**Table 1: Names, target positions, sequences, and specificities of the probes used in this study.**

<table>
<thead>
<tr>
<th>Probe Name</th>
<th>Target Groups</th>
<th>Sequence (5’-3’)</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nso190</td>
<td>CAO</td>
<td>GACGTGTAATGTC</td>
<td>Species-specific for CAO (nitrite-oxidizers)</td>
</tr>
<tr>
<td>NIT3</td>
<td>CNO</td>
<td>CACCACGAGAGAT</td>
<td>Species-specific for CNO (nitrous acid-oxidizers)</td>
</tr>
</tbody>
</table>

**Table 2: Most Probable Numbers (MPN) of chemolithoautotrophic NH$_3$-oxidizers (CAO) and nitrite-oxidizers (CNO) detected in spruce needles.**

<table>
<thead>
<tr>
<th>Species</th>
<th>MPN (cell numbers g$^{-1}$ needle dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAO</td>
<td>1.0 $	imes$ 10$^5$</td>
</tr>
<tr>
<td>CNO</td>
<td>5.0 $	imes$ 10$^5$</td>
</tr>
</tbody>
</table>

**Fig. 1:** Representative example for a series of analyses of in situ identification of bacteria called "autotrophic NH$_3$-oxidizers" and "nitrous acid-oxidizers" recorded with a 543 nm HeNe-Laser and colored red by image analysis. The experiments revealed that autotrophic NH$_3$-oxidizers and nitrous acid-oxidizers were located inside rather than outside the needles (within the stomatal cavity), the flux of gases like NH$_3$ and NO are being reduced of NH$_3$-deposition is due to inhibition of the activity of autotrophic ammonia-oxidizers and these microorganisms are located predominantly in the needle apoplast and not on the needle-surface. This conclusion is in agreement with the results obtained from the microbiological study.

**5. References:**


**Fig. 2:** Representative example for the correlation between NH$_3$ flux (J NH$_3$) and stomatal conductance for water vapour (g H$_2$O), a measure for stomatal aperture, and the fraction of NH$_3$ deposition caused by autotrophic NH$_3$-oxidizers (Figure 2). These data strongly suggest that (a) the observed reduction of NH$_3$-deposition is due to inhibition of the activity of autotrophic ammonia-oxidizers and (b) these microorganisms are located predominantly in the needle apoplast and not on the needle-surface. This conclusion is in agreement with the results obtained from the microbiological study.

**Economic significance and potential consequences:**

Since nitrification is an acid producing process (nitrous acid and nitric acid), the question arises whether acid induced needle-injuries are not only due to rain as described by Rennenberg et al. (1990) but might also be due to colonisation of the needles with nitrifiers.

Since the autotrophic nitrifiers are located inside the needles (within the stomatal cavity), the flux of gases like NH$_3$ from the atmosphere into the needles is not exclusively - as has been assumed in the past - a plant physiological process but is the net result of stomatal and the atmosphere plus microbiological processes. Experiments are in progress to prove our hypotheses that this also applies for the observed NO$_2$ fluxes to the plant.

Since nitrifiers produce and consume NO and NO$_2$ and were demonstrated to live inside the needles, it is most likely that these microorganisms not only significantly contribute to the exchange of these N-trace gases between soils and the atmosphere, but also to the exchange of these gases between the needles and the atmosphere. This would imply consequences for our present understanding of the complex air-chemical processes and reallocation of N-trace gases which urgently need to reduce our deficits in knowledge in this field.

5. References:


