# Greenhouse Gas Fluxes as Affected by Urea Fertilizer, Nitrification Inhibitor, and Biomass Residue Application to Soil

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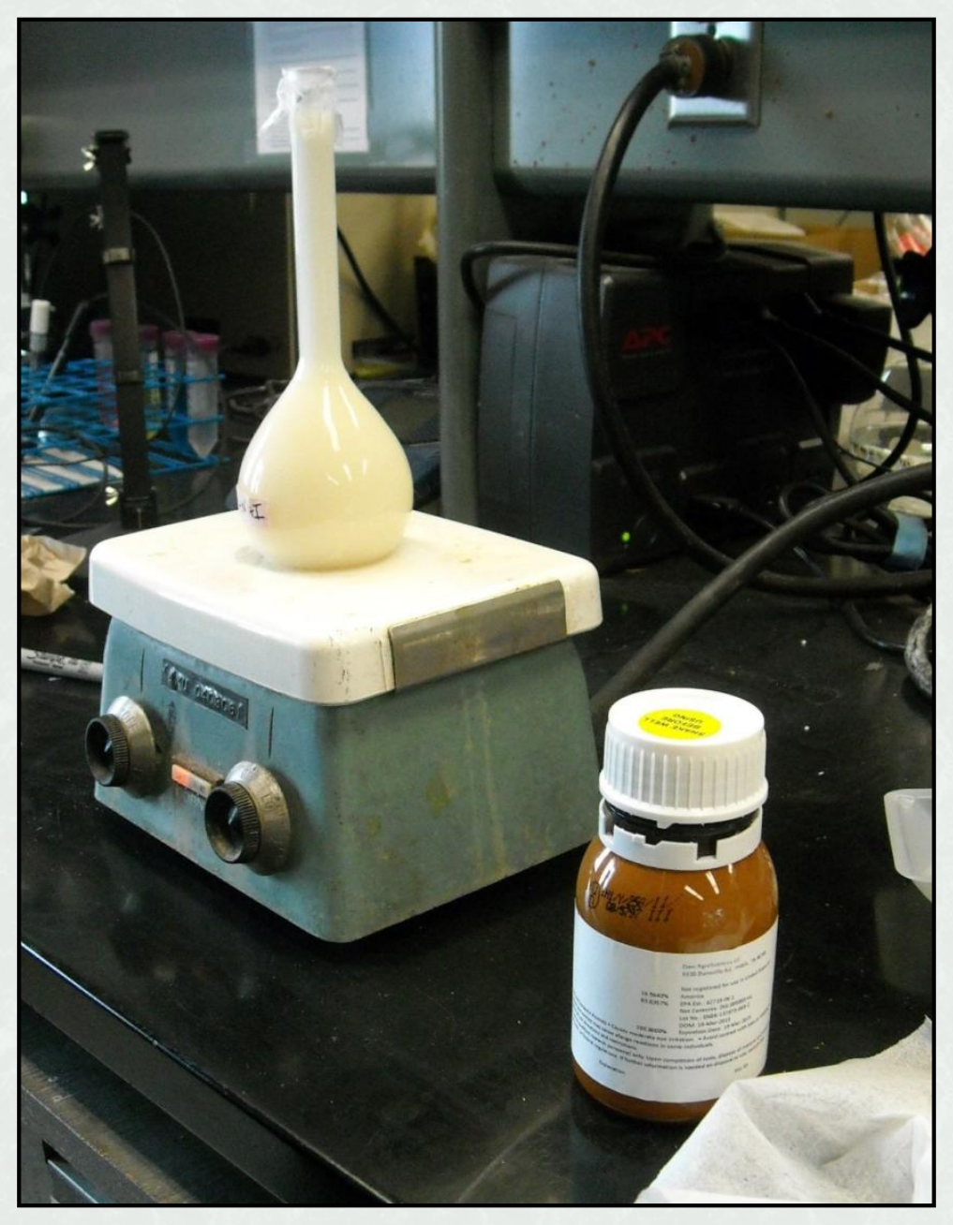
## Abstract

Nitrogen (N) fertilizer consumption has been increasing and a portion of the fertilizer applied can be lost via leaching, or gaseous emissions. Nitrification inhibitors (NI) are designed to inhibit nitrification, the microbial conversion of ammonium to nitrate, a highly mobile form of N most prone to loss. The objective of this study was to determine the impact of nitrapyrin on $N_2O$ and other greenhouse gas (GHG) emissions as well as to determine what impact sorghum residue has on the efficiency of the nitrification inhibitor and nutrient cycling. A greenhouse study was designed in order to quantify fluxes of GHGs from soils amended with N fertilizer, nitrification inhibitor, and sorghum residue. Experimental treatments included every combination of the treatment scenarios with or without N fertilizer, Instinct II© nitrification inhibitor, and sorghum biomass residue, with 3 replications. Emissions of $CO_2$, $N_2O$, $CH_4$, and $NH_3$ were measured for 8 weeks with a mobile Fourier Transform Infrared (FTIR) gas analyzer integrated with a LI-COR chamber. The addition of residue increased cumulative $CO_2$ emissions, most likely due to increased heterotrophic microbial activity. Nitrogen fertilizer increased cumulative $N_2O$ and $NH_3$ emissions, with highest emissions for both gases occurring within one month after application. Nitrapyrin effectively lowered cumulative $N_2O$ emissions but increased $NH_3$ loss about two and a half weeks after application.

## Introduction

- GHG emissions from agricultural soils are a major source of total anthropogenic emissions and potential drivers of global climate change.
- Further research is needed to help identify sustainable management practices that also lower GHG emissions.
- Nitrogen fertilizers are commonly used to increase crop yields, but can lead to increases in GHG emissions, especially $N_2O$.
- Nitrification inhibitors can be used to inhibit nitrification and potentially reduce $N_2O$ losses (Bremner, 1997).
- **Hypothesis:** Treatments fertilized with urea fertilizer will exhibit greater $N_2O$ emissions than those without, but nitrification inhibitor and sorghum residue will decrease total $N_2O$ emissions.

Above: Li-Cor chamber atop a PVC treatment column



Above: Preparing nitrification inhibitor and urea-N fertilizer solution in the laboratory

## Objectives

Determine the impact of NI on $N_2O$ and other GHG emissions as well as the effect of sorghum residue on the efficacy of the NI.

## Methods

***Soil*:** Soil used was a Weswood silty clay loam. This soil tests high in extractable P, K, Mg and Ca, is calcareous, and had a pH of 8.2. Soil moisture was maintained at approximately 50% water-filled pore space throughout the study.

***Bioenergy Sorghum Residue:*** Bioenergy sorghum (*Sorghum bicolor* L.) residue was derived from a high-biomass, photoperiod-sensitive variety, "4Ever Green". The crop was mechanically harvested on September 9, 2013 and oven-dried at 60˚C prior to analysis and storage. Average C:N of biomass residue was ~65. Residue was applied at rates to mimic field application rates. Field treatments returned residue at a rate of 50% total biomass yield which was 13,720 kg $ha^{-1}$ for +N treatments and 8,282 kg $ha^{-1}$ for –N treatments, corresponding to 6.12 and 3.69 g residue $kg^{-1}$ soil.

***Experimental Design:*** This study was a factorial design where PVC columns (33 cm x 10 cm, i.d.) were prepared by filling the bottom 15 cm of each column with unamended soil and the top 15 cm (top 6") with soil amended with every possible combination of the following three factors at two levels (3 replications of each):

- Either zero (-N) or 0.2715 g dissolved-urea $kg^{-1}$ soil (+N)
- Either zero (-NI) or 1.094 mg nitrification inhibitor $kg^{-1}$ soil (+NI)
- Either zero (-R) residue return or field-mimicked rate (+R) (see above description)

***Gas Measurement:*** A mobile FTIR spectrophotometer (Gasmet DX4030) paired with a 10-cm diameter survey chamber (Li-Cor 8100-102) was used to quantify gas fluxes from the soil surface of each column. Measurements were taken at the same time of day over a 5 week period.

***Analysis:*** Flux rates were calculated by determining linear regressions of gas concentrations versus time. Cumulative emissions were calculated via linear integration over the 5 weeks. The effect of N fertilization, NI, and residue application and their interactions on cumulative $CO_2$, $CH_4$, $N_2O$, and $NH_3$ losses were tested using a mixed ANOVA in SAS (Version 9.2) with significance criteria of P<0.05. Fisher's LSD was utilized for means separation following a significant treatment effect.

## Results

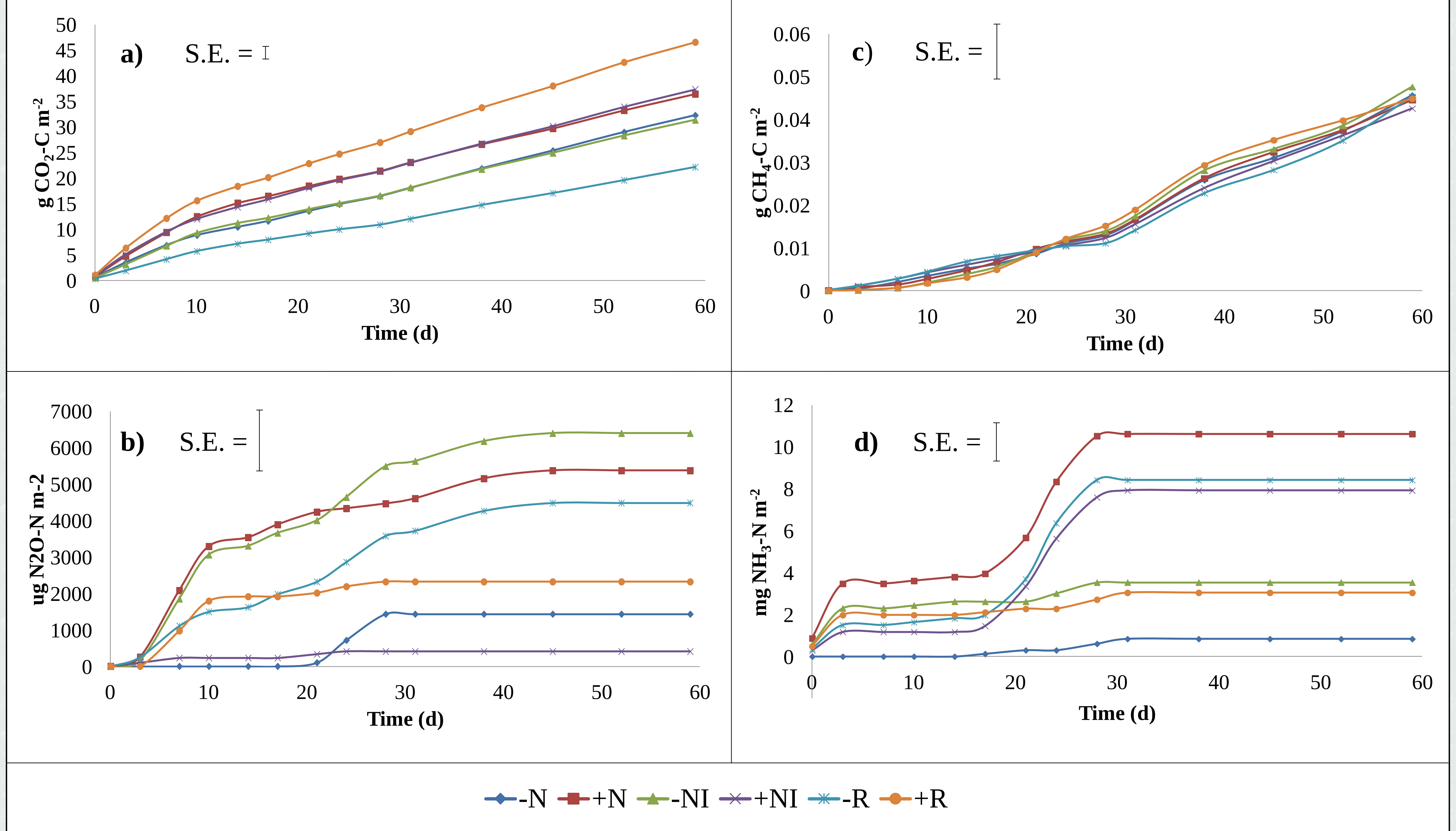
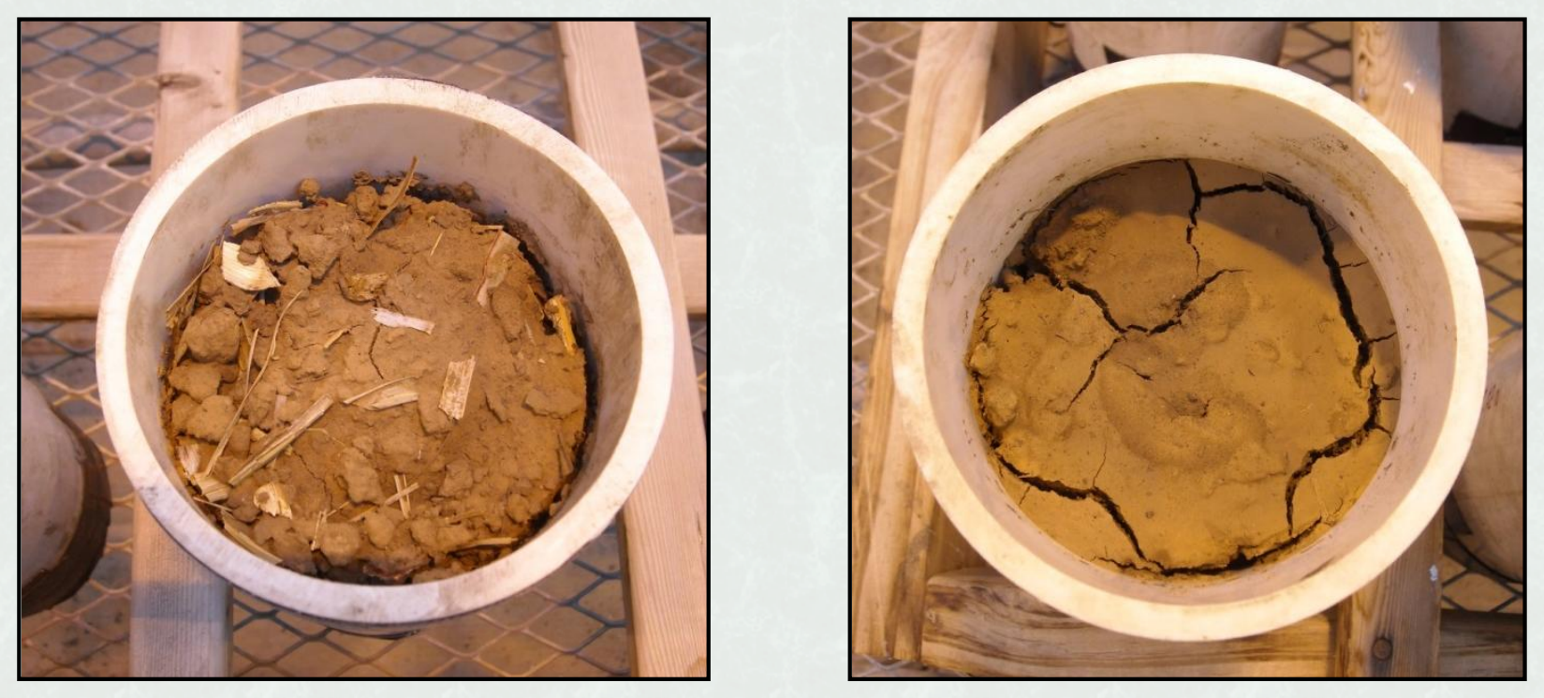


**Figure 1. Cumulative Greenhouse Gas Fluxes**
Above: (a) $CO_2$-C and (b) $N_2O$-N, (c) $CH_4$-C and (d) $NH_3$-N. Values represent mean cumulative gas fluxes. S.E. (standard error) bars depict significance difference ($p < 0.05$) of primary treatments based on final cumulative value.

| Effect | $CO_2$ | $N_2O$ | $CH_4$ | $NH_3$ |
|---|---|---|---|---|
| | -------------------- | p-value | -------------------- | |
| N-fert. | **0.058** | **0.010** | 0.909 | **<.0001** |
| NI | **0.010** | **0.0004** | 0.593 | **0.004** |
| Residue | **<.0001** | 0.128 | 0.962 | **0.001** |
| N-fert.*NI | 0.121 | **0.012** | 0.755 | **0.052** |
| N-fert.*Residue | 0.115 | 0.997 | **0.046** | **<.0001** |
| NI*Residue | **0.005** | 0.146 | 0.620 | 0.076 |
| N-Fert.*NI*Residue | 0.533 | 0.559 | 0.604 | **0.006** |

**Table 1.** ANOVA p-values for effects of N fertilizer (N-fert.), nitrification inhibitor (NI), and sorghum residue (Residue), and their interactions on cumulative $CO_2$, $N_2O$, $CH_4$, and $NH_3$ losses.



Above: (Left) PVC column with residue (+R), and (Right) PVC column without residue (-R).

**Cumulative Greenhouse Gas fluxes:**

***Carbon Dioxide (Fig. 1 a)***

- Treatments with residue [+R] lost 71% greater cumulative $CO_2$ emissions compared to treatments without residue [-R].
- Addition of N fertilizer [+N] caused 12% more $CO_2$ emissions than treatments without N fertilizer [-N].
- Nitrification inhibitor [+NI] had 17% higher emissions than treatments without the inhibitor [-NI].
- Regardless of [NI], treatments with [+R] had at least 56% more cumulative $CO_2$ emission than treatments without addition [-R], and the combination of [+R,+NI] had the most cumulative $CO_2$ emission.

***Nitrous Oxide (Fig. 1 b)***

- Treatments with [+NI] had 19 times less cumulative $N_2O$ emissions compared to treatments without [-NI].
- Treatments with [+N] had approximately 100% more cumulative $N_2O$ emissions than treatments without [-N].
- Regardless of [N], soils with [+NI] had 1.7 times less cumulative $N_2O$ than treatments without [-NI].

***Methane (Fig. 1 c)***

- Treatments with [+N, +R] had 36% higher cumulative $CH_4$ emissions than those without residue [+N, -R].

***Ammonia (Fig. 1 d)***

- Treatments with [+N] had 170% greater $NH_3$ emissions than those without [-N].
- Soils treated with [+NI] caused 77% more $NH_3$ emissions than treatments without [-NI].
- Regardless of [R], [+N, +NI] had 66% greater emissions of $NH_3$. Cumulative emissions were generally lower for treatments with [+R].
- Treatments with [+R] showed almost 100% less $NH_3$ emissions than treatments without [-R].
- Regardless of [NI], treatments with [+N,+R] exhibited at least 90% more $NH_3$ emissions.
- Regardless of [R], soils treated with both [+N,+NI] had the most effect on $NH_3$ emissions and had approximately 80% more $NH_3$ emission.

## Conclusions

- Nitrapyrin was very effective at reducing $N_2O$ emissions but led to increased $CO_2$ and $NH_3$ emissions.
- Sorghum residue application increased $CO_2$ emissions, generally decreased $NH_3$ emissions and had no effect on $N_2O$ emissions; potentially due to temporary immobilization of N.
- The combination of sorghum residue and NI increased $CO_2$ emissions more than treatments with residue alone.

## Acknowledgements

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## References

- Bremner, J. M. 1997. Sources of nitrous oxide in soils. Nutr. Cycle. Agroecosyts. 49:7-16.