Field emissions of NH₃ and NOₓ following urea application to wheat

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Abstract

Within the scope of international efforts for air pollution abatement, emissions of N-containing trace gases from sustainable and effective cultivation become of more importance. The objective of this investigation was to determine actual NH₃ and NOₓ emissions from surface applied urea fertiliser in field experiments with modified instrumentation based on the dynamic chamber technique. In 1999 and 2000 urea or CAN (calcium-ammonium-nitrate) were supplied to winter wheat in several applications (N application rate: 80 kg N ha⁻¹). Nitrogen emissions were measured continuously for 10 days after each fertilisation. Under weather conditions favouring losses (high temperature and lack of precipitation) urea application led to NH₃ emissions up to 4.4 kg NH₃-N ha⁻¹ or 5.5 % of the applied nitrogen. The NH₃-emissions of CAN reached a maximum of 1.2 kg NH₃-N ha⁻¹ or 1.5 % of the applied nitrogen. NOₓ emissions were low (up to 140 g NOₓ-N ha⁻¹ for both fertilisers). The results from this study suggest that the risk of NH₃ losses is significantly smaller under the semi-humid weather conditions of Southern Germany than has previously been assumed.

Introduction

The potential for gaseous N losses from urea fertiliser following surface application has been recognised for many years. With the increasing use of urea as a source of N, all over the world, it is gaining more attention. NH₃- and NOₓ-emissions from applied urea, and thus its fertiliser use efficiency, depend on soil characteristics and environmental factors (Rachhpal-Singh, 1987; Vermoesen et al., 1996). The release of NH₃ by hydrolysis of urea is affected by pH, NH₄⁺ concentration in the soil solution, soil moisture, soil temperature and soil texture (Fleisher et al., 1987). The most important process related to the production of NOₓ in soils can be nitrification as well as the result of denitrification and chemodenitrification (Williams et al., 1992). Although an increase in NOₓ emissions with addition of N has been recorded (Galbally, 1989), the effect of fertiliser type on NOₓ losses has not been thoroughly investigated (Maggiotto et al., 2000).

The objective of this study was to determine actual NH₃ and NOₓ emissions from surface-applied urea and CAN fertiliser in field experiments under the environmental conditions of Southern Germany.

NH₃ and NOₓ volatilisation measurements

NH₃ and NOₓ emissions were measured with a modified instrumentation based on the dynamic chamber technique. Ambient air was continuously drawn through chambers, (covering ¼ m² soil surface) with a constant flow rate. Sample air was collected and led to the NH₃/NOₓ-analyser (CLD700AL + NH₃-Converter, Fa. EcoPhysics, Günten, Switzerland) by magnetic valves. NH₃ and NOₓ fluxes were calculated from the difference of NH₃ and NOₓ concentration in ambient and sample air and from the airflow through the chamber.

To minimise the influence of the artificial climate inside the chambers (higher temperature, drying out the soil surface) on the volatilisation processes, the chambers were moved to an undisturbed part of the plot up to four times a day dependent on the weather conditions.

Six chambers were used simultaneously to get comparative measurements with different N fertilisers. For ten days after each fertilisation NH₃ and NOₓ fluxes were determined.

Additional data of temperature and precipitation were collected from a meteorological station close to the experimental area.

Results and discussion

In both years, significant differences were found between the NH₃ emissions in the single periods (Table 1). Urea led to higher NH₃ emissions (up to 4.4 kg NH₃-N ha⁻¹ or 5.5 % of the applied nitrogen) than CAN (up to 1.2 kg N ha⁻¹ or 1.2 %). Maximum losses for both fertiliser types were found, when they were applied on 26 April 2000. For the other application dates the losses were less or even NH₃ deposition was found. These results are in contrast to Schulz et al. (1999) establishing NH₃ emissions of 23 % (urea) or 11 % (CAN) of the applied N by a micrometeorological technique in fields of Eastern Germany.
Higher NH₃ losses (up to 50 %) than determined in this study were also found in laboratory experiments and under tropical climate in rice culture (Vermoesen et al., 1996; De Datta et al., 1989; Freney et al., 1993).

5 June 2000 and 10 May 1999, shows a distinct decrease when rain occurs immediately after the fertilisation (Figure IA). Late precipitation had no more influence on the total NH₃ losses of the period (Figure IB). The relation between soil moisture and NH₃ emissions was discussed by Vermoesen et al. (1996).

NOₓ volatilisation were low (up to 153 g NOₓ-N ha⁻¹) for both fertilisers compared to NH₃. A correlation between the environmental conditions and NOₓ losses was not found. Urea, as an ammonium-based fertiliser, tended to a smaller release of NOₓ than CAN (nitrate-based) in accordance with investigations of Beauchamp (1997) and Maggiotto et al. (2000).

The results from this study suggest that the risk of NH₃ and NOₓ losses is significantly smaller under the prevailing environmental conditions of Southern Germany than has previously been assumed.

References

Table 1. Cumulative NH₃ and NOₓ losses, precipitation and temperature within 10 days following surface application of urea and CAN to wheat at several dates.

<table>
<thead>
<tr>
<th>Date of Fertilisation</th>
<th>NH₃ Emissions Urea %</th>
<th>NH₃ Emissions CAN %</th>
<th>NOₓ Emissions Urea g N ha⁻¹</th>
<th>NOₓ Emissions CAN g N ha⁻¹</th>
<th>Temperature °C</th>
<th>Precipitation mm</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 March</td>
<td>0.6</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td>51</td>
<td>0.1</td>
</tr>
<tr>
<td>06 April</td>
<td>-0.1</td>
<td>&gt;0.1</td>
<td>&lt;0.1</td>
<td>&gt;0.1</td>
<td>153</td>
<td>0.2</td>
</tr>
<tr>
<td>26 April</td>
<td>0.5</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>36</td>
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</tr>
<tr>
<td>10 May</td>
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<td>2.0</td>
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<td>0.1</td>
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<tr>
<td>17 June</td>
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<td>0.1</td>
<td>&gt;0.1</td>
<td>46</td>
<td>0.2</td>
</tr>
<tr>
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<td></td>
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<tr>
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<td>&lt;0.1</td>
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<tr>
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<td>0.2</td>
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<td>&gt;0.1</td>
</tr>
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<td>0.7</td>
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<td>144</td>
<td>0.1</td>
</tr>
</tbody>
</table>

¹ percent of applied N (80 kg N ha⁻¹)