Ammonia volatilization: On-farm assessment of the amount and timing of nitrogen fertilizer application in corn production

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Abstract
An on-farm field experiment was carried out for three years at Ottawa, ON and two years at Guelph, ON and Saint-Valentin, QC, Canada. Our objectives were to (1) quantify the flux and the amount of NH_3 volatilization as affected by the rate and time of N fertilizer; (2) assess the impact of rainfall and soil temperatures on NH_3 volatilization; and (3) determine the threshold level of N fertilizer at which large NH_3 volatilization losses occur. Using the static chamber method, NH_3 volatilization was monitored after preplant or sidedress N application. Rate of NH_3 volatilization peaked at 3 to 7 d and then dropped sharply within the next 7 d before levelling off in the following weeks. The amount of NH_3 volatilization increased with increasing N levels applied preplant or sidedress at all site-yrs. Peak NH_3 volatilization ranged from 40 to 8000 g N/ha/d after preplant fertilization and from about 100 to 2100 g N/ha/d after sidedress, resulting in NH_3 losses of 0.1 to 47 kg N/ha and 0.6 to 20 kg N/ha, respectively. Our data clearly indicate that sidedress applications may reduce NH_3 volatilization losses simply due to lower total N rates.

Key Words
Corn or maize, peak emissions, environmental factors, N fertilization, minimizing NH_3 volatilization

Introduction
The global synthetic N input increased sharply in the past 50 yr and NH_3 volatilization still is one of the main loss pathways for the applied N. In Canada, an estimated 584×10^3 Mg N was released into the atmosphere as NH_3 in 2002 (Environment Canada 2004), and agriculture activities accounted for 91% of the total NH_3 emission (Chambers *et al*. 2001). Grain corn (*Zea mays* L.) is the main field crop covering a large portion of cropland in eastern Canada. Corn requires larger quantities of N nutrition during the growing season than other small grain cereal crops (Ma and Dwyer 1998). Ammonia volatilization from corn fields depends on fertilizer type, rate, and timing of application (Keller and Mengel 1986; Rozas *et al*. 1999), soil characteristics (Oberle and Bundy 1987), soil temperatures (Rozas *et al*. 1999), rainfall events (Zhu *et al*. 2000), and agronomic measures such as use of urease inhibitors (Rozas *et al*. 1999).
The objectives of this on-farm research were to (1) qualify the magnitude of NH_3 volatilization from the corn agroecosystem after chemical fertilizer N input at several sites from central and eastern Ontario to southern Quebec; (2) identify environmental factors or on-farm practices that minimize NH_3 volatilization; and (3) determine the practical level of fertilizer N application that resulted in the minimum NH_3 volatilization loss.

Materials and Methods
An on-farm field experiment assessing the amount and timing of N fertilizer application to corn on NH_3 volatilization was carried out in Ottawa, ON (45° 18′ N, 75° 43′ W) from 2005 to 2007, and in Guelph, ON (43°34′ N, 80°25′ W) and Saint-Valentin, QC (45º05′ N, 73º21′ W) in 2006 and 2007.
The experiment, which consisted of 14 to 18 combinations of rate and timing of N fertilizer application, was arranged in a randomized complete block design with four replications in each site-yr (Ma *et al*. 2010a). A subset of the treatments with the same rate and application timing of N were chosen for monitoring NH_3 volatilization (Ma *et al*. 2010b). Preplant N fertilizer (urea) at the designated rates was broadcast and incorporated with a cultivator on the same day as planting. For sidedress application, urea ammonium nitrate (UAN; 275 g N/kg) was applied as a single band furrow (10 cm wide by 10 cm deep) between adjacent corn rows, at the V6 to V8 growth stage.
A semi-open static cylinder system (Oberle and Bundy 1987) was used to monitor NH_3 volatilization from the plots. The measuring discs were collected at 1, 3, 7, 14, 21 and 28 d after fertilizer application. Sidedress

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plots received 30 kg N/ha at preplant, and thus there were two periods of 28-d NH_3 monitoring in these plots. Precipitation, air and soil temperatures were recorded hourly at the experimental sites using automated weather stations. All the data were subjected to analysis of variances using the GLM procedure of SAS.

Results and Discussion

Ammonia volatilization induced by preplant nitrogen application

With zero N applications, NH_3 volatilization was on average 39 g N/ha/d, but ranged from 0 to 116 g N/ha/d, which was primarily affected by soil disturbance associated with field operations and complicated by rainfall events. Increasing N supply increased the rate of NH_3 volatilization sharply ($P<0.05$), with peak readings of 40 to 8000 g N/ha/d which occurred primarily within 3 to 7 d after fertilizer application (Figure 1).

Ammonia volatilization induced by nitrogen fertilizer applied at sidedress

The rate of NH_3 volatilization increased with sidedress N fertilizer applied as a single band at the V6 to V8 growth stage. In all cases, there was a negligible rate of NH_3 volatilization in the zero N plots; while NH_3 volatilization increased with increasing fertilizer N rates in five out of seven site-yr, except for Guelph in 2006 and 2007 (Figure 2).

Grain yields in this study ranged from 6.3 to 10.8 Mg/ha, and responded to the applied N fertilizer quadratically with a similar trend for preplant and sidedress application. In nearly all cases, except for the Ottawa site in 2005, the calculated maximum economic optimum rates of N were from 90 to 130 kg N/ha. In comparison, producers usually apply 150 kg N/ha for grain corn production in this region. Both total cumulative and specific NH_3 volatilizations increased exponentially with the applied N fertilizer rates (Figure 3). Specific NH_3 volatilization, i.e. total NH_3 emission (kg NH_3-N/ha) as a function of corn grain yield (Mg/ha) being produced, increased from about 0.10 to 0.94 kg NH_3-N Mg^{-1} grain for preplant, or to 0.77 kg NH_3-N Mg^{-1} for sidedress application (Figure 3), in this cool and humid region (Ma *et al*. 2010b).

Conclusions

In eastern Canada, NH_3 volatilization induced by N fertilizer in corn fields through soil-atmosphere interface ranged from 0.1 to 47 kg N/ha after preplant N application and from 0.6 to 20 kg N ha^{-1} after sidedress at the V6-V8 growth stage, respectively. This fertilizer-induced NH_3 emission accounted for 0.1 to 38% of preplant and 0.3 to 13% of sidedress N application in these two periods. In general, the peak emission occurred within the first and the second week after fertilizer N was incorporated before planting or sidedress in a single band at the V6 to V8 growth stage, respectively. Fertilizer induced NH_3 emission was sustained for 4 wk or shorter. Total cumulative NH_3 losses increased with increasing N fertilizer rates. The most important factor controlling NH_3 loss was rainfall, and its effect was complicated by other factors including soil texture, fertilizer timing and soil disturbance. No rainfall within one month after pre-planting fertilization resulted in low NH_3 volatilization, as observed at the Guelph site in 2006. Such conditions occurred infrequently in this region. A lack of rainfall within 10 to 14 d after fertilization usually induced negligible amount of total NH_3 volatilization, but soil moisture conditions before and after a rainfall event appeared to be a controlling factor. However, the impediment effect from the rain was ephemeral and other factors could take over the control shortly. Although it is difficult to make a general conclusion about the timing and levels of N fertilization to corn, it appeared that potential losses are equally variable from both timings and that loss at each timing is related to rainfall/soil moisture conditions at the time of application. Clear evidence indicates that sidedress applications enable reduction in total N fertilizer input for economic crop yields, and may reduce NH_3 losses simply due to lower fertilizer rates.

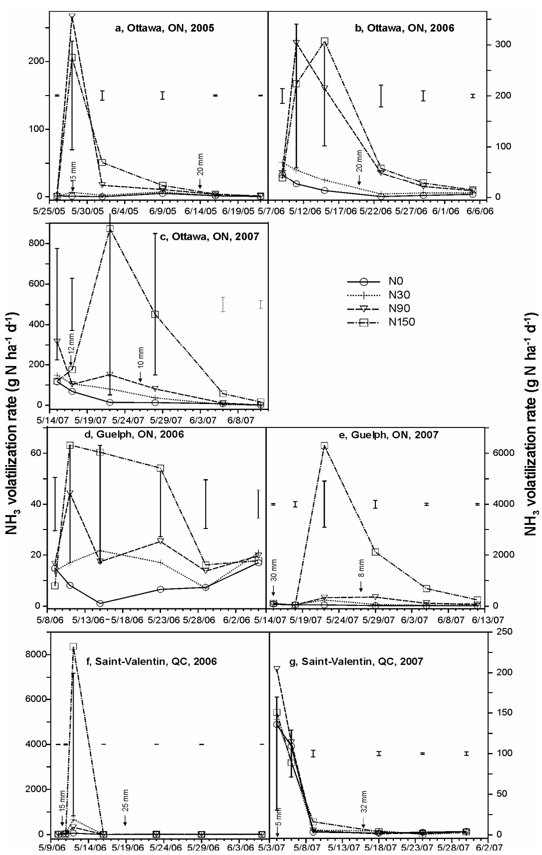

Figure 1. Rate of ammonia volatilization within 4 wk after N was incorporated right before planting at the sites. The vertical bars represent $LSD_{0.05}$ values.

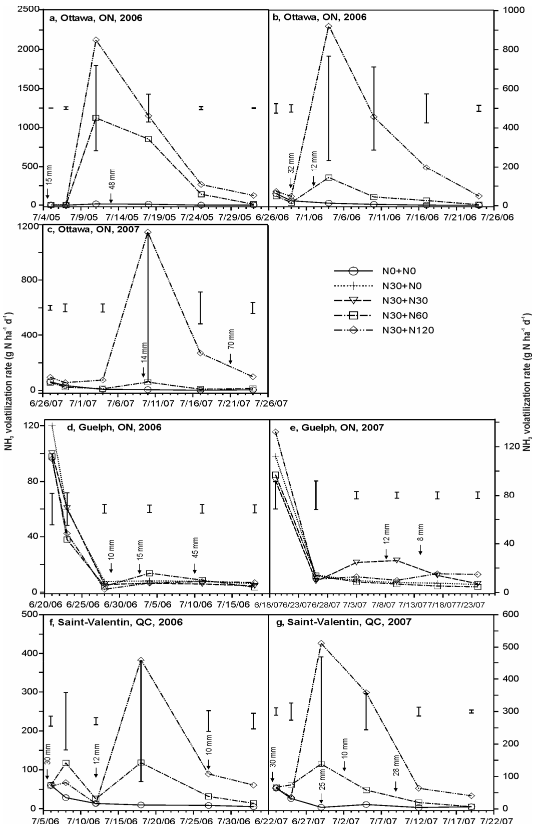

Figure 2. Rate of ammonia volatilization within 4 wk after N was banded at V6-V8 growth stages at all site-years. The vertical bars represent $LSD_{0.05}$ values.

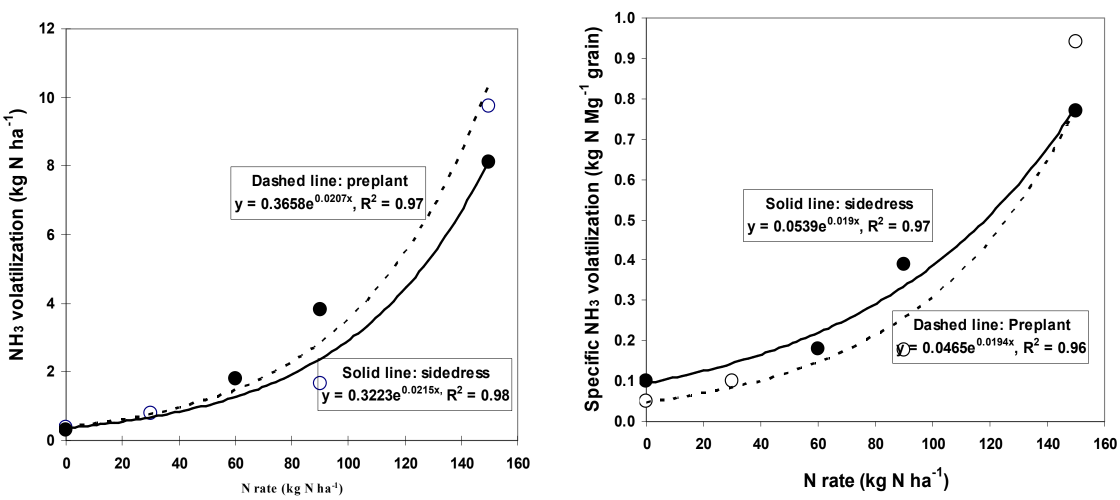

Figure 3. Total and specific NH_3 emissions (i.e. total NH_3 volatilization as a function of corn grain yield being produced) as affected by preplant and sidedress N application to corn, averaged across seven site-years in Ontario and Quebec.

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