Fertilizer-N Management and Nitrous Oxide Emissions from four sites in Saskatchewan.

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Abstract

Nitrous oxide (N_2O) is a powerful greenhouse gas that also depletes stratospheric ozone. The use of fertilizer-N for agricultural purposes is thought to contribute significantly to Canadian anthropogenic N_2O emissions. However, the influence of fertilizer-N form, placement, rates of application, and their interaction with soil and climate is not well understood. We report on a 3-year project that compared N_2O emissions from four locations with contrasting soil and climatic conditions in Saskatchewan. Spring wheat was fertilized with urea and anhydrous ammonia (AA) banded in the fall, or in mid-row and side-row positions at seeding time in the spring. N_2O emissions were similar from AA compared to urea. Emissions tended to be higher when fertilizer-N was placed in a mid-row compared to side-row banded position. Within the range of rates applied in this study, N_2O emissions increased linearly with fertilizer-N rate. The percentage of fertilizer-N lost as N_2O calculated from our data ranged from near zero (in drought conditions) to 1.0 %. Most values fell at or below 0.4 % with an overall mean of 0.2 %.

Introduction

Nitrous oxide (N_2O) is a powerful greenhouse gas that also depletes stratospheric ozone. Current estimates suggest that agricultural activities contribute approximately 60% of all Canadian anthropogenic N_2O emissions, with more than 50% of the agricultural total being associated with nitrogen (N) fertilizer use. These estimates are prepared using the Intergovernmental Panel on Climate Change (IPCC) methodology which assumes that 10% of fertilizer N is volatilized and that 1.25% of the remaining N is lost directly as N_2O. However, the influence of fertilizer-N form, placement, rates of application, and their interaction with soil and climate is not well understood.

Placing N fertilizer into bands increases crop uptake efficiency. Side-row banding (fertilizer placed to the side of each crop row) and mid-row banding (fertilizer bands placed between alternate crop rows) are two widely used fertilizer application systems on the prairies of western Canada. Doubling of the fertilizer rate per band in mid-row banded placement alters the localized concentration of applied N and could have a considerable effect on the amount of N_2O emitted. Also, some workers have reported much higher losses of N_2O from anhydrous ammonia (AA) compared to other N sources. This is a concern because AA is used extensively in Saskatchewan, however no direct comparison of N_2O emissions from different fertilizer N sources have been conducted under Saskatchewan conditions.

There is limited information regarding the appropriateness of using the IPCC emission factor to estimate fertilizer induced emissions (FIE) of N_2O for the western Canadian prairies, and even less information regarding the influence of fertilizer formulation, placement and timing. This research project was designed to help answer the following applied questions:

How much N from fertilizers is lost directly as N_2O under western Canadian conditions?

Does fertilizer N source influence direct losses of N_2O?

Does application time (spring vs. fall) influence direct losses of N_2O?

Does fertilizer placement influence agronomic performance and/or direct losses of N_2O?

Materials and Methods

- Experimental sites included Swift Current (Brown soil zone), Scott (Dark Brown), Indian Head (Black) and Star City (Dark Gray). Selected soil characteristics for each site are provided in Table 1.

Table 1. Basic soil characteristics (0-30 cm) at four experimental sites in Saskatchewan**.**

Soil property	Star City	Indian Head	Swift Current	Scott
pH	7.2	8.0	7.8	7.1
EC(S/cm)	0.2	0.2	0.2	0.2
Organic carbon(%)	1.3	1.5	0.7	1.4
Total nitrogen(%)	0.12	0.17	0.12	0.11
% total sand	14.4	22.1	43.3	46.6
% total silt	33.0	8.3	32.1	28.0
% total clay	52.6	69.6	24.6	25.4

- Spring wheat (AC Barrie in 2000 and 2001 and AC Eatonia in 2002) was direct seeded into Canola stubble. Seed row openers were located at 25 cm (10 in.).
- Fertilizer N treatments are summarized in Table 2. All sites received P, S and K fertilizer to ensure sufficiency of these nutrients.
- Nitrous oxide samples were collected using vented soil chambers. Plexi-glass frames (22 cm x 45.5 cm x 15 cm high) were inserted into the soil to a depth of 5 cm. The frames were designed to fit snugly between crop rows.

Table 2. Treatment combinations applied at each of the four sites. Treatments were applied in a randomized complete block design in four replications.

N Formulation	Placement	Timing	N rate
Urea	Mid-row	Spring	0.5 x recommended[Y]
Urea	Mid-row	Spring	1.0 x recommended
Urea	Mid-row	Spring	1.5 x recommended
Urea	Side-row	Spring	1.0 x recommended
Urea	broadcast	Spring	1.0 x recommended
Urea	Band	Fall	1.0 x recommended
AA[Z]	Mid-row	Spring	1.0 x recommended
AA	Side-row	Spring	1.0 x recommended
AA	Band	Fall	1.0 x recommended
Check	na	na	no N

[Z] AA = anhydrous ammonia
[Y] Recommended rate = 80 kg N ha^{-1} at Melfort and Indian Head and 60 kg N ha^{-1} at Swift Current and Scott.

- N_2O flux was estimated from the concentration change in the chamber headspace over a 30 or 60 minute collection period. The concentration of N_2O in the samples was determined using a gas chromatograph equipped with an electron capture detector.
- Gas samples were collected at least twice weekly from snow melt until the end of July. Sampling frequency was reduced to once a week or less during the latter part of the season when soil-water contents were low.
- Seasonal estimates of N_2O emissions were calculated by interpolating between data points and integrating over time assuming a constant flux.
- The percentage of fertilizer-N lost as N_2O was calculated by subtracting the N_2O lost from the check (no N applied) treatment and dividing that difference by the total N applied as fertilizer (x 100).
- Seasonal estimates were analysed using GLM procedure in SAS, and $LSD_{0.01}$ or contrasts were used for mean separation. Linear and quadratic effects of N rate were determined by orthogonal contrasts. All contrasts were done for individual groups, combined and their interactions. ‘Significance’ in the text refers to $P < 0.1$ if the P value is not given.

Results and Discussion

Scott and Indian Head received about average precipitation during the 2000 growing season, but precipitation was above average at Star City and Swift Current. Late fall and winter were dry at all sites with snowfall being particularly low at Scott and Swift Current. Indian Head received only 30% of long-term mean precipitation, while Swift Current, Scott, and Star City received 60%, 63% and 73% respectively during the 2001 growing season. All sites received very limited snowfall during the over-winter period, and conditions remained very dry during the early part of the 2002 growing season. Conditions remained dry throughout the balance of the season at Scott resulting in complete crop failure. Above average precipitation at Swift Current and Indian Head during the latter part of the 2002 growing season resulted in modest crop yields at these two locations. At Star City, the rains came too late (July) for the wheat crop to recover.

Inter-annual variability of N_2O loss reflected precipitation patterns. At Star City for example, average to above average precipitation during the 2000-2001 cycle resulted in N_2O losses ranging between 162 and 672 g N ha^{-1}. In the following much drier year, N_2O losses ranged between 7 and 25 g N ha^{-1}. A similar, but less pronounced pattern can be observed at the other three sites.

Table 3 presents estimated N_2O loss summed across the three years of the study. Nitrogen applications significantly increased N_2O emissions compared to the check treatment at 3 of the 4 sites. The lack of significance at Star City can be explained by the unusually high loss on the check treatment during the spring of 2001. This resulted in a 3-year cumulative loss estimate for the check treatment that was equal or even somewhat higher than on some of the fertilized treatments.

Emissions were significantly higher from fall versus spring banded N at Star City, but not at any other site. Likewise, emissions from AA were significantly higher than urea at Star City, but not at any other location. The latter outcome was related to a particularly high loss from AA treatments in only one of the three years. Broadcasting rather than banding urea resulted in significantly higher 3-year cumulative estimates at Indian Head and Star City, while mid-row was significantly higher than side-row at Scott and Star City. N_2O loss showed a significant linear increase to fertilizer rate at 3 of 4 sites.

The percentage of fertilizer-N lost as N_2O-N for the four sites are presented in Table 4. The percentage of fertilizer-N lost as N_2O calculated from our data ranged from near zero (in drought conditions) to 1.0 %. Most values fell at or below 0.4 % with an overall mean of 0.2 %.

Table 3. Estimated 3-year cumulative (May 2000-April 2003) N_2O loss at four sites in Saskatchewan, and significance levels for selected treatment contrasts.

Treatment	**Swift Current**	**Scott**	**Indian Head**	**Star City**
		grams N ha^{-1}		
AA Fall band	624	484	287	1064
AA Side-row band	699	420	313	863
AA Mid-row band	807	625	218	1280
Urea Fall band	947	451	365	1268
Urea Side-row band	563	264	225	515
Urea Mid-row band (0.5x rate)	521	336	151	767
Urea Mid-row band	879	443	246	856
Urea Mid-row band (1.5x rate)	1327	861	210	848
Urea broadcast	761	507	406	1290
Check (no N applied)	381	180	100	884
Contrasts	***Significance***			
N applied vs. no N applied	0.07	0.02	<0.01	ns
Fall banded N vs. Spring banded N	ns	ns	ns	0.02
Mid-row vs. Side-row banded N	ns	0.07	ns	<0.01
NH3 vs. Urea	ns	ns	ns	0.09
Urea broadcast vs. Urea spring band	ns	ns	0.02	<0.01
Orthogonal Contrasts for N rate				
rate	<0.01	<0.01	<0.01	ns
linear	<0.01	<0.01	<0.01	ns
quadratic	ns	ns	ns	ns

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 4. Three-year mean estimated percentage of fertilizer-N lost as N_2O-N at four sites in Saskatchewan.

Treatment	**Swift Current**	**Scott**	**Indian Head**	**Star City**
	———	%	———	
AA Fall band	0.2	0.2	0.1	0.3
AA Side-row band	0.2	0.1	0.1	0.1
AA Mid-row band	0.3	0.3	0.1	0.2
Urea Fall band	0.4	0.2	0.1	0.2
Urea Side-row band	0.1	0.1	0.1	0.1
Urea Mid-row band (0.5x rate)	0.2	0.2	0.1	0.1
Urea Mid-row band	0.3	0.1	0.1	0.1
Urea Mid-row band (1.5x rate)	0.4	0.3	0.0	0.1
Urea broadcast	0.2	0.2	0.1	0.5

Conclusions

- N_2O emissions increased with fertilizer N applications, and within the range of rates applied in this study, emissions increased in a linear fashion.
- The percentage of fertilizer-N lost as N_2O calculated from our results averaged 0.2 %, suggesting that the current N_2O loss coefficient of 1.25 % applied to fertilizer-N use in western Canada needs to be modified.
- N_2O emissions were similar from AA compared to urea.
- There was a weak trend for emissions to be higher when urea was broadcast rather than banded, and when fertilizer-N was mid-row rather than side-row banded.
- In general, N_2O emissions were comparatively low and the results suggest that the specific N fertilizer system selected is of less consequence than ensuring the optimal use of N fertilizer additions.

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