

Climate Change and Nitrous Oxide

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Background

The atmospheric concentrations of nitrous oxide (N₂O), carbon dioxide (CO₂) and methane (CH₄) have been increasing rapidly. We are concerned about this because all three gases absorb long-wave radiation thereby increasing the amount of heat trapped in the earth's atmosphere. In addition, N₂O is involved in the destruction of stratospheric ozone, which shields the earth from biologically harmful ultra-violet radiation. Chlorofluorocarbons (CFCs), used in refrigeration systems, were the major contributors to ozone destruction. Their recent phase out has not resulted in as rapid a recovery of the ozone layer as had been anticipated. Simulation studies now suggest that the rapid increase in stratospheric N₂O is slowing the recovery, and will eventually begin to reverse some of the gains already made.

Canada, as a signatory of the Kyoto Protocol, has committed itself to significantly reducing greenhouse gas emissions within the next decade. There is still considerable political debate surrounding the Protocol, and about what plan Canada should adopt to reduce greenhouse gas emissions, however this issue will likely remain a concern for the foreseeable future. Current estimates suggest that agricultural activities are responsible for 10 to 15 % of Canada's human-induced greenhouse gas emissions. While CO₂ is the major concern for most industries, the main greenhouse gas emitted by the agricultural sector is N₂O.

Some N₂O is emitted from agricultural soils as a consequence of naturally occurring processes; however farming practices can strongly increase the amount of N₂O produced. This is of some practical concern since the "N" (nitrogen) in N₂O is an important crop nutrient. While the amount of N lost as N₂O is generally small (a few pounds per acre), most often N₂O is accompanied by much a larger (as much as 10 times more) loss in other gaseous N forms. Thus, limiting N₂O emissions from our farming operations can be beneficial from both an environmental as well as a practical standpoint.

The world's expanding human population continues to require food. If eating isn't optional, then clearly agricultural production isn't optional either. The pertinent question to ask then becomes "What farming practices realize the maximum units of crop production per unit of greenhouse gas produced?" In the balance of this paper, we will use some examples from an ongoing research project to explore this question in the context of crop production in Saskatchewan.

Study Description

The examples used in this paper are taken from an ongoing study investigating the influence of timing, placement and form of N fertilizer on N₂O emissions. Briefly, this study includes field experiments at four locations, Swift Current, Scott, Indian Head and Star City. There are three test crops, canola, flax and wheat, at each site although only measurements made on the wheat crops are presented in the examples used in this paper. Treatments that will be referred to here consist of urea and anhydrous ammonia (AA) banded in the fall or spring. Spring banded N was placed either to the side of the seed row (side-row band) or midway between alternate crop rows (mid-row band).

Nitrogen fertilizer was applied at 80 kg N ha⁻¹ at Star City 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 P₂O₅ ha⁻¹ at Scott and Swift Current and 23 kg P₂O₅ ha⁻¹ at Star City and Indian Head. Phosphorus was placed with the seed except for the side-banded urea treatments where both N and P were placed in the side-row band. A blanket treatment of K₂SO₄ was broadcast prior to seeding at all sites to ensure sufficiency of these nutrients.

Trace gas samples were collected using vented soil chambers as described by Lessard et al. (1994). Sample collection and analysis followed accepted protocols similar to those described by Lemke et al. (1998). Annual estimates of N₂O loss are the sum of N₂O lost during the growing season plus the following spring thaw period.

Discussion

Previous studies in western Canada have shown that N fertilizer application generally increases N₂O emissions when emissions are considered on a “per acre” basis (e.g. Corre et al. 1999, Lemke et al. 1999). Preliminary results from our study confirm these findings, but in our study the differences were frequently not statistically significant. For example, in the 2000/2001 season (estimates presented in Table 1) N fertilizer increased N₂O emissions significantly only at Indian Head. Our results also indicate very little difference in total N₂O emissions from the N application systems we compared. Emissions from plots receiving N as AA tended to be slightly higher than those receiving N as urea, however the differences were not statistically significant. Similarly, emissions tended to be higher from mid-row compared to side-row banded N, but statistically significant differences were infrequent (less than 50% of the time). Applying N in the fall seems to increase the risk of N₂O emissions during the following spring thaw, but annual N₂O emissions were generally not significantly affected. It should be noted that snow cover during the winter of 2001 was limited, which in turn reduced the risk of N₂O production during spring thaw. As a consequence, we have limited confidence in the results of the spring vs. fall applied N comparison.

Table 1. Estimated annual N₂O loss (g N) for selected treatments at four sites in Saskatchewan (May 2000 – April 2001).

N-form / Band Placement	Swift Current	Indian Head	Scott	Star City
	————— g N ha ⁻¹ —————			
Urea side-row ¹	301	114	121	162
Urea mid-row ²	393	186	115	501
Urea fall banded	340	218	236	672
AA ³ side-row	246	200	110	472
AA mid-row	411	140	166	758
AA fall banded	301	187	194	414
Check (no N)	231	52	85	631
Contrasts		Significance		
no N vs. N applied	ns ⁴	0.02	ns	ns
Fall vs. Spring banded N	ns	ns	ns	ns
Mid-row vs. Side-row	0.06	ns	ns	0.01
AA vs. Urea	ns	ns	ns	ns

¹ side-row = fertilizer placed to one side of the crop row

² mid-row = fertilizer band placed midway between alternating crop rows

³ AA = anhydrous ammonia

⁴ ns = not significant (p>0.1)

Comparing emissions on a “per acre” basis is certainly informative, but as we have already pointed out, factoring in production levels places that comparison into a more useful context. We took the grain yield for each treatment and divided by the estimated N₂O loss. The resulting ratios (grain yield per unit N₂O) are presented in Table 2. These ratios provide an indicator of the “N₂O efficiency” (the higher the value the more efficient the system) of a particular system. When the comparisons are made in this way, the unfertilized systems actually had lower ratios compared to the fertilized systems at Star City and Scott. At these two sites, crop yield but not N₂O emissions increased significantly when N fertilizer was applied, thus yield per unit N₂O was optimized. At Indian Head both crop yield and N₂O emissions increased significantly, whereas at Swift Current N₂O emissions increased moderately but crop yield did not. Using the results from the Scott site as an example, producing 36 units of grain on the unfertilized system would have produced 4 units of N₂O. However, producing those same 36 units of grain on the urea side-band system would have produced only 2 units of N₂O. In this case, reducing N fertilization would not have been the correct response to the issue of N₂O emission. In fact, we would argue that N fertilizer is essential and that the issue is really one of determining its optimal use relative to N₂O emissions.

Table 2. Ratio of grain yield (kg ha^{-1}) divided by estimated annual N_2O loss (g N) for selected treatments at four sites in Saskatchewan during 2000.

N-form / Band Placement	Swift Current	Indian Head	Scott	Star City
Urea side-row ¹	14	20	18	13
Urea mid-row ²	10	12	20	5
Urea fall banded	11	10	10	3
AA ³ side-row	14	10	16	5
AA mid-row	8	16	10	3
AA fall banded	14	11	9	5
Check (no N)	17	25	9	2

¹ side-row = fertilizer placed to one side of the crop row

² mid-row = fertilizer band placed midway between alternating crop rows

³ AA = anhydrous ammonia

Summary

Our preliminary results confirm that N_2O emissions are generally increased by fertilizer N use, but also indicate that emissions are comparatively low from well-managed cropping systems in western Canada. We have shown that care must be taken in how these comparisons are made. Trends observed depended upon whether the comparison was made on a “ N_2O per acre” or a “yield per unit N_2O ” basis. The latter comparison is, in our opinion, of greater importance. In any case, our results suggest that the specific N fertilizer system selected (side-row vs. mid-row, anhydrous vs. urea) is of less consequence than ensuring the optimal use of N fertilizer.

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