Can we reduce N losses and increase spring wheat grain yields with Urease and Nitrification Inhibitors?

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Introduction

Urease and nitrification inhibitors have the potential to reduce nitrogen (N) losses and increase crop productivity from urea-fertilized soils. In a recent meta-analysis, Thapa et al., (2016) found:

- Nitrification inhibitors (NI) can reduce N_2O emissions by 38% and increase crop yields by 7% as compared to conventional N fertilizers.
- Double inhibitors (combined application of both urease and nitrification inhibitors: DI) can reduce N_2O emissions by 30% as compared to conventional N fertilizers.
- DI might provide added benefits over NI in alkaline soils, coarse-textured soils, and irrigated systems.

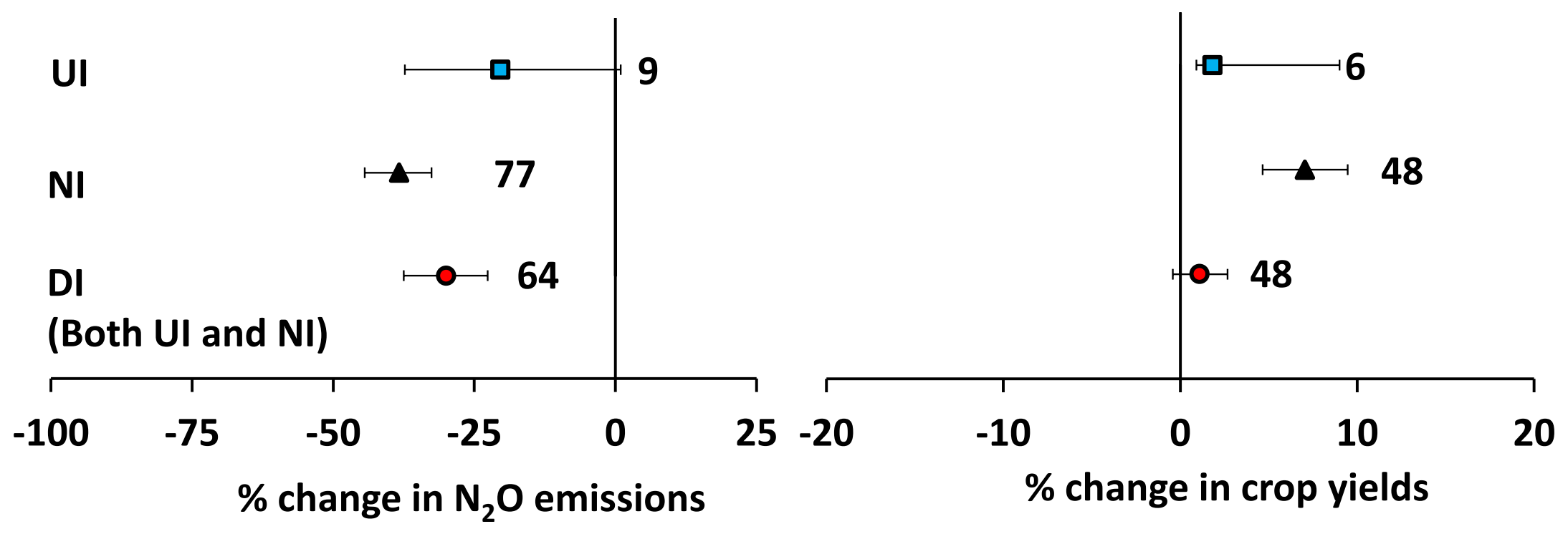


Figure 1. Effect size ± 95% confidence intervals of the effect of enhanced efficiency fertilizers on nitrous oxide (N_2O) emissions and crop yields in major cereal systems. Numbers represent the sample size (pair-wise comparisons).

Source: Thapa et al., (2016)

Objectives: To assess the impact of NI and DI, as well as N application rate on N losses (NH_3 volatilization and N_2O emissions) and spring wheat grain yields under rainfed conditions.

Experimental Approach

- **Research site:** Glyndon, MN (46˚ 54' 45'' N, 96 ˚ 36' 35'' W), Previous crop: Soybean.
- **Soil type:** Bearden silt clay loam (a fine-silty, mixed, superactive, frigid Aeric Calciaquolls).
- **Basic soil properties:**
  Soil pH, 8.1-8.4; Cation exchange capacity (CEC), 26-27 $cmol_{(+)}$ kg^{-1} soil; Organic matter, 4.5-4.7%, Clay, 32.5-33%, Silt, 58-59%, Bulk density, 1.28-1.30 Mg m^{-3}, Soil NO_3-$N_{(0-60\ cm)}$, 45-49 kg N ha^{-1}.
- **Experimental design:** Randomized Complete Block Design (RCBD) with 4 replicates.

Table 1. Nitrogen source and nitrogen rate treatments during 2014, 2015 and 2016 growing seasons under rainfed spring wheat production systems. In 2014, only 7 spring fertilizer treatments (^{x}) were applied. The N treatments were control (no N addition) and three N sources: urea (U), urea with urease inhibitor NBPT and nitrification inhibitor DCD (DI), and urea with nitrification inhibitor nitrapyrin alone (NI). Values in parenthesis represents the total N applied (both fall and spring application).

S. No.	Treatments	2014	2015	2016
1	Control	x	x	x
2	U@100% Fall (146 kg N/ha)	-	x	x
3	DI@ 100% Fall (146 kg N/ha)	-	x	x
4	U@ 75% Fall:25% Spring (146 kg N/ha)	-	x	x
5	DI@ 75% Fall:25% Spring (146 kg N/ha)	-	x	x
6	U@ 50% Fall:50% Spring (146 kg N/ha)	-	x	x
7	DI@ 50% Fall:50% Spring (146 kg N/ha)	-	x	x
8	U@ 100% Spring (146 kg N/ha)	x	x	x
9	U@ 100% Spring (168 kg N/ha)	x	x	x
10	NI@ 100% Spring (146 kg N/ha)	x	x	x
11	NI@ 100% Spring (168 kg N/ha)	x	x	x
12	DI@ 100% Spring (146 kg N/ha)	x	x	x
13	DI@ 100% Spring (168 kg N/ha)	x	x	x

- Ammonia (NH_3) volatilization and nitrous oxide (N_2O) emissions were measured during 2014 and 2015 only. Open chamber ammonia traps were used to measure NH_3 volatilization (Jantalia et. al., 2012). The NH_3 volatilized from soil were trapped in polyfoam strips soaked in 0.5 M H_3PO_4 solution, extracted with 250 ml of 2 M KCl, and then analyzed in Timberline TL2800 ammonia analyzer. Cumulative NH_3 volatilization were determined by summing the NH_3 loss between sampling days.
- Nitrous oxide (N_2O) fluxes were measured using static chamber methods (Parkin and Venterea, 2010). Three headspace gas samples at 0, 30 and 60 mins after chamber deployment were obtained. Samples were analyzed for N_2O concentrations using a DGA-42 Dani Master gas chromatograph fitted with ^{63}Ni electron capture detector. The N_2O fluxes was determined using linear or quadratic regression. Cumulative N_2O emissions were determined by trapezoidal integration of N_2O fluxes over time.
- At Physiological maturity, wheat harvested using small plot combine harvester, grains were dried at 60˚C for 3 days and adjusted to 14% moisture level before recording grain yield.
- Statistical analysis: Single df linear contrasts for cumulative NH_3 and N_2O emissions in SAS 9.3.

Results & Discussion

Semi-static open chamber NH_3 traps

Static PVC chambers for N_2O sampling

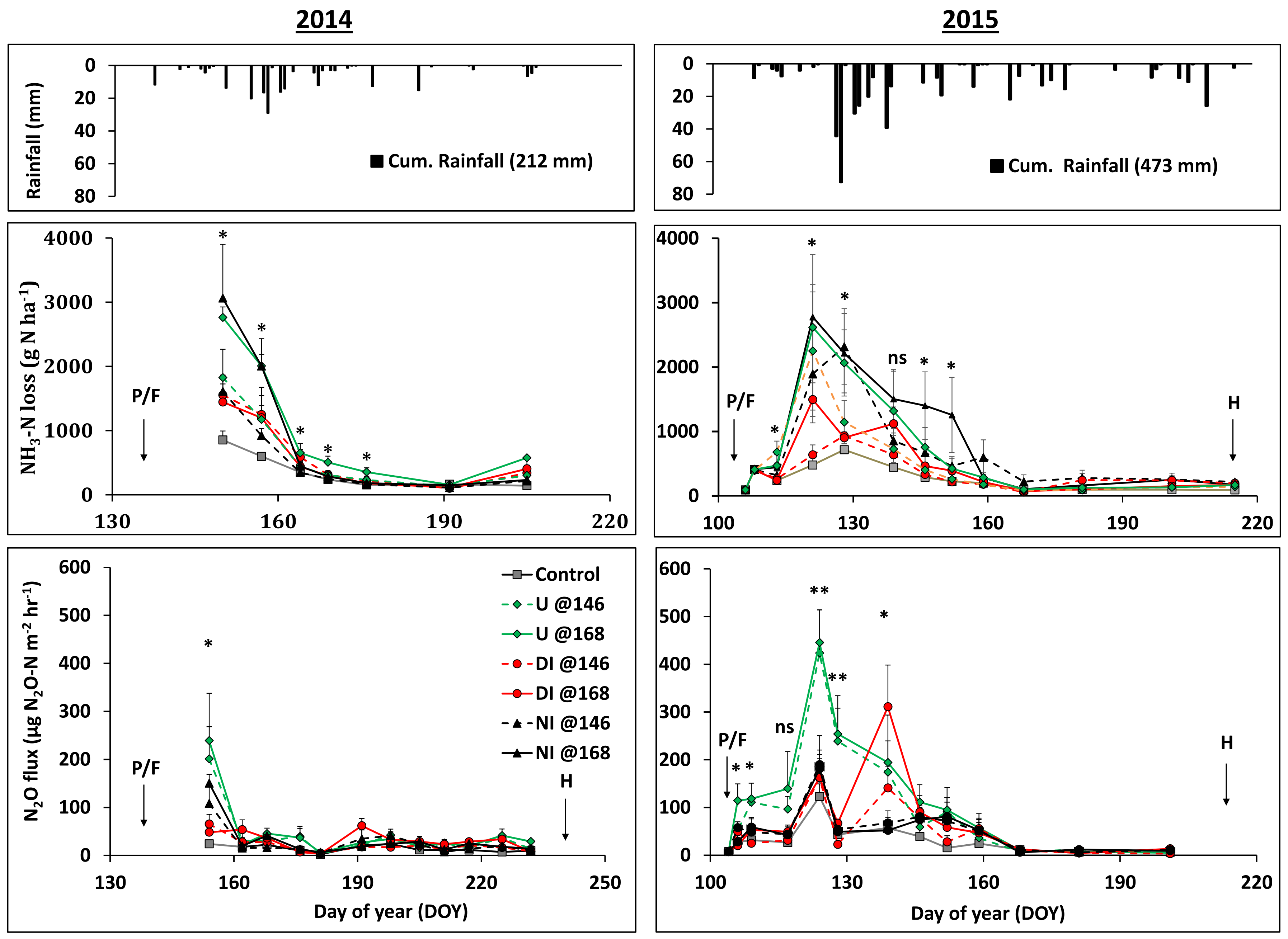
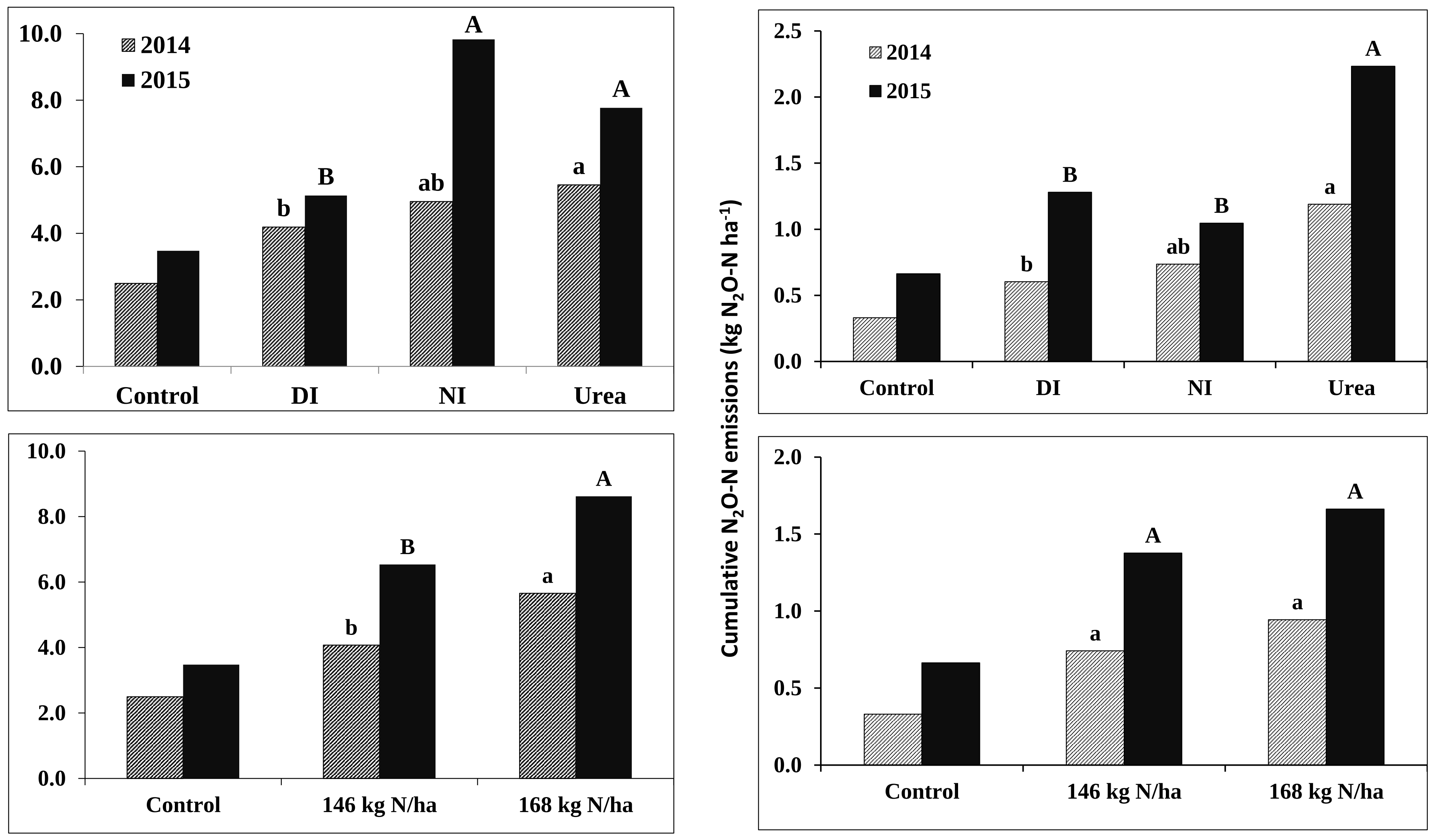


Figure 2. Temporal variations in (a) rainfall, (b) mean ammonia (NH_3) volatilization loss during the sampling period, and (c) mean nitrous oxide (N_2O) fluxes for all N treatments during 2014 and 2015 growing season in a rainfed spring wheat production system. The N treatments were control (no N addition) and three N sources: urea (U), urea with urease inhibitor NBPT and nitrification inhibitor DCD (DI), and urea with nitrification inhibitor nitrapyrin alone (NI), each applied at the rate of 146 and 168 kg N ha^{-1}. Asterisk sign indicates the significant differences among treatments at the 0.05 level. Downward pointing arrows indicate the date of fertilizer application (F), planting (P), and harvesting (H). "ns" not significant.

- 2015 growing season is relatively wetter and cooler as compared to 2014 growing season.
- In both years, the peak NH_3 and N_2O fluxes occurred during the initial 30-40 days following fertilization.

Figure 3. Effect of N source and N application rate on cumulative ammonia (NH_3) volatilization and cumulative nitrous oxide (N_2O) emissions under rianfed spring wheat production systems during 2014 and 2015 growing seasons. Columns with different lowercase or uppercase letters represents significant differences among treatments at $p<0.05$.



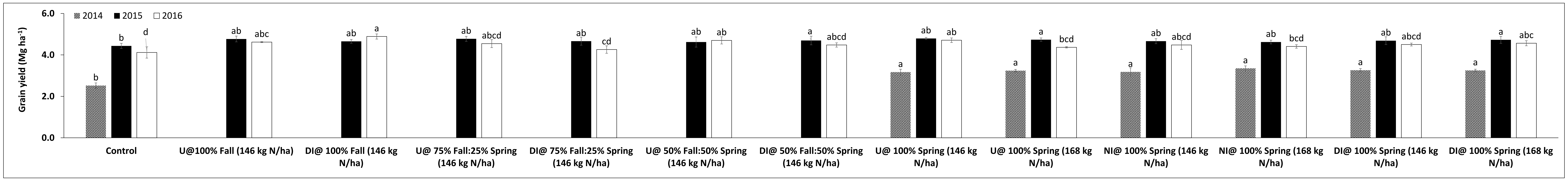
Effect on Cumulative NH_3 volatilization:

- DI significantly reduced cumulative NH_3 loss by 26 to 34% as compared to urea (U) alone across both years (Figure top left).
- NI, however, have similar NH_3 loss to that of urea (U) alone. Moreover, NI significantly increased NH_3 loss by 48% as compared to DI in 2015 (Figure top left).
- Increasing N application rate from 146 to 168 kg N/ha also significantly increased NH_3 loss by 24 to 29% (Figure bottom left).

Effect on Cumulative N_2O emissions:

- DI significantly reduced cumulative N_2O emissions by 43 to 50% as compared to urea (U) alone (Figure top right).
- NI also significantly reduced cumulative N_2O emissions by 53% as compared to urea (U) alone in 2015 (Figure top right).
- N application rate showed no effect on cumulative N_2O emissions (Figure bottom right).

Figure 4. Effect of N source (U, NI, and DI), N application rate (146 and 168 kg N/ha), application time (fall vs. spring), and mode of application (single vs. split) on grain yields of spring wheat under rainfed conditions during 2014, 2015 and 2016 growing seasons. Columns with different lowercase letters within each year were significantly different at $p<0.05$.



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Conclusions

- In summary, N loss from urea-fertilized fields depends upon environmental conditions, especially rainfall pattern and distribution over the growing season. Higher N_2O-N fluxes were observed when soil water-filled pore space lies between 35-60%, soil temperature is above 10-12 ˚C, and at higher soil nitrate levels (>5 mg NO_3-N kg^{-1} soil).
- Amending urea with either NI or DI reduced N_2O emissions as compared to un-amended urea by slowing down the rate of nitrification.
- DI also significantly reduced NH_3 volatilization as compared to untreated urea by delaying urea hydrolysis. However, NI tends to increase NH_3 volatilization by prolonging NH_4^+ retention in soil.
- Combined application of both urease and nitrification inhibitor (DI) might be the effective strategy over NI to reduce both NH_3 volatilization and N_2O emissions from urea-fertilized soils, while sustaining grain yields in rainfed systems.