Nutrient uptake in soil niches affected by plant species and drought stress

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Background

- Many parts of Europe: production grasslands mainly sown as monocultures
- Renewed interest in grassland mixtures:
  - Potentially higher yields in mixtures
  - Higher resistance and resilience
- More diverse swards better utilise available resources
  - Facilitation / positive interactions between species
  - Niche differentiation
Soil niche complementarity between deep and shallow rooting species

**Background**

- Important under drought stress
  - Deep rooting species advantage: access to relatively wet deeper layers
  - Changing niche in response to drought?

**Better resource utilisation**

**Niche complementarity in mixtures**

**Niche differentiation in mixtures**
Objective

Assess belowground niche differentiation in grassland mixtures and monocultures of shallow-rooting and deep-rooting species under benign and drought conditions.
Materials and methods: Tracer method

- Measure niche differentiation $\rightarrow$ nutrient uptake at different depths
  - Root mass or root length:
    - Hard to distinguish between different species
    - Root mass $\neq$ root activity
  - Tracer method:
Materials and methods: Tracer method

- Tracer: Rubidium (Rb), rare element --> K+ analogue
- Injection depth: 5 & 35 cm (separate sub-plots)
- 4 weeks after: harvest plant material, and determine Rb concentrations
- Data:
  - Plant Rb uptake
  - Proportion of Rb uptake from 35 cm: \( \frac{\text{RbU}_{35}}{\text{RbU}_{5} + \text{RbU}_{35}} \)
**Materials and methods**

- 66 plots, 3 x 5m, Tänikon Research Station, Switzerland, 2011
- Stands: 4 monocultures, 6 binary mixtures and one 4-species mixture (3 reps)

<table>
<thead>
<tr>
<th>4 species:</th>
<th>Shallow roots</th>
<th>Deep roots</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N-fixation</strong></td>
<td>![Shallow roots](Trifolium repens L. (Tr))</td>
<td>![Deep roots](Trifolium pratense L. (Tp))</td>
</tr>
<tr>
<td><strong>No N-fixation</strong></td>
<td>![Shallow roots](Lolium perenne L. (Lp))</td>
<td>![Deep roots](Cichorium intybus L. (Ci))</td>
</tr>
</tbody>
</table>
Materials and methods

- Drought treatment: 10-week summer rain exclusion
- Plots cut 6 times per year
Results: effect of drought

- Rainfall: 306 mm rain excluded, 33% of total annual rainfall

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Drought</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative humidity</td>
<td>0.79</td>
<td>0.77</td>
<td>-3%</td>
</tr>
<tr>
<td>Mean air temperature (°C)</td>
<td>20.3</td>
<td>21.1</td>
<td>4%</td>
</tr>
</tbody>
</table>

Soil moisture content (cm³ cm⁻³)
Results: Species Rb uptake

- Much greater uptake from 5 cm compared to 35 cm depth
- 5 cm depth: Control >> Drought
- 35 cm depth:
  - Control ≤ Drought
  - Ci & Tp > Lp & Tr, particularly under drought
Results: Relative Rb uptake

- Significant shift to deeper layers under drought
- Deep-rooted species deeper, particularly under drought conditions → Niche complementarity
- No effect of mixture on proportional uptake from 35 cm → no evidence for niche differentiation
Results: Resource utilisation

- Significantly lower total Rb uptake under drought
  - No evidence of increased resistance under drought
- Significantly higher total Rb uptake in mixtures
  - No significant effect of rooting depth on total Rb uptake
  - Total Rb uptake higher in mixtures and monocultures containing legumes
Conclusions

- Tracer method showed clear niche complementarity between shallow and deep-rooting species
- Total resource utilisation (Rb uptake) was higher in mixtures than monocultures, but the increase could not be attributed to rooting depth
- Drought treatment resulted in a significant shift in Rb uptake to deeper soil layers, particularly for deep rooted species
- However, there was no clear evidence of increased drought resistance for deep rooting species or mixtures

Next steps:
- Look at niche complementarity of different resources (i.e. water, nitrogen)
- Herbage yield advantages of deep rooting species under drought
- Herbage yield advantages of combining deep and shallow rooting species in mixtures
Thanks for your attention!

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## Results: effect of drought on growth

<table>
<thead>
<tr>
<th>Yield reduction</th>
<th>Shallow roots</th>
<th>Deep roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-fixation</td>
<td>Tr: -29%*</td>
<td>Tp: +3% ns</td>
</tr>
<tr>
<td>No N-fixation</td>
<td>Lp: -51%**</td>
<td>Ci: -48%**</td>
</tr>
</tbody>
</table>

* Lp: Low productivity

** ns: Not significant