Drainage and Nitrogen Application Time and Rate Impact Nitrous Oxide Emissions in Poorly Drained Soils in Minnesota

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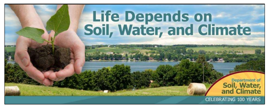

Background

In poorly drained soils, denitrification could be a pathway of nitrogen (N) loss that also reduces crop N use efficiency. Little is known about the effect of split-N applications in reducing nitrous oxide (N_2O) emissions from corn (*Zea mays* L.). Similarly, studies evaluating the effect of soil drainage on N_2O emissions are lacking.

Objective

To quantify in-season N_2O emissions over two corn growing season in a corn-soybean rotation under tile-drainage and natural (no tile) conditions with different N fertilization management.

Materials and Methods

- Field study established near Wells, Minnesota in a Marna silty clay loam and Nicollet silty clay loam soil.
- Data collection during the 2014 and 2015 corn growing seasons.
- Tile drainage was installed in 2011 in all plots, but since installation some have been open and others closed to create drainage treatments (**Drained and Undrained**).
- Urea-N management: **Zero-N control**, a single pre-plant application of 135 kg N ha^{-1} (**Single Preplant**), and a split application (45 kg ha^{-1} pre-plant, and 90 kg ha^{-1} [with urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT)] at V4 development stage) (**Split**).
- Volumetric water content and soil temperature was measured at 0-5, 5-10, and 10-15 cm depth increments during both growing season.
- N_2O emissions were measured using the non-steady state chamber method, twice a week through July and weekly thereafter until harvest.
- Corn grain yield was measured at harvest and adjusted to 155 g kg^{-1} moisture content.
- Statistical analysis was conducted using the PROC GLIMMIX procedure of SAS with year, drainage systems, and N management variable as fixed effects and block and block by drainage as random effect.

Results and Discussion

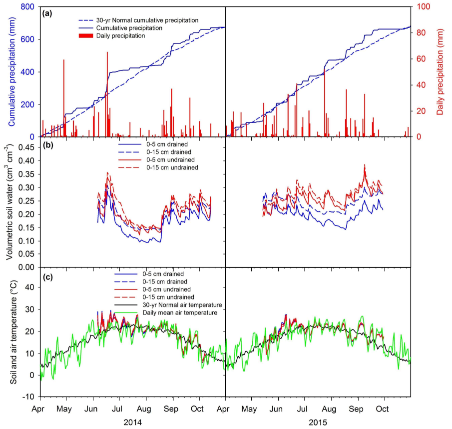

Figure 1. Daily and cumulative precipitation and 30-yr normal cumulative precipitation (a), volumetric soil water content at 0-5 and 0-15 cm soil depth for Drained and Undrained treatments (b), and soil and air temperature at 0-5 and 0-15 cm soil depth (c) in 2014 (left) and 2015 (right).

- Precipitation (Fig. 1a) influenced soil volumetric water content (VWC)(Fig. 1b). The Undrained soils had greater VWC than Drained soils, but the differences were more pronounced in 2015 than 2014 (Fig. 1b).
- Air temperature was close to the 30-yr mean except in July where it was 2.1°C cooler in 2014 (Fig. 1c). In 2015, air temperature was lower than the 30-yr normal from the start of the growing season to mid-July, and greater thereafter.
- Soil temperature was similar between drainage systems and followed air temperature closely in 2014. In 2015, soil temperature was greater at the beginning of growing season in the Drained than Undrained soils, but this differences disappeared in early July (Fig. 1c).

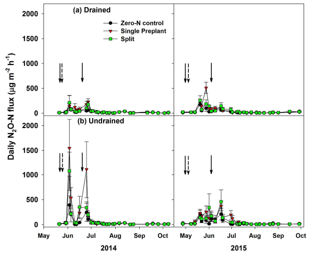

Figure 2. Daily N_2O-N emissions (µg m^{-2} h^{-1}) in Drained (a) and Undrained (b) treatments for the Zero-N control, Single-Preplant and Split application in 2014 (left) and 2015 (right). Downward-pointing arrows indicate the pre-plant and side-dress fertilizer application dates (solid) and planting date (dash).

- Episodic increases in N_2O flux and substantial increase in cumulative emissions occurred through June, especially in Undrained conditions (Fig. 2) probably because it was closer to the time of fertilization and precipitation was high (Fig. 1a). Even though significant precipitation took place later in August, daily N_2O fluxes were near background levels likely due to rapid uptake of water and N by the crop.

Table 1. Means of grain yield, area-scale N_2O emissions (aN_2O), yield-scale N_2O (yN_2O), and fertilizer-induced cumulative N_2O emission factor (EF) for fixed sources of variation and their interactions. Only significant interactions are shown.

	Grain Yield	Area-scaled N_2O†	Yield-scale N_2O†	EF†
	Mg ha^{-1}	kg N ha^{-1}	g N Mg grain^{-1}	%
Year				
2014	10.6	1.84	168.1	0.99
2015	11.0	1.82	180.0	0.72
P>F	**ns**	**ns**	**ns**	**ns**
Drainage Systems				
Drained (D)	11.5 a	1.29 b	112.7 b	0.52 b
Undrained (UD)	10.0 b	2.36 a	235.4 a	1.20 a
P>F	**0.004**	**0.099**	**0.025**	**0.003**
N management (N)				
Zero-N control	8.6 b	1.17 c	151.1 b	--
Single Preplant	12.2 a	2.48 a	204.3 a	1.00 a
Split	11.6 a	1.84 b	166.7 ab	0.71 b
P>F	**<0.0001**	**<0.0001**	**0.047**	**0.062**
Y x D				
2014-D	10.7 ab	--	--	0.36 b
2014-UD	10.5 ab	--	--	1.63 a
2015-D	12.3 a	--	--	0.68 b
2015-UD	9.6 b	--	--	0.77 ab
P>F	**0.010**	**ns**	**ns**	**0.017**

† Statistical analysis is based on $\log_{10}$ transformed cumulative season-long data.

- Undrained soils had 1.8 and 2.1 times more aN_2O and yN_2O than Drained soils, respectively (Table 1).
- Cumulative N_2O emissions of the applied N (135 kg N ha^{-1}) were 1.8% for the Single Preplant and 1.4% for the Split application.
- Relative to the Zero-N control, Single Preplant and Split applications increased aN_2O emissions 2.1 times and 1.6 times, respectively. Single Preplant increased aN_2O emissions 1.3 times and EF 1.4 times compared to the Split application (Table 1).
- Single Preplant produced 35% greater yN_2O than the Zero-N control, but the Split had similar values to the Zero-N control (Table 1).
- Drainage did not impact grain yield in 2014, however Drained soils had 28% greater grain yield than the Undrained soil in 2015 (Table 1).
- Single Preplant and Split applications had similar corn grain yield but greater than the Zero-N control (Table 1).

Summary

Tile-drainage can reduce N_2O emission in poorly to somewhat-poorly drained soils.

Split N application can help reduce N_2O emission without negatively impacting corn yield in these soils.

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