BELOW GROUND EFFECTS OF O$_3$ IN MEADOWS

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WHY TO STUDY?

✓ Studies on semi-natural vegetation at community level scarce
  • pot-grown monocultures: legumes most sensitive
✓ Impact on below-ground processes unstudied
✓ Protected biotopes
✓ Interaction with CO$_2$
HYPOTHESES

O$_3$

Plant productivity

Soil NH$_4^+$ availability

Microbial community

Growth, maintenance and mortality

Microbial N immobilisation

Leaf and root litter
Production, mortality and chemistry

Substrate availability

Ecosystem N$_2$O, CO$_2$ and CH$_4$ fluxes

Gross N mineralisation
Jokioinen (60°49’ N, 23°28’ E)

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (mm)</td>
<td>207</td>
<td>302</td>
<td>397</td>
</tr>
<tr>
<td>Mean temperature (°C)</td>
<td>15,8</td>
<td>14,3</td>
<td>13,3</td>
</tr>
<tr>
<td>Temp. OTC - open field (°C)*</td>
<td>0,7</td>
<td>0,8</td>
<td>0,6</td>
</tr>
</tbody>
</table>

* during the fumigations
GROUND-PLANTED MESOCOSMS

MONOCULTURED PLANTS IN POTS

SOIL
✓ peat:sand (1:1, v:v)
✓ $pH_{H_2O}$ 6.8, C 3.3%, N 0.07%, P 8.3 mg/l
✓ NPK fertilizer (twice in 2002)
✓ *Rhizobium* inoculation (2002)
GROUND-PLANTED MESOCOMS

✓ 2.25 m², rooting depth 25 cm
✓ 2 grasses: *Agrostis capillaris*, *Anthoxanthum odoratum* (25 seedlings/species)
✓ 3 forbs: *Campanula rotundifolia*, *Fragaria vesca*, *Ranunculus acris* (25 seedlings/species)
✓ 2 legumes: *Trifolium medium* (5), *Vicia cracca* (8)
Agrostis capillaris AND Lathyrus pratensis MONOCULTURES

✓ 15 l pots, 33 cm in diameter
✓ 113 plants / m²
O₃ decreased bulk soil NH₄⁺ concentration

**Fig. 1** (a) Concentrations of NH₄⁺-N, (b) and NO₃⁻-N, (c) NH₄⁺-N/NO₃⁻-N ratio and (d) mineral N concentration. Means marked with different letters within each sampling differ at P < 0.05 (measured with one-way ANOVA). A tendency (P < 0.10) between the NF control treatment and the other treatments are marked with a P value. Error bars represent positive standard deviation of the means (n = 3)
# O₃ reduced N₂O, CH₄ and CO₂ fluxes

Table 3
Main effects (p-values) of elevated O₃ and/or CO₂ and time and treatment (O₃ and CO₂) interactions on the daily fluxes of N₂O, CH₄ and CO₂ in the growing seasons 2002–2004

<table>
<thead>
<tr>
<th>Source</th>
<th>N₂O</th>
<th>CH₄</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002</td>
<td>2003</td>
<td>2004</td>
</tr>
<tr>
<td>O₃</td>
<td>n.s.</td>
<td>n.s.</td>
<td>0.076</td>
</tr>
<tr>
<td>CO₂</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>O₃ + CO₂</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time</td>
<td>&lt;0.001</td>
<td>0.093</td>
<td>0.034</td>
</tr>
<tr>
<td>Time*O₃</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time*CO₂</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time*O₃ + CO₂</td>
<td>0.070</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

n.s. not significant (p > 0.10).
Impact of other abiotic factors on GHG fluxes

Table 5
Spearman’s correlation coefficients of the fluxes of N₂O, CH₄ and CO₂ with soil and environmental variables

<table>
<thead>
<tr>
<th></th>
<th>N₂O</th>
<th>CH₄</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>N</td>
<td>r</td>
</tr>
<tr>
<td>Mineral N spring&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.12</td>
<td>45</td>
<td>0.15</td>
</tr>
<tr>
<td>Mineral N fall&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.29</td>
<td>45</td>
<td>-0.72</td>
</tr>
<tr>
<td>Total N&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.35</td>
<td>30</td>
<td>-0.70</td>
</tr>
<tr>
<td>Organic C</td>
<td>0.16</td>
<td>30</td>
<td>-0.13</td>
</tr>
<tr>
<td>pH&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.41*</td>
<td>30</td>
<td>-0.16</td>
</tr>
<tr>
<td>Denitrification potential&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.11</td>
<td>30</td>
<td>-0.20</td>
</tr>
<tr>
<td>Nitrification potential&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.16</td>
<td>30</td>
<td>-0.15</td>
</tr>
<tr>
<td>Total plant biomass&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-0.28</td>
<td>30</td>
<td>-0.59</td>
</tr>
<tr>
<td>Plant biomass inside the collar&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-0.71</td>
<td>15</td>
<td>-0.26</td>
</tr>
<tr>
<td>Air temperature</td>
<td>0.27**</td>
<td>237</td>
<td>0.06</td>
</tr>
<tr>
<td>Soil temperature</td>
<td>0.34**</td>
<td>210</td>
<td>0.02</td>
</tr>
<tr>
<td>Soil water content</td>
<td>0.53**</td>
<td>120</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Asterisks denote two-tailed significances (*p < 0.05; **p < 0.01; ***p < 0.001).
O₃ decreased microbial (PLFA) biomass in bulk soil

### Table 2
O₃ and CO₂ main and interaction effects (as P-values) on the total, bacterial, actinobacterial, fungal, and mycorrhizal PLFAs as well as the fungal:bacterial PLFA ratio in 2002 and 2004 (two-way ANOVA), when the open-field plots (AA) were excluded from the analyses.

<table>
<thead>
<tr>
<th></th>
<th>Total PLFA</th>
<th>Bacterial PLFA</th>
<th>Actinobacterial PLFA</th>
<th>Fungal PLFA</th>
<th>Mycorrhizal PLFA</th>
<th>Fungal: bacterial PLFA ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₃</td>
<td>n.s</td>
<td>0.007</td>
<td>n.s</td>
<td>0.034</td>
<td>n.s</td>
<td>0.029</td>
</tr>
<tr>
<td>CO₂</td>
<td>n.s</td>
<td>n.s</td>
<td>n.s</td>
<td>0.034</td>
<td>n.s</td>
<td>n.s</td>
</tr>
<tr>
<td>O₃ x CO₂</td>
<td>n.s</td>
<td>n.s</td>
<td>n.s</td>
<td>n.s</td>
<td>n.s</td>
<td>n.s</td>
</tr>
</tbody>
</table>

n.s., Not significant.
✓ O₃ decreased bulk soil microbial (PLFA) biomass
✓ O₃ x rust interaction?
✓ O₃ decreased P availability?
✓ O$_3$ positively correlated with bulk soil C and negatively with P and C:N ratio
✓ O$_3$ decreased *Agrostis* (shoot and total) biomass
Mesocosms mimic natural meadows as regards greenhouse gas fluxes and potential activities of nitrifying and denitrifying bacteria

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![Graph showing daily N₂O fluxes from natural meadows and mesocosms](image)

Figure 3. Daily N₂O fluxes from the natural meadows 1, 2 and 3 (Nm 1, 2 and 3) and from the mesocosms of the chambered and unchambered plots in June—September 2003. Error bars represent standard deviation of the means (n = 3).
The soil was low in N. However,

 ✓ Shoot biomass:  
   mesocosms (NF 528 g/m²) ≈ natural meadows;  
   3-7 x biomass in monocultures

 ✓ Root-to-shoot ratio:  
   mesocosms 1.03; *Agrostis* 0.25 and *Lathyrus* 0.16

 ✓ Bulk soil total microbial biomass, C and N:  
   mesocosms ≈ monocultures
DECREASED N₂O, CO₂ AND CH₂ EMISSIONS / FLUXES

PLANT PRODUCTIVITY
Shoot biomass
- mesocosms -40%*
- *Agrostis* -46%
- *Lathyrus* +18%

Root biomass
- mesocosm -35%*
- *Agrostis* -49%
- *Lathyrus* +48%

LITTER QUALITY
Visible injury / Rust

MICROBIAL COMMUNITY SIZE AND STRUCTURE

NH₄⁺ AVAILABILITY -35%

PO₄³⁻, SO₄²⁻
THANK YOU!

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