Effects of ammonium sulfate and/or ozone on the growth and photosynthesis of Japanese larch and hybrid larch F₁

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Introduction

Asia: Changes in atmospheric environment
- N deposition, (NH₄)₂SO₄ has been increasing
  → Changing soil condition, causing forest decline finally
- Ground-level ozone (O₃, 0~11 km), made by NOx, VOC
  → Absorbed via stomata, affects trees negatively

Japanese larch (JL), Hybrid larch F₁ (HL)
- Larch (Larix spp.): high growth, survival rate → Afforestation
- NH₄NO₃ decreased O₃ sensitivity of JL
- The mechanism of this responses are unknown

[Research subject]
The mechanism of the responses to (NH₄)₂SO₄ and O₃ in both larch species

Results & Discussion ~ Leaf scale~

<table>
<thead>
<tr>
<th>Nₐrea (mgN m⁻²)</th>
<th>JL</th>
<th>HL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>6</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>7</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>8</td>
<td>d</td>
<td>c</td>
</tr>
</tbody>
</table>

(N) (NH₄)₂SO₄ increased Aₙarea in both species
- Under (NH₄)₂SO₄, O₃ decreased PNUE of HL (p < 0.05)
- (NH₄)₂SO₄ increased Gₙ: HL < JL
- Under (NH₄)₂SO₄, O₃ decreased Gₙ of only JL
  → More O₃ may be absorbed by HL
  
(NH₄)₂SO₄ and O₃ did not significantly effect LMA in both species

Results & Discussion ~ Individual scale~

Dry mass (g) & LWR (g g⁻¹)

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Control</th>
<th>O₃</th>
<th>O₃+N</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>c</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>17</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>23</td>
<td>c</td>
<td>a</td>
<td>b</td>
</tr>
</tbody>
</table>

(N) (NH₄)₂SO₄ increased height of both species
- (NH₄)₂SO₄ and O₃ increased LWR of JL, respectively (p < 0.05)
- (NH₄)₂SO₄ increased dry mass of HL however not LWR
- Under (NH₄)₂SO₄, O₃ decreased dry mass of HL
  → Species difference in the dry mass response to (NH₄)₂SO₄ and O₃ may depend on difference in the biomass allocation to needle

Conclusions

The responses to (NH₄)₂SO₄ and O₃ depend on larch species

- The growth response
  - Under (NH₄)₂SO₄, O₃ decreased dry mass of hybrid larch F₁
  - Species difference may be caused by difference in biomass allocation to needle
- The photosynthesis response
  - (NH₄)₂SO₄ + O₃ decreased PNUE of hybrid larch F₁
  - More O₃ may be absorbed by hybrid larch F₁

Materials & methods

Location
Sapporo, Exp. For. Hokkaido Univ. (N43.07, E141.38, 15 m a.s.l.)

Plants and Design
2-year-old seedlings planted in 7L pots with Immature volcanic ash soil

Japanese larch (Larix kaempferi, JL)

Hybrid larch F₁ (Larix gmelini var. japonica × L. kaempferi, HL)

O₃: 60 ppb, June ~ Oct., 2015, OTC (→)
May ~ Sept., 2016, 4 OTC per treatments
N: Total of 50kg ha⁻¹ yr⁻¹, 5 times each year → 6/11, 6/27, 7/7, 7/22, 8/11 (2016)

Measurements
- Aₐₙ: Assimilation rate, G: Stomatal conductance (light saturation & 380 CO₂)
  - LI-6400 (Li-)
  - Soils sampling (0~5 cm): soil pH(F), 7/29
  - Inorganic nitrogen contents- Flow injection analyzer (Aqua lab), 7/29
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  - Height (May, 2015 ~ Aug., 2016), Final Harvest (Sept. 2016) ~ Separator shoots

Acknowledgement
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Results & Discussion ~ Soil condition~

<table>
<thead>
<tr>
<th>pH</th>
<th>Control</th>
<th>O₃</th>
<th>O₃+N</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>a</td>
<td>b</td>
<td>c</td>
</tr>
<tr>
<td>5.6</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>5.7</td>
<td>c</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>5.8</td>
<td>d</td>
<td>a</td>
<td>b</td>
</tr>
</tbody>
</table>

(N) NO₃⁻ increases significantly however acidification was not significant

4 treatments × 4 seedlings × 2 species × 4 replications

[Note]
Different letters: significant differences of Aₐₙ or LMA, Tukey HSD, p < 0.05

[Research subject]
The mechanism of the responses to (NH₄)₂SO₄ and O₃ in both larch species

(Family: Gaussian, O₃: Control/O₃, N: Control/Spp.: Control/Hybrid, OTC: 16)

Estimation of coefficients by GLM

Height: 12.3 -0.61 6.48 8.96 -0.20 -3.05 2.06 -2.92
Dry mass: 15.3 -5.35 1.51 0.75 6.58 2.22 7.60 -10.50
LWR: 0.253 0.064 0.069 -0.001 -0.113 -0.051 -0.060 0.077

(Bold letters: significant effect in GLM, p < 0.05)