How does inorganic N fertilizer affect soil N mineralization?

Navreet K. Mahal[1]*, Fernando E. Miguez[1], Hanna J. Poffenbarger[1], John E. Sawyer[1], William R. Osterholz[2] & Michael J. Castellano[1]

[1]Department of Agronomy, Iowa State University, Ames, Iowa, USA (50011)

[2] Department of Agronomy, University of Wisconsin-Madison, Wisconsin (53706)

*nmahal@iastate.edu

INTRODUCTION

- Fertilizer nitrogen (N) use efficiency (FNUE) is key to improve nitrogen use efficiency (NUE) of agricultural systems.
- The two methods to determine FNUE, produce different results.
  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 typically 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

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

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

HYPOTHESES

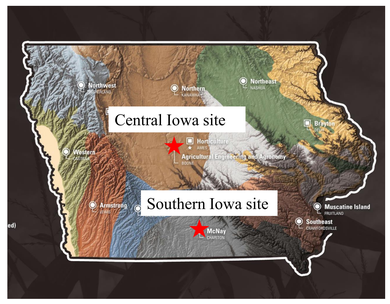
- Inorganic N fertilizer increases soil N mineralization.

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)).

A)



B)

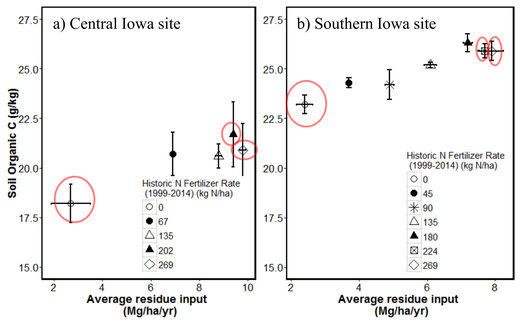


Figure 1. A) Locations of two long-term N trials in Iowa and B) Mean Soil organic C concentration (±standard error indicated as vertical bars) and Average above ground residue inputs (±standard error indicated as horizontal bars) as influenced by different long term-N fertilizer rates at a) central Iowa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

Experimental set-up: Field study

- In 2015, three of the historical N rates (1999-2014) were selected at each site:
  - Zero, Moderate (202 kg N/ha at central and 224 kg N/ha at southern site), High rate (269 kg N/ha)
- From 1999-2014, the AONR for each site was 202 and 269 kg N/ha at central and southern site, resp.
- In 2015, each historical 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).
- 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.
- Gross ammonification rates were determined using ^{15}N isotope dilution in the laboratory immediately after sampling.

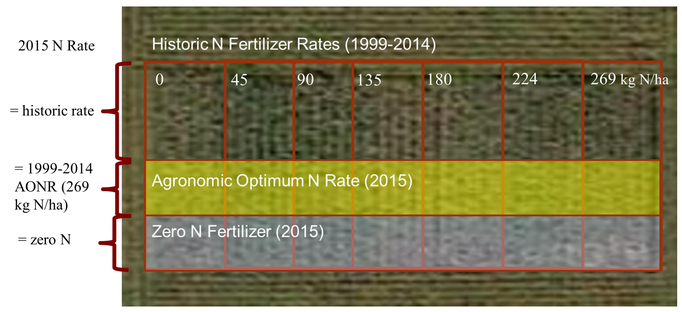


Figure 2. One block of the completely randomized block design at southern site, showing the 7 historical N rates as they were applied from 1999-2014 (top) and the subsequent 2015 treatments (side).

Experimental set-up: Laboratory study

- Historical N rates (1994-2014): Zero kg N/ha from central and southern Iowa sites.
- AONR application in lab: With (202 and 269 kg N/ha at central and southern site, respectively) and Without N application in lab.
- Gross ammonification rates were determined using ^{15}N isotope dilution method.

RESULTS

Field study

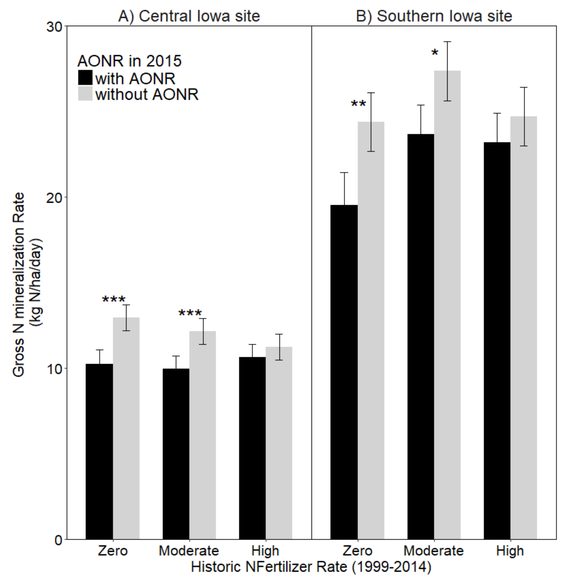


Figure 3. Mean gross N mineralization rate and standard error (vertical bars) in continuous maize for three historical N rates of zero, moderate and high at (A) central and (B) southern Iowa sites where either no N or the long-term AONR fertilizer rates were applied; determined at the V5 maize growth 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 historical 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.
- Impact of AONR application in 2015 decreased with an increase in the historical N rate at both sites.
- At the V5 growth stage at the central Iowa site, N fertilization with the AONR reduced gross ammonification rate by 20 and 18% in the historical zero and moderate rates, respectively.
- Similarly, at the southern Iowa site, AONR application in 2015 reduced gross ammonification rates by 17 and 13% in the historical zero and moderate rates, respectively.
- In contrast, at the highest long-term historical 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.
- No effect of N fertilizer on gross ammonification at the V12 maize growth stage at either site.

Laboratory study

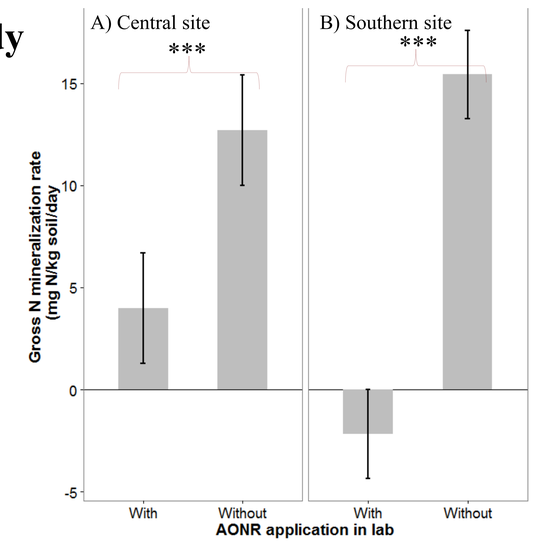


Figure 4. Gross N mineralization rates (mg N/kg soil/day) in soil collected from 2015 zero-N subplots from the 1999-2014 zero-N historical rate after laboratory application of N fertilizer at the AONR for the (A) central and (B) southern Iowa sites. Vertical bars represent 95% confidence interval. *** indicates the difference between zero and AONR fertilizer application is significant at P <0.0001

- In laboratory study, gross ammonification rate was 68% lower with AONR fertilizer application as compared to without fertilizer at the central site.
- At the southern site, gross ammonification rate was numerically negative, which could be due to large ammonium pool size and low isotopic enrichment reducing the detection limit.

CONCLUSIONS

- N fertilizer application reduces gross ammonification rate.
- Impact of fertilizer decreases with the increase in historic N rate.
- Reduction in ammonification directly related to N fertilizer addition, not ecosystem effect
- N fertilizer application does not enhance SOM decomposition.
- 'N difference' method is more accurate for measurement of FNUE.

ACKNOWLEDGEMENTS

▪This work is supported by the National Science Foundation under CyberSEES award number 1331390.

▪ We acknowledge the support of Professional Development Grant from Sustainable Agriculture Graduate program and GPSS Professional Development Grant, which enabled me to present my work and attend this conference.