UM in 2000 was fairly evenly distributed over the three measured soil depths, perhaps indicating some leaching. Although plots amended with UM in 2000 appeared to have more $^{15}NO_3$–N than plots amended with forage manure (FM), this result was not significant.

Statistical analyses showed that manure type or year of application did not significantly affect soil $^{15}NO_3$–N level. However, plots amended with manure in 2000 had somewhat greater ($p < 0.088$) $NO_3$–N levels (0 to 90 cm) than plots amended in 1999. This can be attributed to differences in the number of corn crops grown between the time of manure application and soil sampling. Whereas plots amended with manure in 1999 had two corn crops, plots amended in the spring of 2000 had only one corn crop before soil sampling in the fall of 2000. Residual $^{15}N$ uptake by corn in 2001 averaged 8% (Table 1), or approximately 21 kg $ha^{-1}$ of the manure $^{15}N$ applied in 2000. Part of this corn $^{15}N$ uptake in 2001 was likely derived from the 5 to 20 kg $ha^{-1}$ of residual $^{15}NO_3$–N (Fig. 1), as well as from the continuous mineralization of the manure $^{15}N$ applied in 2000.

There were no significant differences in total soil $^{15}N$ levels due to manure type or year of application. Total soil $^{15}N$ levels in plots amended with FM were 123 and 92 kg $ha^{-1}$, and in plots amended with UM 128 and 142 kg $ha^{-1}$ in 1999 and 2000, respectively (Fig. 2). Depth differences in $^{15}N$ recovery were statistically significant ($p < 0.001$), with highest recoveries (79%) obtained from the top 0- to 30-cm depth. No differences in $^{15}N$ recovery were observed between the 30- to 60- (15%) and 60- to 90-cm (6%) depths. This suggests either relatively little downward movement of applied manure N, or that leached N may have moved out of the 0- to 90- layer. Averaged across years, the relative amount of $^{15}N$ recovered in the 0-30, 30-60 and 60-90 cm soil depths were very similar for each manure type, averaging 32, 6 and 3% in the FM-amended plots and 38, 7 and 3% in the UM-amended plots, respectively (Table 2). On average, 67% of applied manure $^{15}N$ was accounted for, either in crop uptake (22%) or in the soil (45%). Most of the $^{15}N$ that could not be accounted for (approximately 30%) was probably lost through ammonia volatilization, and to a lesser extent via denitrification.

| | Soil Depth (cm) | | | | | | |
|---|---|---|---|---|---|---|---|
| Manure Enrichment Method | 0-30 | 30-60 | 60-90 | 0-90 | Crop† | Total | Unaccounted for |
| | N recovery (% of applied manure $^{15}$N) | | | | | | |
| Forage | 32 (6.8) ‡ | 6 (1.3) | 3 (0.6) | 41 (2.9) | 21 (2.7) | 62 | 38 |
| Urea | 38 (8.8) | 7 (1.6) | 3 (1.9) | 48 (4.0) | 23 (4.9) | 71 | 29 |

† Total crop N first and second year uptakes for each manure type were averaged for 1999-2000, and 2000-2001 (Table 2). Soils were sampled in fall of 2000. .
‡ Standard errors in parentheses

Table 2. Average total $^{15}$N recovery in soil and corn for different dairy manure types in south-central Wisconsin.

Conclusion

A recent analyses of three years data from the main plots of the long-term trial showed that $^{15}$N-labeled dairy manure (forage method) provided much more accurate estimates of (1) the contribution of manure N to crop N requirements compared to the “difference method” and “fertilizer equivalent” approach, and (2) effects of manure application on soil $NO_3$ and total N levels (Muñoz et al., 2002). Our results reported here suggest that the less laborious and costly urea method of labeling the labile dairy manure N components (urine and fecal endogenous N) would be adequate for evaluating short-term N dynamics in manure-amended soils. The contribution of fecal undigested feed N to soil N dynamics in continuously manured soils needs to be assessed before knowing if this manure component needs to be labeled using the forage method to produce manure for use in long-term N cycling studies

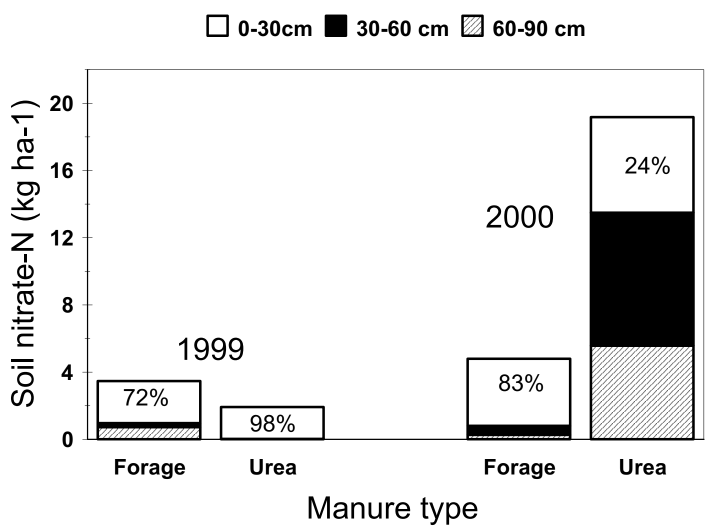


Figure 1. Soil $NO_3$–N increase over non-manured control plots due to manure type and year of application as estimated by $^{15}$N measurements in south-central Wisconsin, 2000. Numbers within each bar represent the percentage of recovered total soil $^{15}$N present in the top 30 cm of soil.

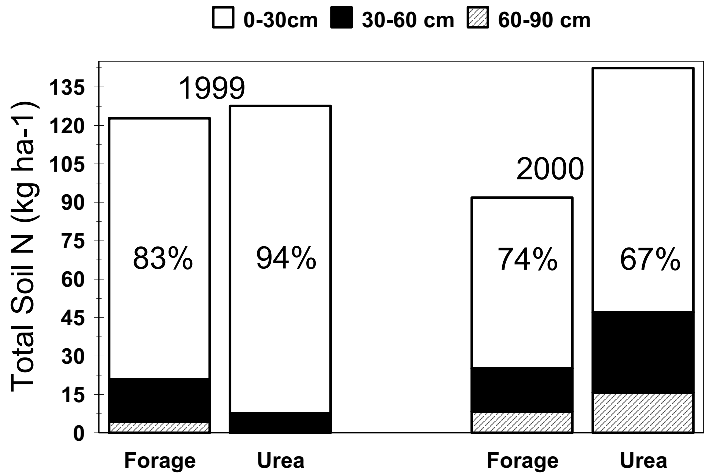


Figure 2. Total soil N increase over non-manured control plots due to manure type and year of application as estimated by $^{15}N$ measurements in south-central Wisconsin, 2000. Numbers within each bar represent the percentage of recovered total soil $^{15}N$ present in the top 30 cm of soil. (no significant differences in total soil N increase in the 0-90 cm depth due to manure type, year of application or interactive effects of these two treatments).

**On Farmers' Ground: Understanding Nutrient Management on Wisconsin Dairy Farms**
J.M. Powell, D. McCrory, H. Saam and Y. Li

In 2001, scientists at the USDFRC and collaborators from the University of Wisconsin-Madison and the Michael Fields Agricultural Institute received a grant from the USDA-CSREES *Initiative for Future Agricultural and Food Systems* to study a range of issues related to nutrient management on dairy farms. A key component of the overall research effort is to better understand how dairy farmers manage agricultural nutrients (the nitrogen and phosphorus contained in feed, fertilizer, and manure) on their farms. The project works closely with 54 dairy farms in Wisconsin over a 12-18 month period in 2002 and 2003.

This on-farm research project is designed to answer questions such as:

* How do management practices used by typical Wisconsin dairy farmers affect the flow of nutrient on their farms?

* What are some innovative solutions that farmers have created to meet their nutrient management challenges?

* What are the most significant obstacles dairy farmers face in managing agricultural nutrients?

Most research to understand and improve nutrient cycling on dairy farms has taken place on experimental farms or other controlled conditions. This research project is designed to improve our understanding of how farmers manage nutrients under more typical production conditions.

Several visits to each farm are being made beginning in the fall of 2002. Dairy farms have been selected from within three regions of distinctive geographic and soil characteristics (Fig. 1), and different stocking densities. Our hope is to understand how farmers living in similar and different biophysical environments, and having different amounts of cropland to grow feed and spread manure, respond to the challenges of managing agricultural nutrients.

**What kinds of information are being collected?**
On our first visit during the latter months of 2002, we sought to understand the overall farm operation, including information on herd size, composition, management and feeding practices, and on land use and other basic operation characteristics. A map of each farm and field boundaries was made using aerial photographs and discussions with farmers (Fig. 2). These maps have been digitized and serve as the basis for collecting detailed information on cropping patterns, tillage, and manure and commercial fertilizer application practices at the field level.

**What will be done with the information?**
Several widely used nutrient management computer models will be used to analyze the information we collect. These models have the ability to estimate, for example, whole-farm nutrient balances (in other words, are more nutrients coming onto a farm than leave in the form of milk, meat, and crops?), which individual fields or points on the landscape might be places where nutrients collect and are lost, etc. During each farm visit, we collect samples of feedstuffs, milk, and manure to help calibrate and validate the nutrient flow models.

We will share with farmers the results of the computer-based nutrient management models and what recommendations the models indicate are needed to increase the efficient use of agricultural nutrients. During this project phase, we will be particularly interested in letting the farmers tell us why they make the nutrient management decisions they do, and what opportunities and obstacles might affect any future changes in their nutrient management behavior.

The results of this study should help identify where the greatest gains in nutrient management on dairy farms can be made. Moreover, an expanded understanding of how farmers think about nutrient management, as well as information about the biophysical (soil, crop, weather), financial, labor, and institutional barriers that limit farmer options, will be used to make suggestions for improving the success and minimizing the costs of future nutrient management policies.

Results of the study will be published in ways that can be used by farmers, dairy extension agents, university researchers, crop and feed consultants, policy makers, and others to improve the management of agricultural nutrient on dairy farms.

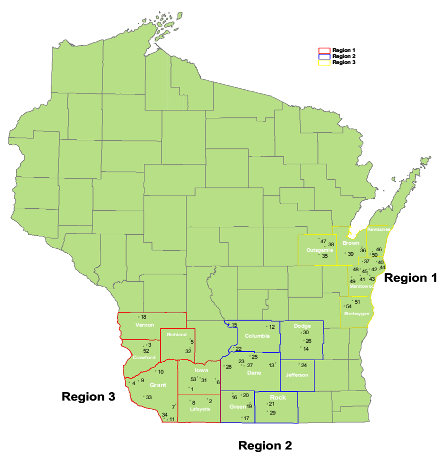


Figure 1. Geographic location of dairy farms participating in “On-Farmers’ Ground”.

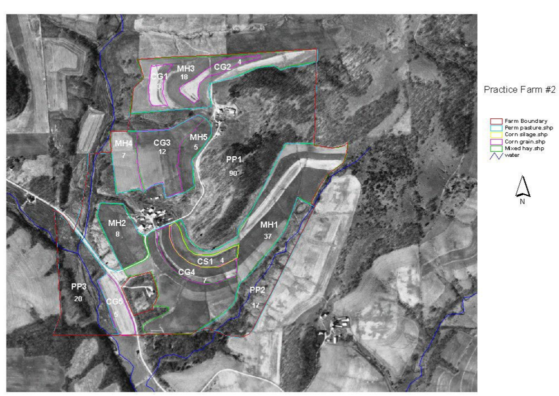


Figure 2. Example of a farm map and its field boundaries for a dairy farm participating in “On-Farmers’ Ground”.

**Nitrogen Availability from Dairy Manure Components**

P. Cusick, J.M. Powell, R. Hensler and K. Kelling.

## Introduction

Manure nitrogen (N) mineralization in soil determines manure N availability for crop uptake. Soil texture and other controls, such as moisture and temperature create environments where great differences in manure N mineralization can be expected. Understanding the influence of these factors on manure N mineralization is critical to better predicting the amount and rate at which manure N becomes available to agronomic crops. The objective of this study was to determine the N mineralization rate of dairy manure components (feces, urine and bedding) in soils of various textures under different environmental conditions.

## Methods

A laboratory incubation study was conducted in which $^{15}N$-labeled or unlabeled feces, urine and oat straw bedding were incubated in soil for 168 days. Six soils (Table 1) were selected to represent prominent dairying areas in the state of Wisconsin. Manure amendments (Table 2) were applied at a rate equivalent to 350 kg N $ha^{-1}$ (36% of total applied N derived from feces, 42% from urine and 22% from bedding) into incubation vessels (glass jars containing 250g soil dry wt.). Triplicate vessels per manure treatment plus controls were packed to natural bulk density, kept at 60% water filled pore space and incubated at 11, 18 and 25 C˚.º Vessels were sampled at 0, 14, 21, 42, 84, and 168 days and analyzed for mineralized N (NH4+ and NO3-) and $^{15}N$ abundance at day 168.

## Results and Discussion

Soil type and temperature had significant effects on fecal N mineralization; an interaction between soil type and temperature was found in straw N mineralization; and soil type and temperature did not significantly affect urine N mineralization (Table 3). Uniform urine N mineralization was likely due to the rapid breakdown of most, if not all urine in the soil. Average $^{15}N$ recovered in the mineralized N fraction in soil amended with labeled urine over all soils and temperatures was 55%. Because it is unlikely N losses occurred during the incubation, the remaining (45%) unaccounted for applied urine N may have exchanged with unlabeled soil N, or may have been immobilized by the soil microorganisms. In a field study conducted in 2001 on a Plano silt loam, it was found that 31% of applied urine $^{15}N$ was taken up by corn during the cropping season after application (unpublished). The difference between urine N availability in our laboratory incubation (55%) versus urine N uptake in the field (31%) illustrates that urine N may be readily available to crops but some N losses are inevitable.

Fecal N mineralization was significantly higher in the Plano and Symco soils than other soils. It is unclear based on the physical properties of these soils why they mineralized the highest amount of fecal N. Temperature also had a significant effect on the mineralization of fecal N. Highest fecal N mineralization (19%) was found at the highest temperature (25˚C). In the aforementioned field study on the Plano silt loam, 17% of applied fecal N was taken up by corn during the cropping season following application, compared to 19% mineralized in Plano silt loam included in the incubation trial.

Whereas straw N mineralization generally increased in Plano, Symco and Loyal with increasing temperature, straw N mineralization decreased in the Rosholt soil with increasing temperature. Straw N mineralization in the Rozetta soil remained stable for all temperatures. It should be noted that straw N mineralization (17% of applied straw N) was similar to fecal N mineralization (15%) over all soils and temperatures.

Soil type did not affect N mineralization in vessels that received all manure components labeled. Temperature was significant with the highest manure N mineralization occurring at 25˚C. The average amount of manure N mineralized over all soils and temperatures in vessels that received all components labeled was 23%. Average manure N mineralization by adding average individual component mineralization rates was 32% our other research on the Plano silt loam found 14% uptake of manure $^{15}N$ by corn (*Zea mays* L.) averaged over 3 years of data. Only feces and urine were labeled in this trial and bedding contributions were not considered. University of Wisconsin recommendations for first year N availability of dairy manure are 30% when surface applied and 40% when incorporated. Though this data suggests that recommendations may be high, it should be noted that isotopic studies generally underestimate availability due to $^{15}N$ exchange with soil organic N pools and the subsequent release of unlabeled soil N. Perhaps estimates of manure N mineralization using $^{15}N$ should be viewed as a minimum N availability.

**Conclusion**

Across soil types, 50 to 60% of applied urine N was apparently plant available. Further investigation is needed to understand how soil type affects N availability of the fecal and bedding components of dairy manure.

**Acknowledgements**

Support for this project was provided by the UW Consortium for Agriculture and Natural Resources, the UW-Madison College of Agricultural and Life Sciences. Appreciation to Jennifer Hegge and Chris Fellner, University of Wisconsin- Stevens Point for their diligent effort in the daily maintenance of this experiment.

Table 1. **Treatment List**

| | |
|---|---|
| Treatment 1 | **$^{15}$N Feces**, $^{14}$N Urine, $^{14}$Bedding |
| Treatment 2 | $^{14}$N Feces, **$^{15}$N Urine**, $^{14}$Bedding |
| Treatment 3 | $^{14}$N Feces, $^{14}$N Urine, **$^{15}$Bedding** |
| Treatment 4 | **$^{15}$N Feces, $^{15}$N Urine, $^{15}$Bedding** |
| Treatment 5 | Control (no manure applied) |

**Table 2.** Initial Soil Properties

| Soil Series | Texture | Tot-C | Tot-Org-C | Inorg-C | Bray-P1 | Total N | Sand | pH |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | mg/kg | % | % | |
| **Loyal** | Silt Loam | **2.61** | **2.35** | **0.26** | **42** | **0.212** | **13** | **7.0** |
| | Fine-loamy, mixed, superactive, frigid Oxyaquic Glossudalfs | | | | | | | |
| **Plano** | Silt Loam | **3.55** | **2.56** | **0.99** | **72** | **0.222** | **26** | **7.4** |
| | Fine-silty, mixed, superactive, mesic Typic Argiudolls | | | | | | | |
| **Rozetta** | Silt Loam | **1.82** | **1.23** | **0.59** | **32** | **0.163** | **4** | **6.8** |
| | Fine-silty, mixed, superactive, mesic Typic Hapludalfs | | | | | | | |
| **Catlin** | Silt Loam | **2.86** | **n/a** | **n/a** | **n/a** | **0.173** | **14** | **n/a** |
| | Fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls | | | | | | | |
| **Symco** | Sandy Loam | **0.81** | **0.80** | **0.01** | **35** | **0.087** | **73** | **6.3** |
| | Fine-loamy, mixed, mesic Aquollic Hapludalfs | | | | | | | |
| **Rosholt** | Sandy Loam | **0.87** | **0.83** | **0.04** | **42** | **0.087** | **53** | **5.7** |
| | Coarse-loamy, mixed, superactive, frigid Haplic Glossudalfs | | | | | | | |

**Table 3.** Mineralized $^{15}N$ recovered from labeled manure components over various soils and temperatures.

| Soil type | Fecal $^{15}N$‡ | | | | Urine $^{15}N$ ‡ | | | | Straw $^{15}N$ ‡ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11ºC | 18ºC | 25ºC | Soil Avg. | 11ºC | 18ºC | 25ºC | Soil Avg. | 11ºC | 18ºC | 25ºC | Soil Avg. |
| | ----------% $^{15}N$ Recovered---------- | | | | | | | | | | | |
| **Loyal** | 8 | 8 | 12 | **10** | 52 | 45 | 69 | **55** | 12 | 20 | 19 | **17** |
| **Symco** | 20 | 16 | 27 | **21** | 49 | 54 | 56 | **53** | 14 | 16 | 22 | **18** |
| **Plano** | 13 | 18 | 26 | **19** | 44 | 60 | 63 | **55** | 15 | 24 | 25 | **22** |
| **Rozetta** | 12 | 5 | 15 | **11** | 61 | 61 | 59 | **60** | 15 | 12 | 16 | **14** |
| **Rosholt** | 15 | 7 | 16 | **13** | 52 | 46 | 51 | **50** | 20 | 14 | 15 | **16** |
| **Catlin** | ----- | ----- | ----- | | ----- | ----- | ----- | | ----- | ----- | ----- | |
| **Temp Avg.** | **14** | **11** | **19** | | **51** | **53** | **60** | | **15** | **17** | **19** | |
| | ----------Statistical Significance---------- | | | | | | | | | | | |

| | Fecal Pr>F † | Fecal LSD† | Urine Pr>F † | Urine LSD† | Straw Pr>F † | Straw LSD† |
|---|---|---|---|---|---|---|
| **Soil** | 0.0001 | 3.81 | 0.2467 | NS | 0.0093 | * |
| **Temp** | 0.0001 | 2.95 | 0.5932 | NS | 0.0015 | * |
| **S*T** | 0.0989 | | 0.6240 | | 0.0036 | |

†See treatment list in Materials and Methods for details.
‡See treatment list in Materials and Methods for details.
*Interaction significant at p≤0.05

**Effects of Manure Handling Systems on Nitrogen Losses from Dairy Farms**
V.R. Moreira and L.D. Satter

**Introduction**

There is growing concern about ammonia and nitrous oxide emissions to the atmosphere from livestock operations, and the potential effect these emissions might have on human health and the environment. Measurements of N loss from livestock operations in Europe suggest that there are variations among management and manure handling systems. In the US, N loss inventories are still lacking for most species, especially dairy cows. Direct measures of volatile N losses from livestock housing and manure storage facilities are often difficult and subject to large error. A new approach to estimating volatile losses was utilized in this study. Since P is not volatilized from manure, the nitrogen to phosphorus ratio (N:P) in manure should reflect volatile N losses The objective of this study was to evaluate the effect of season and manure handling system on nitrogen (**N**) loss from dairy manure utilizing information on manure nutrient content from manure samples submitted to commercial laboratories.

**Materials and Methods**

The dataset consisted of 1517 manure analyses, unevenly distributed among three commercial laboratories located in MN, PA and WI. Samples deviating more than 2.5x SD (Standard Deviation) from the overall mean were deleted from the original data set, resulting in 1496 manure analyses. Subsets of this larger data set contained information that allowed examination of the effect of different types of management on the N:P ratio in manure. Since dietary N and P content affects the N:P ratio in manure, it was assumed that a large number of manure samples would diminish the impact of variation in individual manure samples due to diet. Phosphorus was used as a marker to compare N disappearance among the different variables, assuming that it would have a recovery of 100%. The ratio between N and P (N/P) was used in this analysis to compare different manure management systems. All samples had the date of sample receipt by the laboratory, and these dates were used to identify season of manure storage. Manure samples were identified as coming from bedded pack (BP), daily haul (DH), or liquid slurry (LS) systems. In addition, some samples had accompanying information indicating type of bedding used. Organic bedding describes those using straw, shavings, sawdust, oat hulls, grass, etc… Inorganic bedding refers to sand, or in some few cases, no bedding. Some liquid slurry samples had information on how the liquid slurry was loaded into the storage systems, i.e., pushed on to the surface of the stored slurry, or pumped into the storage facility from below the slurry surface. Also, some manure samples had information on whether the slurry storage was covered or not.

**Results and Discussion**

In Fig. 1, no difference was detected between daily haul and liquid slurry (earthen basin and pit) ($P \leq .51$). The interaction between season and storage system ($P \leq .02$) indicated that liquid storage had significantly higher N/P throughout the year, except during the winter, when bedded pack apparently retained more N. The ratio of nitrogen to phosphorus tended to increase ($P \leq .07$) by loading liquid slurry into the storage facility from the bottom (below the surface) instead of pushing slurry on to the surface (Fig. 2). Smaller N:P ratios observed during the summer (interaction $P \leq .16$) could be explained by high ammonia loss from the barn floor before manure went into slurry storage. Table 1 shows the N:P ratio of liquid slurry from covered or uncovered storage facilities. In this population of samples, covering did not reduce N loss. However, only 53 samples were available for this analysis, 12 of which were from covered storage. Season interactions could have had a masking effect on the potential for covers to retain more nitrogen in the manure. Table 2 shows the impact of bedding type on manure characteristics. It has been suggested that organic bedding might be expected to help reduce volatile losses by forming a floating mat or cover on the liquid storage and by providing substrate for conversion of ammonia into microbial N. Nonetheless, no effect of bedding type was noted in this population of manure samples. Overall, manure samples analyzed in the spring resulted in higher N/P than in samples analyzed in the autumn ($P \leq .01$), and tended to be higher than summer samples ($P \leq .12$) (Fig. 3). However, a lower winter N/P in the Minnesota dataset resulted in a significant interaction between laboratory source and season ($P \leq .002$).

## Conclusion

The N:P ratio in manure provides one approach for estimating extent of N loss due to manure management practices in a variety of conditions. Liquid slurry storage, the most common method of manure storage in the datasets studied, appeared to be an efficient system for conserving manure nitrogen. Although our analyses did not show statistical differences due to storage cover and type of bedding, it indicated that loading method might have a significant impact on reducing nitrogen losses. The lack of information about diets prevents a reliable estimate of actual N loss in the various data subsets. If we assume an average N:P ratio in dairy manure at the time of excretion of 6.84, and this would be approximately correct when the diet contained about 17.5%CP and .44%P (dry basis), then N:P ratios of 6, 5 and 4 would represent volatile N losses of approximately 12.3, 27.0, and 41.6% of total excreted nitrogen.

Figure 1.

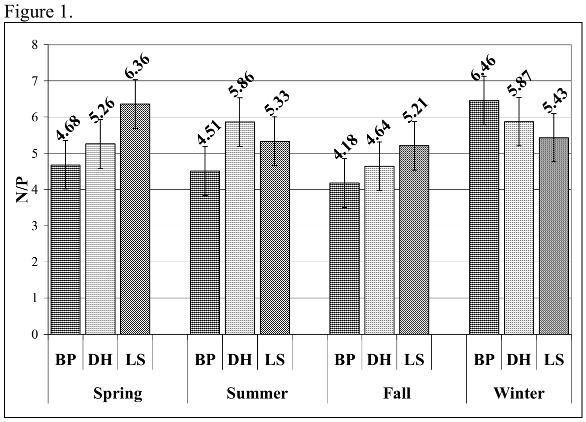


Figure 2.

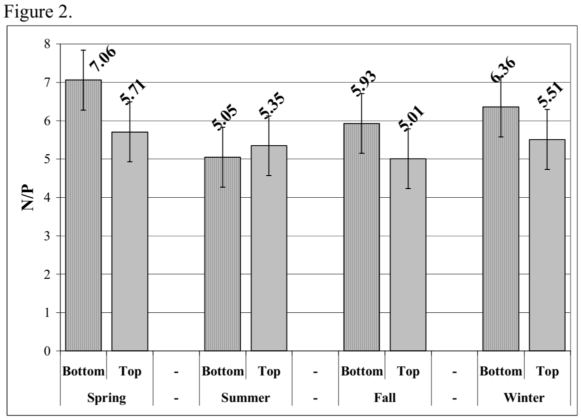

Figure 3.

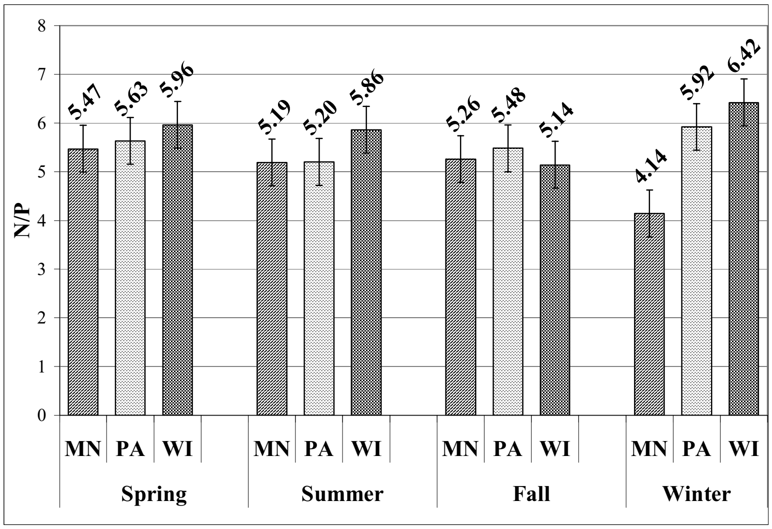


Table 1.

| | | | | Main effects | | | |
|---|---|---|---|---|---|---|---|
| | **C**[1] | **UC**[2] | **SEM** | **Cover** | **Season** | **Year** | **Cvr x Ssn**[3] |
| **n** | 12 | 41 | | | | | |
| **DM (%)** | 10.4 | 9.74 | 2.93 | 0.81 | 0.87 | 0.66 | 0.46 |
| **TN (%DM)** | 5.65 | 5.21 | 1.09 | 0.67 | 0.96 | 0.24 | 0.38 |
| **N-NH3 (%DM)** | 2.56 | 2.35 | 0.61 | 0.71 | 0.93 | 0.1 | 0.49 |
| **P (%DM)** | 0.89 | 0.82 | 0.11 | 0.47 | 0.18 | 0.47 | 0.12 |
| **N/P** | 6.07 | 6.18 | 0.71 | 0.87 | 0.06 | 0.19 | 0.69 |

[1] C = covered;
[2] UC = uncovered;
[3] Cvr x Ssn = coverage versus season interaction.

Table 2.

| | | | | Main effects | | | |
|---|---|---|---|---|---|---|---|
| | **Inorganic**[1] | **Organic**[2] | **SEM** | **Bedding** | **Season** | **Year** | **Bed x Ssn**[3] |
| **N** | 38 | 33 | | | | | |
| **DM** | 14.20 | 7.78 | 2.43 | 0.05 | 0.35 | 0.98 | 0.62 |
| **TN (%DM)** | 3.66 | 4.79 | 0.43 | 0.06 | 0.16 | 0.36 | 0.93 |
| **P (%DM)** | 0.71 | 0.82 | 0.07 | 0.29 | 0.005 | 0.63 | 0.30 |
| **N/P** | 5.50 | 6.02 | 0.49 | 0.43 | 0.004 | 0.72 | 0.20 |

[1] Manure samples with accompanying information indicating that sand or no bedding was used. This also included samples where there was no information about bedding.
[2] Manure samples with accompanying information indicating that straw, hay, grass, sawdust, shaving or oat hulls were used for bedding.
[3] Bed x Ssn = bedding versus season interaction.