Nitrous Oxide Production in an Eastern Corn Belt Soil: Sources and Redox Range

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Justification

- Nitrous oxide (N_2O) is a main greenhouse gas and destroyer of ozone layer.
- Sources and regulation of N_2O production are not well understood.
- Agroecosystems are an important, highly-dynamic source of N_2O.
- Discrimination of soil N_2O sources may enhance our prediction ability of regional and global N_2O emissions.
- The interactive effect among increasing soil water content, redox potential (Eh), agricultural N management practices and crop growth stage on N_2O production need to be examined in detail.
- New knowledge about N_2O production may enhance N management and efficiency for different N sources (e.g.: manure vs. synthetic).

Experimental site (WQFS - Purdue University): corn plot.

Objective

- To estimate magnitude and sources of N_2O production as affected by N management, soil water content, Eh and corn growth stage.

Hypothesis

- Urea-ammonium nitrate (UAN) favors nitrification and liquid swine manure (M) favors denitrification.
- Manured soils have a higher, narrower Eh range of N_2O production than soils receiving UAN.

Materials and Methods

<u>Experimental Site and Treatment Management</u>:

- The Water Quality Field Station (WQFS) at Purdue University – Agronomy Center for Research and Education (ACRE) on Drummer (Typic Endoaquoll) and Raub (Aquic Argiudoll) soil series.
- Continuous corn (CC) fertilized with UAN (28% N) 157 kg N ha^{-1} at V5, or liquid swine manure (M) at 255 kg N ha^{-1} in the fall (F). Treatments were CCFM and CCUAN in a randomized complete block design.

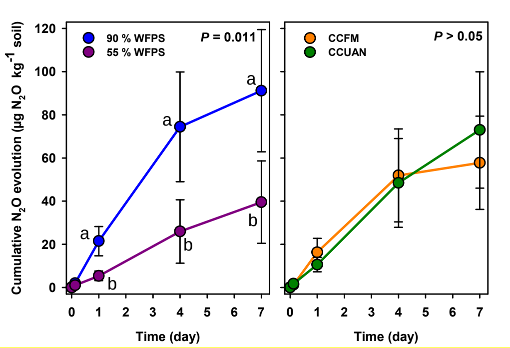
<u>Soil Sample Collections and Incubation Experiments</u>:

- Soil cores (n: 18) were collected (0 – 15 cm depth) at preplant (PP) and at V6, sieved to aggregate size (< 6.4 mm), packed to 1.2 g cm^{-3}, and preincubated (3 d) at 45 % water filled pore space (WFPS).
- I. Aerobic Incubation (7 d): 90 g soil (oven-dried equivalent, OVDE) in 0.97 L Mason jars (n: 96)
- II. Aerobic Incubation – Source-partitioning (24 hr): 90 g soil (OVDE) in 0.97 L Mason jars (n: 64)
  - Labeling (20 atom excess a.e.%) N pools with $^{15}N\text{-}NH_4^+$ for nitrification and $^{15}N\text{-}NO_3^-$ for denitrification
  - Primary assumption: uniform pool labeling within each microcosm for both ions.
  - Assuming natural abundance: 0.3663 % (^{15}N a.e.). Sources expressed as % of N_2O production at 24 h.
- III. Anaerobic Incubation (15 d): 60 g soil (OVDE) in 0.25 L centrifuge bottles (n: 12). Degassed H_2O:soil 2.3:1. Amendment: KNO_3 at 50 mg N kg^{-1} soil. Pure N_2 flow in headspace. Electrode: Ag/AgCl sat. KCl.
  - Eh values were corrected to standard H_2 electrode (+ 199 mV) and to pH 7.
- Experimental factors in the incubation were soil moisture (55 and 90 % WFPS or submerged), 2 trt (CCFM and CCUAN), 2 soil sample collections (PP and V6) and 4 field replicates (blocks)

<u>Analysis Procedures</u>:

- Extractable dissolved organic carbon (EDOC): 20 g (OVDE) of air-dried soil in 100 mL (5 mM $CaCl_2$), shaking, centrifugation, filtration and TOC analyzer. Soil organic C (SOC) by dry combustion.
- Nitrous oxide analysis: GC with ECD. ConFlow III GC/IRMS for $\delta^{15}N$ in N_2O with a cryotrap.
- Statistics: Cook's distance for outliers, VIF for multicollinearity, adjusted R^2 for variable selection, Linear Regression, RM ANOVA and Tukey test for pairwise comparisons.

Results Part I: Soil Moisture and N Source Impacts on N_2O Production (Aerobic Incubation)

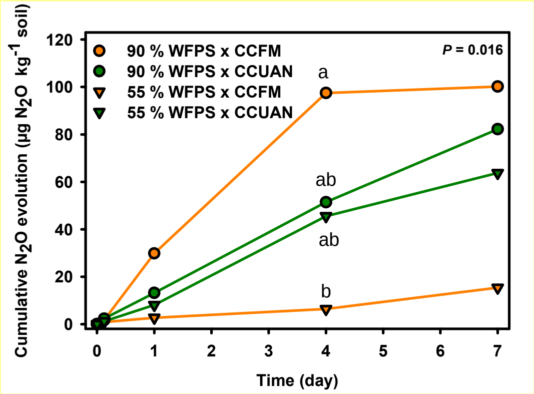


Individual Factor Effects on N_2O Production:

- Much greater N_2O production (2.3 times) with high WFPS due to limited O_2 availability.
- N management effect was not significant.
- Greater CO_2 production (1.3 times at 7th d) with 90 than 55 % WFPS (*P*< 0.01, data not shown).

Interaction Effect on N_2O Production:

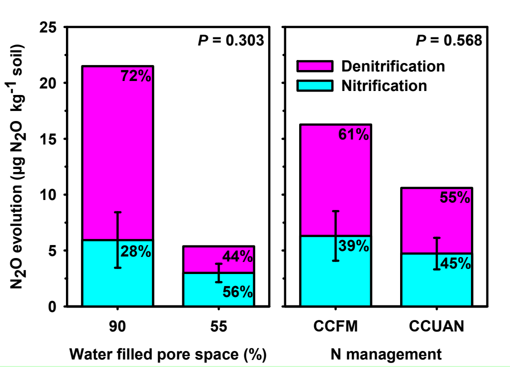
- Among the 4 treatment combinations, the highest, shortest-lived N_2O production occurred with manured soils at high water content.



Results Part II: N_2O Source-partitioning (Aerobic Incubation)

N_2O Derived from Nitrification vs. Denitrification:

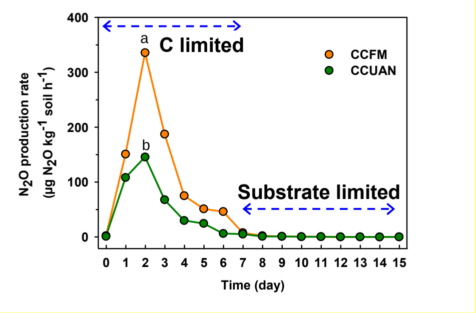
- Non-significant results for both factors, but clear tendency of greater denitrification proportion (from 44 to 72 %) with increasing soil water content.
- SOC and EDOC were 1.07 (*P* = 0.023) and 1.21 (*P* = 0.046) times greater in CCFM than CCUAN (data not shown). Higher EDOC in CCFM also supports denitrification as main pathway for N_2O production.
- Also, greater CO_2 production (1.2 times at 7th d) in CCFM than in CCUAN (*P*= 0.057, data not shown).
- Microsite anaerobiosis favored by increased microbial respiratory demand of O_2 in CCFM may have enhanced denitrification.

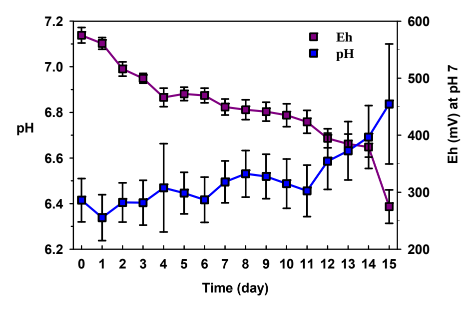


Results Part III: Redox Potential Impacts on N_2O Production (Anaerobic Incubation)

N_2O Production Rates, Eh and pH Patterns with Time:

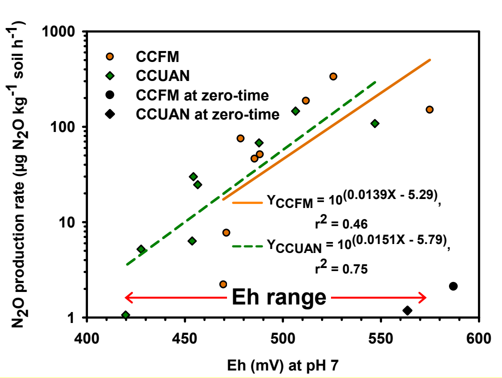
- N_2O production rate was 2.3 times higher in CCFM than in CCUAN on day 2 (*P* = 0.018).
- Most N_2O was produced within the first four days of incubation coinciding with a sharp drop in Eh.
- As expected, when Eh progressively declined with time, pH tended to increase (r: -0.89, *P* < 0.001).





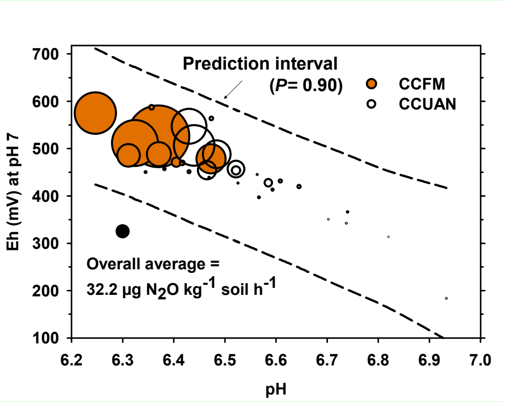
Redox Potential Range for N_2O Production:

- N fertilizer source caused minimal treatment differences between N_2O production rate patterns:
  - In general, Eh range for N_2O production was not affected by N management.
  - Although fall manured soils (470 to 575 mV) tended to have a range shifted to higher Eh values than soils receiving UAN (420 to 550 mV), the two Eh ranges overlapped each other.
- The two N fertilizer treatments showed similar, sharp exponential declining phase of N_2O production rates with decreasing Eh.



Eh Prediction Interval with Varying pH:

- Bubble areas correspond to N_2O production rates.
- Higher N_2O production was at high Eh and low pH.
- Linear regressions:
  - Eh = 3400 – 453pH ($r^2 = 0.78$, $P < 0.001$).
  - N_2O production rates= 3.18 – 0.47pH ($P < 0.01$).
  - N_2O production rates= -0.309 + 0.000936Eh ($P < 0.01$).
- Redundancy between pH and Eh as predictors was demonstrated by moderate collinearity (VIF > 4.5).
- The interactive, pH-Eh-N_2O pattern suggested enhanced prediction ability when combining the two master variables (pH and Eh).
- N fertilizer did not impact the pH-Eh-N_2O pattern.



Conclusions

- Increasing soil water content and fall liquid swine manure showed a synergistic interaction that enhances soil N_2O production in aerobic conditions.
- Extreme increases of soil water content favored denitrification as predominant pathway of the largest pulse of N_2O production in aerobic conditions.
- In anaerobic conditions, fall manured soils registered greater N_2O production than soils receiving side-dressed urea-ammonium nitrate shortly after flooding.
- The first 4-days of our incubations showed the highest magnitude and dynamic of N_2O production.
- Redox potential range (420 to 475 mV) for soil N_2O production was not affected by N fertilizer source.
- No temporal effects (corn preplanting vs. growth stage V5) were observed in our experiments.
- Additional variable screening for new covariates (e.g. soil microbial biomass C, light POM C, electrical conductivity), model development and data validation are necessary for better understanding of N_2O production.
- Future work may include the impact of soil aggregate size, microsite diversity, entrapped air and/or root exudates on magnitude and sources/sinks of soil N_2O production/consumption.
- Headspace acetylene additions and isopotomers (positional preference) techniques may also be helpful in N_2O source-partitioning studies.
- Assessing dissolved N_2O production in anaerobic incubations may enhance our current understanding on N_2O emissions from flooded soils.

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