Nitrous Oxide Emissions from Fertilizer Nitrogen

THE ATMOSPHERIC CONCENTRATIONS of nitrous oxide (N₂O), carbon dioxide (CO₂), and methane (CH₄) have been found to be increasing. There is concern 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.

The Kyoto Protocol, with Canada as one of the signatory countries, is committed 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. While CO₂ is the major concern for most industries, the main greenhouse gases emitted by the agricultural sector are N₂O and CH₄.

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) in the northern Great Plains, most often N₂O is accompanied by a much larger (as much as 10 times more) loss in other gaseous N forms. Thus, limiting N₂O emissions from farming operations can be beneficial from both an environmental as well as an agronomic standpoint.

Relative to CO₂, N₂O is considered to have 310 times the net atmospheric warming potential per molecule. Some estimates indicate that agriculture contributes 60% of all Canadian anthropogenic N₂O emissions, with more than 50% of the agricultural total being associated with N fertilizer use. This is particularly important for western Canada, as 82% of all fertilizer N used in Canada occurs in the three prairie provinces of Manitoba, Saskatchewan, and Alberta. None of the Intergovernmental Panel on Climate Change (IPCC) estimates of N₂O emissions considered the environment in this region.

Have you ever wondered about the N₂O emission estimates being used by the IPCC? Well, we did and wanted to evaluate how fertilizer use in western Canada influenced the loss of N₂O. Working with groups from various parts of Europe and North America, the IPCC established values that could be used to calculate direct N₂O emissions from fertilizer N use in various parts of the world. This value was set at 1.25% of the N fertilizer applied being lost as N₂O.

The relationship between the amount of N applied and the N₂O emitted is not considered to be linear. Rather, it is governed by a complex interaction between environmental conditions, soil properties, and the form, placement, and timing of the fertilizer N. When N is applied close to the time of crop requirement, N-use efficiency should be increased and N₂O emissions reduced. While band application of fertilizer N has been shown to increase
crop uptake, concentration of N in bands can also cause alterations in soil pH, osmotic potential, and free ammonia concentrations, all of which may impact N₂O losses. Nitrogen fertilizer form has been suggested as a major factor influencing the loss of N₂O from fertilizer bands. In fact, anhydrous ammonia (NH₃) has been reported to have losses five times those found with other N sources. We decided it was time to clarify these reported differences.

This 3-year study includes field experiments at six locations: Swift Current, Scott, Indian Head, and Star City in Saskatchewan, and Brandon and Winnipeg in Manitoba. Measurements presented were made on spring wheat. Treatments that will be referred to here consist of urea and NH₃ banded in the fall or spring, and urea broadcast in the 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 71 lb N/A at Star City, Indian Head, Brandon, and Winnipeg, and 53 lb N/A at Swift Current and Scott.

All sites received applications of phosphorus (P) fertilizer (11-51-0), at rates of 15 lb P₂O₅/A at Scott and Swift Current, 20 lb P₂O₅/A at Star City and Indian Head, and 35 lb P₂O₅/A at Brandon and Winnipeg. 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 potassium sulfate (K₂SO₄) was broadcast prior to seeding at all sites to ensure sufficiency of these nutrients. Trace gas samples were collected using vented soil chambers and sample collection and analysis followed accepted protocols. Annual estimates of N₂O loss are the sum of N₂O lost during the growing season plus the following spring thaw period.

This collaborative project was established between the Canadian Fertilizer Institute and researchers at Agriculture and Agri-Food Canada and the University of Manitoba to measure the loss of N₂O from fertilizer N additions using common practices characteristic of western Canada. To address these issues the project established a series of questions for which answers were pursued.

**How much N from fertilizer is lost directly as N₂O under western Canadian conditions?**

The study results found that N₂O emissions increased with fertilizer N application, and that within the range of fertilizer N rates considered (53 to 71 lb N/A), emissions were found to increase in a linear fashion. For five of the six trial locations, the great majority of measured losses were at or below 0.4%. At the sixth site, Winnipeg, the values were higher at 0.82%. The results of this study clearly indicate that the IPCC N₂O loss coefficient of 1.25% applied to western Canada is grossly in excess of measured results.

**Does fertilizer N source influence direct losses of N₂O?**

The study found that N₂O emissions were similar from NH₃ and urea. There were weak trends for emissions to be higher when urea was broadcast rather than banded, and when the fertilizer N was mid-row (double the localized concentration) rather than side-row banded. Interestingly, urea appeared to provide slightly better yields at one location, but NH₃ and urea appeared to perform equally at the other five locations.

**Does application time (spring vs fall) influence direct losses of N₂O?**

Results from this study found that fall banded N and broadcast urea are less efficient than their spring banded at seeding counterparts. In both instances, these fall application methods place fertilizer at random into the soil system, avoiding the linkage with the seed rows in spring banding. In addition, over-winter losses of N by leaching or denitrification could account for some of the differences observed.

**Does fertilizer placement influence agronomic performance and/or direct losses of N₂O?**

Yes. In 16% of the cases considered in the project, there was a difference in the agronomic performance of the fertilizers evaluated. When these differences occurred, the advantage in agronomic performance was divided equally between the side banded and the mid-row banded treatments. However, in none of these measured cases was the difference in agronomic performance reflected in any direct loss of N₂O.

**Summary**

The results of this study indicate that N₂O emissions are comparatively low from well-managed cropping systems in the northern Great Plains, and suggest that the specific N fertilizer system selected (side-row vs. mid-row, NH₃ vs. urea) is of less consequence than ensuring the optimal use of N fertilizer additions. There is little argument that the N₂O emissions, and amount of fertilizer-induced N₂O emitted, was significantly different among the sites with much lower emissions from the more arid locations. The great majority of the measured losses were at or below 0.4%. It is important to point out again that a total of 82% of all fertilizer N used in Canada is applied in the prairie region of Manitoba, Saskatchewan, and Alberta.

Despite the high degree of uncertainty surrounding the estimates in this study, the results clearly indicate a need to modify downward the N₂O loss coefficient. The study clearly indicates that the IPCC N₂O loss coefficient of 1.25% that is currently applied to fertilizer N use in western Canada.