The Impact of N-Fertilizer Management on N_2O Emissions in Saskatchewan

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Introduction

Nitrous oxide (N_2O) emissions represent a significant portion of Canada's contribution to atmospheric greenhouse gases (GHG). In 1996, Canada's total anthropogenic GHG emissions were estimated to be 671 Tg CO_{2equiv} (Table 1), with N_2O emissions representing about 10 % of that total. Nitrous oxide (N_2O) emissions represented an even larger portion, nearly 20%, of Saskatchewan's total GHG emissions for the same year. Agricultural activities are considered the predominant source of N_2O emissions. This is particularly true in Saskatchewan where N_2O emitted from agricultural activities represented over 90% of the province's total N_2O emissions. The use of nitrogen fertilizer is by far the largest source of N_2O emissions from Saskatchewan agriculture, contributing approximately one-half of total N_2O emissions (Table 2). In light of Canada's international commitments to reduce GHG emissions, effective N fertilizer management will clearly be an important consideration, particularly for Saskatchewan.

Table 1. Estimated Nitrous Oxide and Total Anthropogenic Greenhouse Gas (GHG) Emissions to the Atmosphere from Canada in 1996.

	N_2O	Total GHG
	Tg CO_2 equivalents	
Canada	66	671
Saskatchewan	11	59
Saskatchewan Agriculture	10	12

Source: Neitzert et al. 1999

Currently, N_2O loss estimates are calculated using a methodology derived by the Intergovernmental Panel on Climate Change (IPCC). The IPCC methodology assumes, as a default value, that 1.25 % of applied N is lost directly as N_2O (IPCC 1997). No accommodations are made for differing soil, environmental, or management situations, all of which are known to strongly influence N_2O emissions. The appropriateness of this factor for western Canadian conditions has not been verified. In addition, some researches have reported substantially higher losses of N_2O from N applied as anhydrous ammonia compared to N applied in other forms (Eichner 1990).

Table 2. Sources of N_2O Emissions, and Their Relative Contribution to Total Emissions from Agricultural Activities in Saskatchewan during 1996.

N_2O Source	Percent of Total	
Livestock Manure	24	
storage & handling		8
land application		10
grazing		6
Crop Production	76	
N fertilizers		50
residues (includes legumes)		23
legumes (direct)		3

Source: (R.L Desjardins, AAFC Ottawa; personal communication).

Recognizing the paucity of research regarding N_2O emissions from N-fertilizer use in western Canada, and the urgent need to identify opportunities to reduce N_2O emissions, an extensive research project has been undertaken to: 1) evaluate the influence N fertilizer formulation, placement, and timing on N_2O emissions, 2) compare the agronomic performance and nitrogen use efficiency of side-banded versus mid-row banded urea and anhydrous ammonia (AA) applied at seeding, as well as fall banding of both formulations, and, 3) calculate a total energy budget for the different formulations, placements, and timings of N fertilizer application. The balance of this presentation will discuss some preliminary results pertaining to the first objective of this project.

Methods and Materials

Field experiments were established in four Saskatchewan soil-climatic zones, using canola, flax and wheat as the test crops. Experimental sites included Swift Current, Scott, Indian Head and Star City. At each site, and separately for each crop, 17 treatments were arranged in a randomized complete block design (RCBD) with four replications. Only a subset of treatments will be discussed in this paper. These treatments are listed in Table 3.

The Prairie Agricultural Machinery Institute (PAMI) conducted the seeding, and nitrogen and phosphorus applications at all sites, ensuring consistent handling of these operations. The treatments discussed in this paper received N fertilizer at 80 kg N ha^{-1} at Melfort and Indian Head, and 60 kg N ha^{-1} at Swift Current and Scott. All sites received applications of P fertilizer (11-51-0), at rates of 17 kg P_2O_5 ha^{-1} at Scott and Swift Current, and 23 kg P_2O_5 ha^{-1} at Melfort and Indian Head. Phosphorus was placed with the seed in all cases except for the side-banded urea treatments where both N and P were placed in the side-band. A blanket treatment of K_2SO_4 was broadcast prior to seeding at all sites to ensure sufficiency of these nutrients.

Table 3. List of Treatments Selected for Discussion in this Paper.

Form of N-Fertilizer	Test Crop	Time of Fertilizer Application	Placement of N
Urea	wheat	spring	mid-row band
Urea	wheat	spring	side-band
Urea	wheat	spring	broadcast
Urea	wheat	fall	band
Anhydrous ammonia	wheat	spring	mid-row band
Anhydrous ammonia	wheat	spring	side-band
Anhydrous ammonia	wheat	fall	band
check (no N applied)	wheat	-	-

Gas samples were collected using vented soil chambers as described by Lessard et al. 1994. Nitrous oxide flux was estimated from the concentration change in the chamber headspace over a 30 or 60 minute collection period. Samples were drawn from the headspace using disposable 20 ml polypropylene syringes. The gas samples were then injected into pre-evacuated 13 ml exetainers for transport to the laboratory. The concentration of N_2O in the samples was determined using a gas chromatograph equipped with an electron capture detector. The field plots were sampled for N_2O emissions at least twice a week from snow melt until late July when soil-water contents were high and the potential for N_2O loss was greatest. Sampling frequency was reduced to once a week or less during the latter part of the season when soil-water content and the potential for N_2O loss was low. Seasonal estimates of N_2O emissions were calculated by interpolating between data points and integrating over time assuming a constant flux (Lemke et al., 1998).

Results and Discussion

Indian Head experienced unusually cool temperatures and above average precipitation during May and June of 2000, and somewhat drier than normal conditions for the balance of the season. Melfort, Swift Current, and Scott experienced moderately dry conditions during early May, then above average precipitation from mid-May through to late July. Fall conditions at Swift Current and Scott were dry. The spring and growing season of 2001 was very dry. Most locations received 65 % or less of their mean long-term precipitation.

Estimated cumulative loss of N_2O was low at each of the four sites during the first complete year of the study (May 2000 – April 2001). In general, emissions were highest at Star City, ranging from 160 to 760 grams N $ha^{-1}yr^{-1}$, and lowest at Indian Head where they ranged from 50 to 220 grams N $ha^{-1}yr^{-1}$. Emissions at Swift Current ranged between 190 and 410 grams N $ha^{-1}yr^{-1}$ while emissions at Scott ranged from 120 to 290 grams N $ha^{-1}yr^{-1}$ (data not shown). These ranges are consistent with loss estimates reported for other studies in western Canada (Lemke et al. 1998; Corre et al. 1999). The reader should note that conditions during the spring of 2001 were quite dry, thus the loss estimates from this time period may be considered conservative.

Table 4. Significance of Selected Treatment Contrasts Comparing the Influence of Placement, Timing and Formulation on N_2O Loss at Four Sites in Saskatchewan (May 2000 - April 2001).

Treatments Contrasted	Swift Current	Scott	Indian Head	Star City
N applied vs. no N applied	0.08	ns [z]	0.02	0.08
Fall vs. Spring applications	0.06	ns	ns	ns
Mid-row vs. Side-band	ns	ns	ns	0.01
Anhydrous Ammonia vs. Urea	ns	ns	ns	0.08
Broadcast vs. Banded	ns	ns	ns	ns

[z] ns = not significant at the $p < 0.10$ level

No significant treatment differences were observed at Scott during the first year of the study (Table 4). At Indian Head and Swift Current, application of nitrogen fertilizer significantly increased N_2O emissions. During the spring thaw period, treatments receiving N in the previous fall had significantly higher N_2O emissions compared to those receiving N at seeding time at both Indian Head (Figure 1) and Star City (not shown). However on an annual basis, even though losses from the treatments receiving fall applied-N were amongst the highest (data not shown), the differences were not statistically significant (Table 4). Similarly, losses were significantly higher from the mid-row compared to side-row banded N at Swift Current during the growing season (Figure 2), but on an annual basis, although losses from these treatments were amongst the highest, the differences were no longer significant.

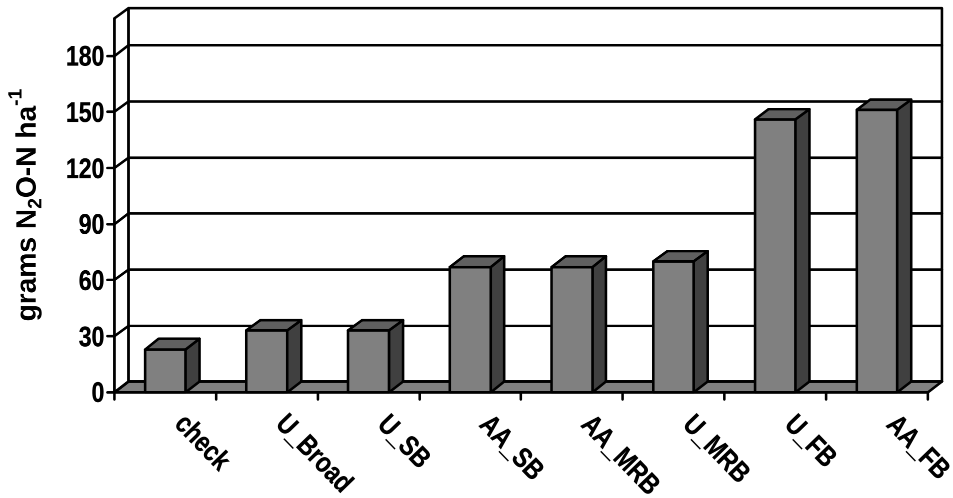

Figure 1. Estimated N_2O loss at Indian Head during the 2001 spring thaw.
AA = anhydrous ammonia; U = urea; SB = side-band; FB = fall band;
MRB = mid-row band and Broad = broadcast.

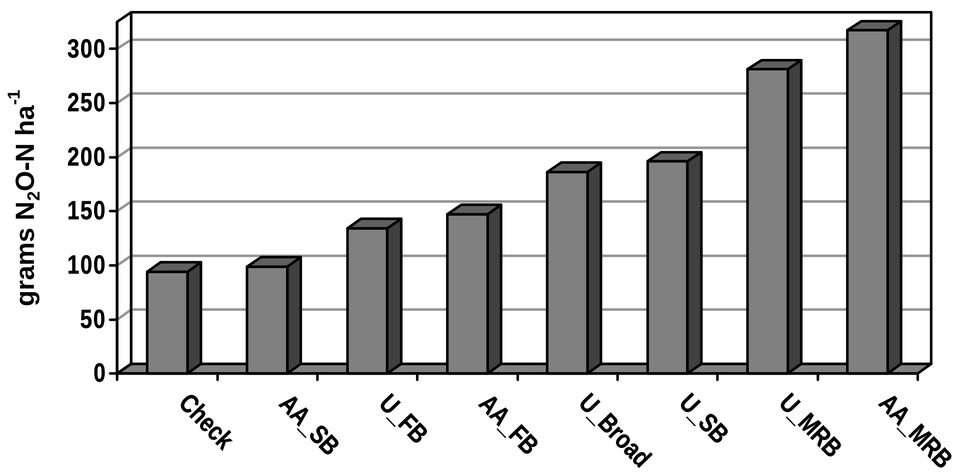

Figure 2. Estimated N_2O loss at Swift Current during the 2000 growing season.
AA = anhydrous ammonia; U = urea; SB = side-band; FB = fall band;
MRB = mid-row band and Broad = broadcast.

We calculated the percentage of N lost as N_2O based on our estimates of annual loss. Assuming that N_2O loss from the check (no N applied) treatment represents a background emission, then the difference between this background value and the amount of N_2O lost from treatments receiving N should represent the "fertilizer induced" N_2O emission. That difference divided by the total N applied as fertilizer (x 100) provides an estimate of the percentage of fertilizer N lost as N_2O. The values calculated for the four sites in this study are presented in Table 5. The values calculated in this study are considerably lower than the IPCC default value discussed earlier. For example, the highest value in Table 5 is 0.36 %, which is approximately 3.5x lower than the 1.25

% proposed in the IPCC methodology. Nitrous oxide emissions from treatments receiving N were always equal to or greater than the check during the growing season. However, emissions from the check treatment at Scott during the spring thaw period were unusually high, resulting in negative values being calculated for many of the treatments. We believe this unusual outcome is an artifact of the high spatial variability inherent to N_2O emissions.

Table 5. Percentage of Fertilizer-N lost as N_2O at Four Sites in Saskatchewan (May 2000-April 2001).

Treatment	Swift Current	Scott	Indian Head	Star City
		%		
AA fall band	0.09	0.16	0.17	0.16
AA mid-row band	0.30	0.14	0.11	0.05
AA side-band	0.05	0.02	0.19	-0.16
Urea fall band	0.14	0.24	0.21	-0.20
Urea mid-row band	0.29	0.05	0.13	-0.27
Urea side-row band	0.14	0.07	0.08	-0.49
Urea broadcast	0.36	-0.05	0.10	-0.59
Mean	0.20	0.10	0.14	-0.21

Nitrous oxide emissions measured during the 2001 growing season were slightly lower than in the previous year. This is no surprise considering the drought conditions encountered at all four sites. Despite the drought conditions, N application did significantly increase N_2O emissions at Swift Current and Star City (Table 6), and emissions were consistently and significantly higher from the mid-row banded compared to side-banded N. The reader is reminded that emissions during the spring thaw period can make up more than 50% of annual N_2O budgets, therefore without the spring 2002 values valid conclusions regarding treatment differences cannot be made.

Table 6. Significance of Selected Treatment Contrasts Comparing the Influence of Placement, Timing and Formulation on N_2O Loss at Four Sites in Saskatchewan (May - October 2001).

Treatments Contrasted	Swift Current	Scott	Indian Head	Star City
N applied vs. no N applied	0.04	ns [z]	ns	0.08
Fall vs. Spring applications	0.005	ns	ns	ns
Mid-row vs. Side-band	0.10	0.08	0.02	0.005
AA vs. Urea	ns	ns	ns	ns
Broadcast vs. Banded	ns	ns	0.06	ns

[z] ns = not significant at the $p < 0.10$ level

Summary

On average, 0.2% or less of fertilizer-N was lost as N_2O during the first year of this study. This value is many times lower than the current factor utilized to estimate N_2O loss from fertilizer N in western Canada. Losses from the fall banded treatments tended to be higher during the spring

thaw, but sometimes lower during the growing season. These treatments tended to have some of the highest losses on an annual basis, but the differences were not statistically significant. Similarly, losses from mid-row placed N tended to be higher than side-row placed N during the growing season, but on an annual basis these differences generally disappeared. There was no indication that anhydrous ammonia increases N_2O emissions relative to urea.

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