How does inorganic N fertilizer affect soil N mineralization?

Navreet K. Mahal*, Fernando E. Miguez, Hanna J. Poffenbarger, John E. Sawyer, William R. Osterholz & Michael J. Castellano

Department of Agronomy, Iowa State University, Ames, Iowa, USA (50011).

*nmahal@iastate.edu

INTRODUCTION

- Fertilizer nitrogen (N) use efficiency (FNUE) is key to improve nitrogen use efficiency (NUE) of agricultural systems.
- Two methods are used to measure FNUE:
  1) Indirect 'N Difference' =
     (N uptake in fertilized plot – N uptake in zero N plot)/ N fertilizer applied
  2) Direct '^{15}N Tracer' =
     ^{15}N fertilizer to track uptake of individual fertilizer atoms
- These methods consistently produce different results; the ***N difference*** method always measures higher FNUE.
  - The ***N Difference*** method may **overestimate** FNUE if N fertilizer increases N mineralization in fertilized plots, but not the zero N controls (i.e.priming).
  - Alternatively, the ***^{15}N Tracer*** method may **underestimate** FNUE because the ^{15}N isotope mixes with the native soil N pool resulting in a diluted ^{15}N signal.

OBJECTIVE & QUESTIONS

Our goal was to quantify the effects of inorganic N fertilizer addition on gross ammonification rate (soil organic matter mineralization) across gradients of SOM in a continuous maize system in Iowa (USA).

- Does inorganic N fertilizer enhance SOM decomposition?
- Which method of FNUE measurement is more accurate?

HYPOTHESIS

- Inorganic N fertilizer increases soil N mineralization.

METHODS

Soil Organic Matter gradient

- At central and southern Iowa trials (fig. 1(A)), long term inorganic N fertilizer (1999-2014) applied to continuous maize increased the residue/yield and soil organic matter stocks with the increase in fertilizer rates (fig 1 (B)).

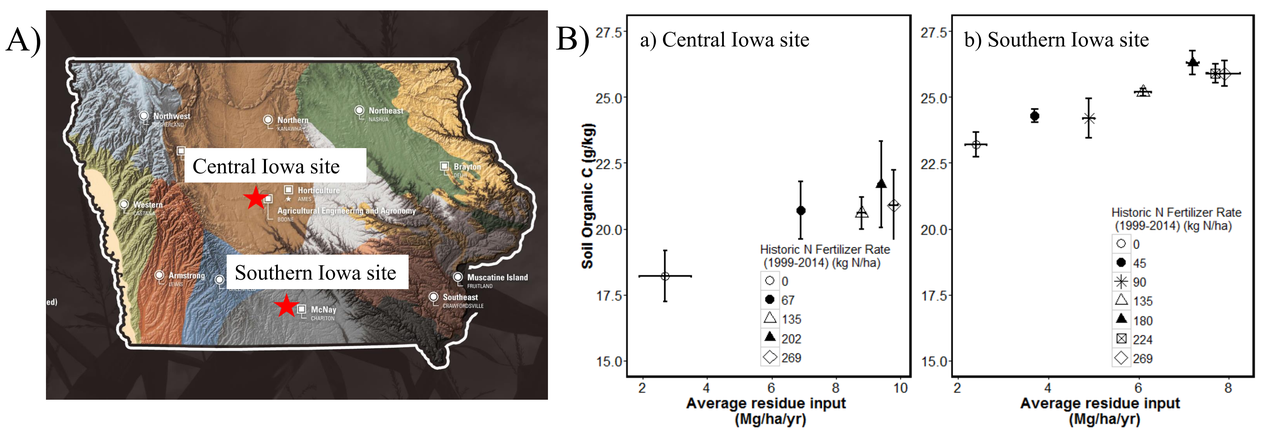

Figure 1. A) Locations of two long-term N trials in Iowa (USA) and B) Mean Soil organic C concentration (±standard error indicated as vertical bars) and Average above ground residue inputs (±standard error indicated as horizontal bars) as influenced by different long term-N fertilizer rates at a) central Iowa and b) southern Iowa sites.

Experimental set-up

- In 2015, three of the historic N rates (1999-2014) were selected at each site:
  - Zero, Agronomic Optimum N Rate (AONR) (202 kg N/ha), excessive rate (269 kg N/ha) at central Iowa site.
  - Zero, lower than AONR (224 kg N/ha), AONR (269 kg N/ha) (highest rate) at southern Iowa site. At this site, the AONR was the highest rate.
- From 1999-2014 the average AONR for each site was 202 and 269 kg N/ha at central and southern site, respectively.
- In 2015, each historic N rate plot (N=4 plots/rate) was subdivided into 3 subplots i) the historical rate; ii) fertilized with the empirically determined AONR for that site, and iii) zero N (without AONR) (fig. 2 (A)).
- Soil samples from 5-15 cm depth were collected at V5 (5 collared leaves) and V12 (12 collared leaves) maize growth stages from with and without AONR subplots (fig 2 (B)).
- Gross ammonification rates were determined using ^{15}N isotope dilution in the laboratory immediately after sampling (ambient moisture, no pre-treatment).

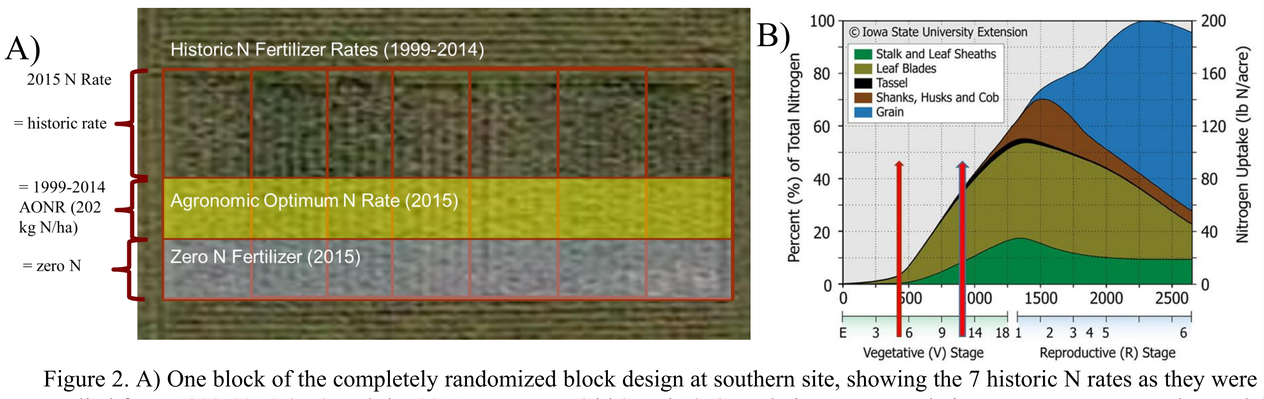

Figure 2. A) One block of the completely randomized block design at southern site, showing the 7 historic N rates as they were applied from 1999-2014 (top) and the 2015 treatments (side) and B) Cumulative N accumulation on a percentage and pound-per-acre basis from emergence to R6 (physiological maturity) maize growth stage, red arrows represent two sampling stages (V5 and V12).

RESULTS

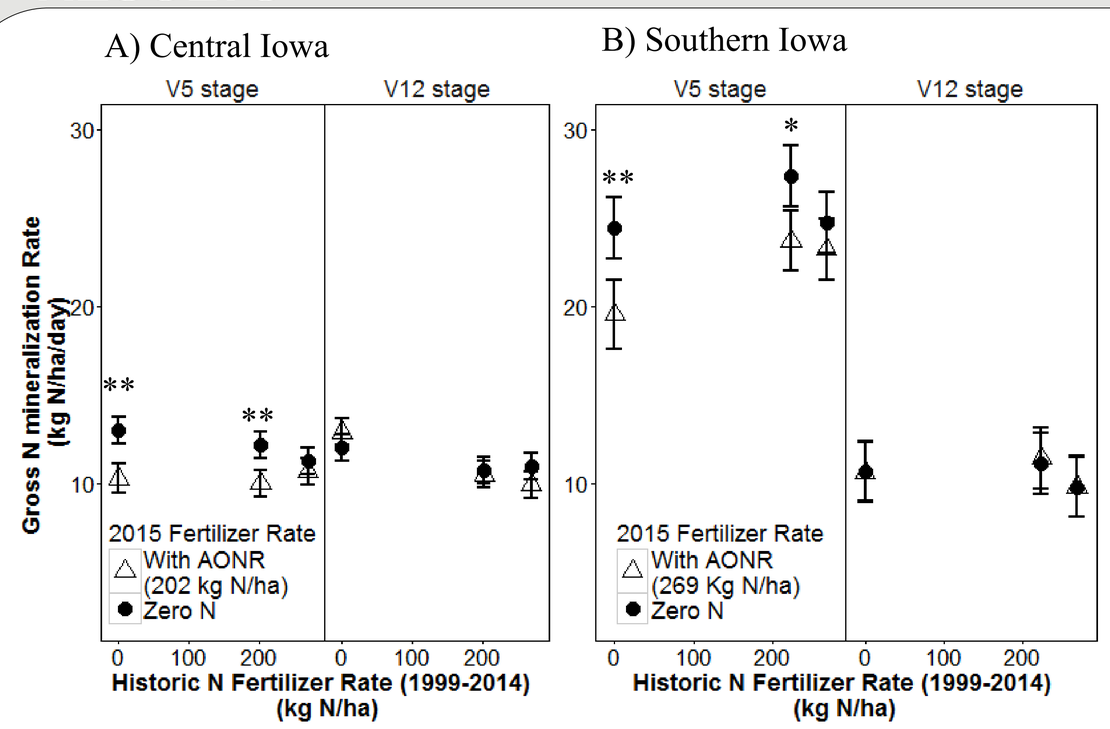

Figure 3. Mean gross N mineralization rate and standard error (vertical bars) in continuous maize for three historic N rates of 0, 202 (long-term AONR) and 269 kg N/ha (highest rate) at the central Iowa site (A) and 0, 224 (rate increment just below the AONR) and 269 (long-term AONR, at the highest rate) at southern Iowa site (B) where either no N or the long-term AONR fertilizer rate was applied; determined at the V5 and V12 maize growth stage. ** indicates the difference between zero and AONR fertilizer application is significant at P = 0.05 and * indicates the differences are significant at P = 0.10.

- Across all historic N fertilizer rates at the V5 maize growth stage, N fertilizer input at the AONR in 2015 reduced gross ammonification rates by 15% as compared to zero fertilizer addition at the central Iowa site, and by 12% at the southern Iowa site.
- No effect of N fertilizer on gross ammonification at the V12 maize growth stage at either site.

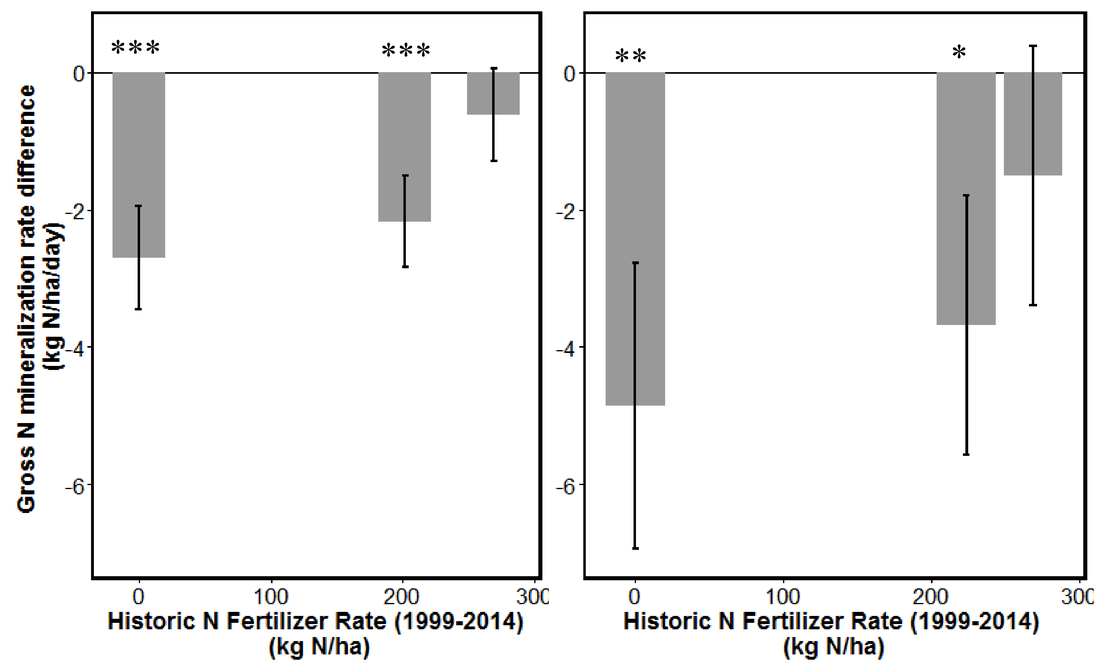

Figure 4. Difference between the gross ammonification rate for with and without AONR application in 2015 at three historic N rates of 0, 202 (long-term AONR) and 269 kg N/ha (excessive rate) at (A) central Iowa site; and 0, 224 (rate increment just below the AONR) and 269 (long-term AONR, at the highest rate) at (B) southern Iowa site determined at the V5 maize growth stage. *** indicates the difference between zero and AONR fertilizer application is significant at P = 0.005, ** indicates P = 0.05 and * indicates the differences are significant at P = 0.10.

- Impact of AONR application in 2015 on N mineralization decreased with an increase in the historic N rate/SOC stock (Fig 1 B) at both sites.
- At the V5 growth stage at the central Iowa site, N fertilization at the AONR in 2015 reduced gross ammonification rate by 20 and 18% in the historic zero and AONR (202 kg N/ha/y), respectively.
- Similarly, at the southern Iowa site, AONR application in 2015 reduced gross ammonification rates by 17 and 13% in the historic zero and 224 kg N/ha/y rate, respectively.
- In contrast, at the highest long-term historic N rate (269 kg N/ha/y), the AONR rate had no effect on gross ammonification compared to no N fertilizer input at either site.

CONCLUSIONS

- N fertilizer application reduces gross ammonification rate.
- Impact of fertilizer decreases with the increase in historic N rate.
- N fertilizer application does not enhance SOM decomposition.
- 'N difference' method is more accurate for measurement of FNUE.

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