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Nitrogen Mineralization of Dairy Manure in a Calcareous Soil Under Field Conditions

David Graybill[1], Amber Moore[1] and Rick Lentz[2]

(1)Plant, Soils, and Entomological Sciences, University of Idaho, Twin Falls, ID (2)USDA-ARS, Kimberly, ID

Introduction

- Southern Idaho had 587,000 lactating dairy cows in 2015 producing an estimated 44,000 Mg of wet manure and 288 Mg total N daily.
- Millions of hectares of agriculture land suitable to receive manure occurs in close proximity to these dairies.
- Monitoring mineral N release from manure applications is needed to develop strategies to maximize crop profitability and reduce environmental damage.

Project goal

- Evaluate cumulative net N mineralization following fall applications of dairy manure to a Portneuf silt loam under fluctuating field temperatures, throughout two growing seasons, utilizing the in-situ buried bag method.

Materials and methods

- **Experimental Design**
  - Portneuf silt loam, with soil organic matter content of 1.1%, $CaCO_3$ of 8.9% and pH of 7.7.
  - Spring barley grown in 2013; sugar beets grown n 2014.
  - RCBD, four replications
  - Treatments
    - Fall-applied stockpiled dairy manure application rates
      - 17.3, 34.7 and 52.0 (dry wt.) Mg ha^{-1}.
      - Fertilizer N was applied at agronomic rates.
    - Annual (2012 and 2013) or biennial (2012 only) frequency in applications.
    - Control (no nutrients added) and fertilizer treatments also included
  - Manure applied in 2012; total N=1.8%; C:N of 17:1; 41% moisture.
  - Manure applied in 2013; total N=2.9%; C:N of 13:1; 64%.moisture
  - At harvest, barley (above ground biomass) and sugar beets (whole plant) were measured for dry matter biomass and total N content to estimate N uptake.
- **Buried bag in-situ N mineralization method**
  - Soil samples collected within one week after planting
    - April 12, 2013 and May 3, 2014
  - 12-16 soil cores per plot at two depths (0-30 and 30-60 cm) composited, placed in 0.10mm thickness low density polyethylene bags, and placed back in core holes (figure 1)
  - Buried bags were removed and destructively sampled either monthly or biweekly from April/May to September/October
  - Nitrate-N and ammonium-N extracted with 2M KCl, analyzed with spectrophotometer
  - Net N mineralization (mg -N kg^{-1}-soil) = Inorganic N – Inorganic $N_{(t=0)}$
  - Net N mineralization data fit to a zero-order linear model.
    - Net N mineralization (mg-N kg^{-1}-soil) = k * t+b
    - k is the N mineralization rate coefficient (mg kg^{-1} day^{-1}), t is time (day), b is the net N mineralization at day=0

Fig. 1. To monitor N mineralization rates after field applications of dairy cattle manure, manured soils were placed in plastic bags and buried in the field. Throughout the growing season the bags were removed and analyzed for nitrate and ammonium. The buried bags function as in-situ incubation containers, protecting soils from plant N uptake and leaching of N.

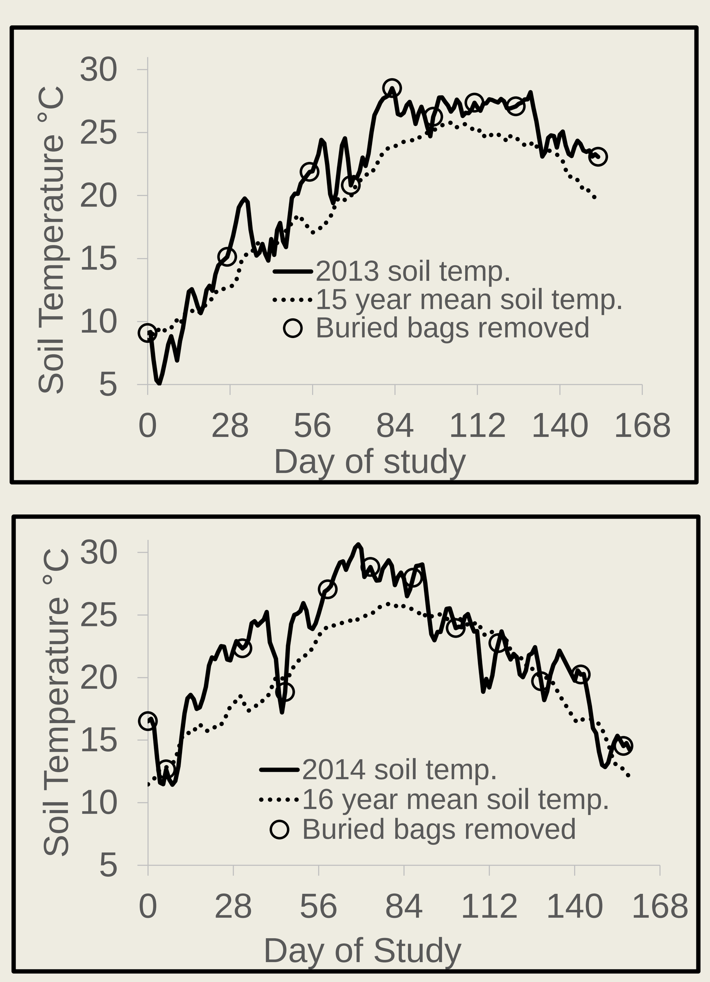

Fig. 2. First and second study years mean daily and historical soil temperatures (10.2 cm depth) and buried bag removal events.

In-situ net N mineralization over the 2013 growing season, following a dairy manure application event in the fall of 2012

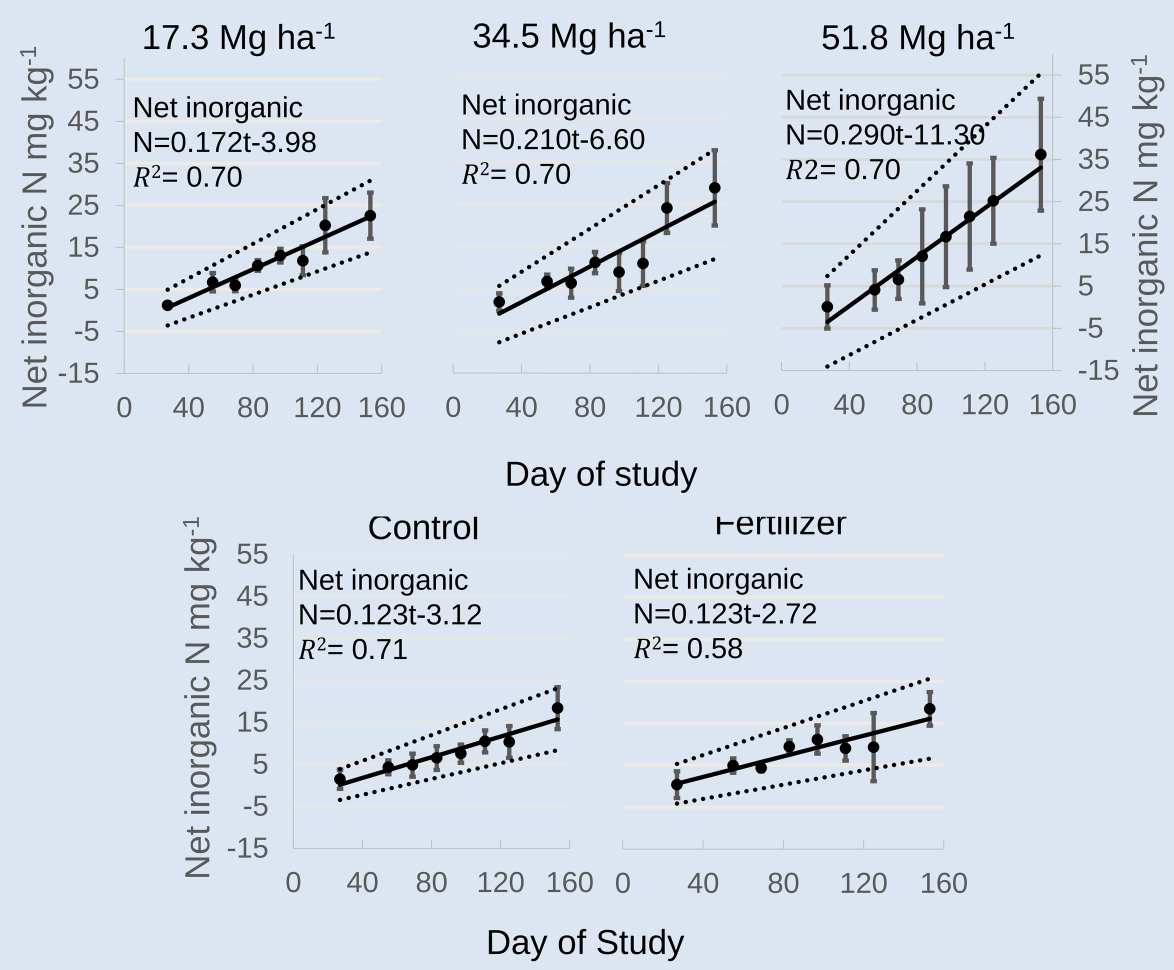

Fig. 3. First year (April 12 to Sept. 12, 2013) in-situ net N mineralization means, standard deviation, zero-order model estimate, 0-30 cm depth.

- Nitrogen mineralization occurred during the growing season as a result of first time fall dairy manure applications at dry rates of 17.3, 34.7 and 52.0 (dry wt.) Mg ha^{-1}.
- As dairy manure application rates increase, zero-order rate coefficients also increase (figure 3). This indicates that the activity of ammonifying and nitrifying soil microorganisms is limited by mineralizable N containing substrates in Portneuf silt loam soils, at least up to manure N rate of 874 kg ha^{-1}.
- Dairy manure N was found to mineralize at a steady rate throughout the growing season. These linear mineralization trends should be considered when cropping with plants that are sensitive to late season N such as sugar beets.
- Inorganic N concentrations in soils at the 30-60 cm depth indicated that there was not a manure treatment effect for any time during the study period (data not shown). Therefore organic-N derived from dairy manure did not move down into the subsoil before the start of the study period.

Table 1. First year (2013) predicted cumulative net inorganic N concentration (0-30 cm soil depth) for the middle and end of the growing season after first time fall dairy cattle manure applications.

Manure rate (dry)	Manure N loading rate	Net inorganic N day 97, 7/18/2013	Net inorganic N day 153, 9/12/2013
Mg ha^{-1}	kg ha^{-1}	mg kg^{-1}	
17.3	290	13	22
34.7	584	14	26
52.0	874	17	33
Control	-	9	16
Fertilizer	-	9	16

Sugar beet N uptake showed a strong correlation (R^2=0.74) with inorganic N measured in the soil indicating that the buried bag technique is adequate to estimate cumulative gross and net inorganic N after manure additions to Portneuf silt loam soils.

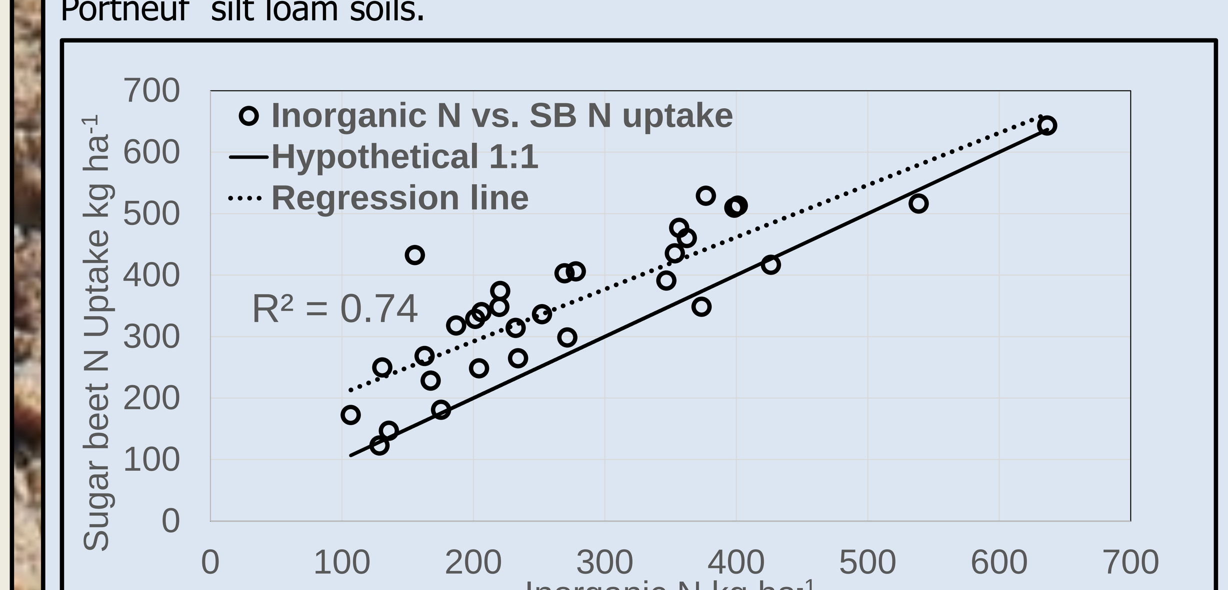

Fig. 4. Whole sugar beet N uptake regressed within inorganic N in the soil. For comparison a hypothetical 1:1 line is also included

In-situ net N mineralization over the 2014 growing season, following dairy manure application events in the fall of 2012 and the fall of 2013 (annual treatment) or only in the fall of 2012 (biennial)

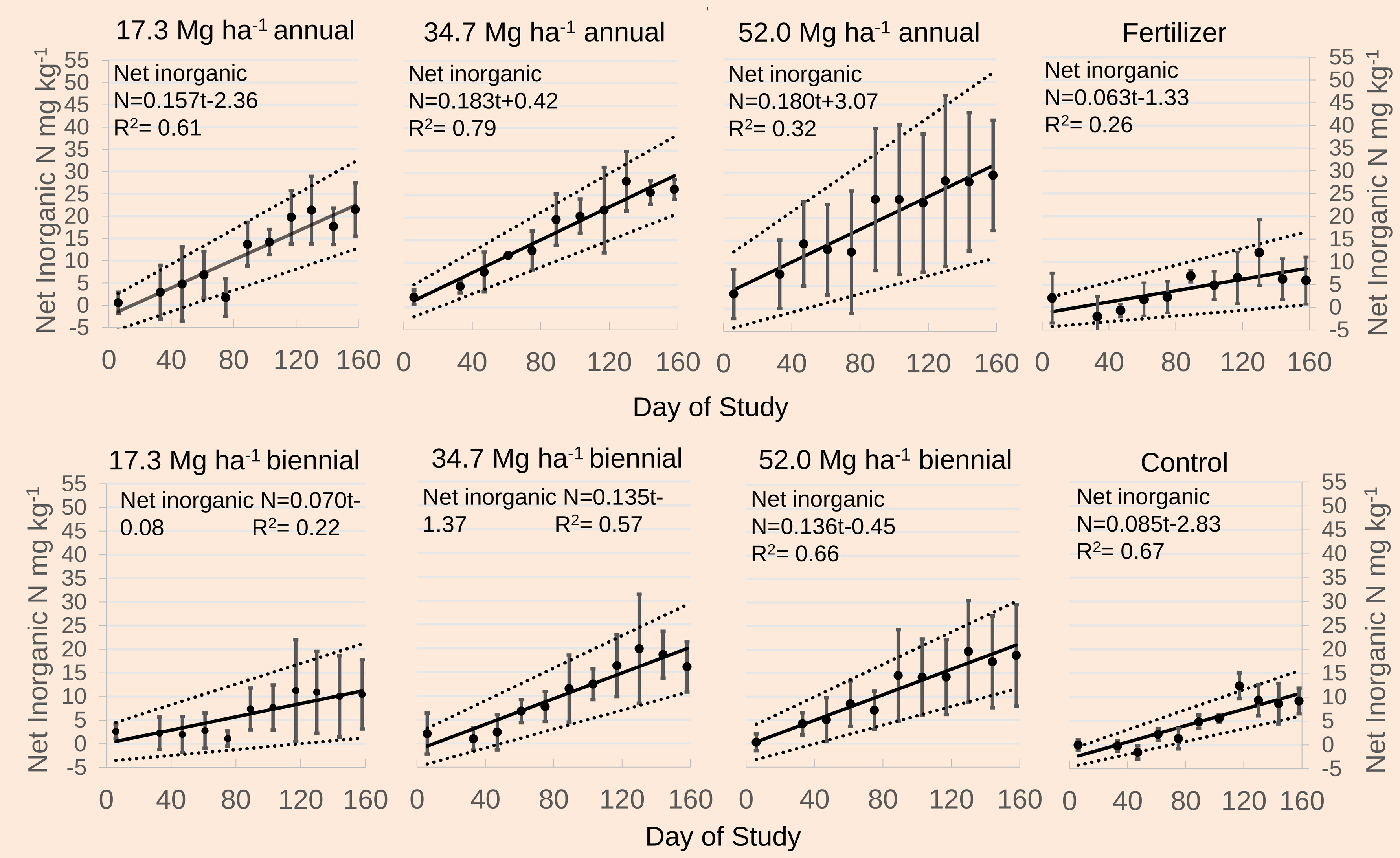

Fig. 5.Second year (May 3 to Oct. 9, 2014) in-situ net N mineralization means, standard deviation, zero-order model estimate, 0-30 cm depth.

- First year fall applications of dairy manure were still mineralizing at significant rates during the second year growing season. This finding indicates that dairy manure is a slow release N fertilizer.
- Increasing manure applications resulted in increasing N mineralization variability (figures 3,5), this variability especially at high cumulative manure rates should be considered.
- Dairy manure was applied biennially at a rate of 34.7 Mg ha^{-1} and was also applied annually at a rate of 17.3 Mg ha^{-1} resulting in a cumulative rate of 34.7 Mg ha^{-1}. Nitrogen mineralization rates between these different manure application timings were not found to be significantly different. This finding indicates that dairy manure applications managed for the second year inorganic N release can be split between years yielding the same inorganic N result.
- Nitrogen mineralization occurred at the subsoil depth of 30-60 cm after a biennial manure application of 52.0 Mg ha^{-1} resulting in mean inorganic N concentrations 3.3 mg kg^{-1} greater than those in control soils. This finding indicates that adequate time is required to allow irrigation and precipitation water to move manure N into the subsoil.

Table 2. Second study year (2014) predicted cumulative net inorganic N concentration (0-30 cm soil depth) after fall dairy manure applications two years previous and after repeated first and second year fall manure applications resulting in cumulative manure rates.

Cumulative manure rate (dry)	Cumulative manure N loading rate	Manure application interval	Net inorganic N day 75, 7/18/2014	Net inorganic N day 158, 10/9/2014
Mg ha^{-1}	kg ha^{-1}		mg kg^{-1}	
34.7	780	annual	9	22
69	1571	annual	14	29
103.6	2352	annual	17	32
17.3	290	biennial	5	11
34.7	584	biennial	9	20
52.0	874	biennial	10	21
Control	-	-	4	11
Fertilizer	-	-	3	9

Conclusion

- Dairy manure applied annually and biennial resulted in distinct N mineralization effects over the first and second growing seasons.
- First year fall manure applications were found to still be mineralizing manure N at significant rates in the second year. This finding shows that dairy manure is an effective slow release N fertilizer.
- Dairy manure can be applied biennially and annually at the same cumulative rate and result in similar N mineralization trends.
- Increasing manure rates result in increasing N mineralization variability.
- Irrigation and precipitation water over time can move manure N into the subsoil.
- Direct measurements of total N in whole sugar beets compared to inorganic N concentrations in manured soils (R^2= 0.74) show that the buried bag method provides an adequate means to estimate N mineralization potential from varying manure rates and timings to Portneuf silt loam soils.