Evidence of local adaptation to high UV-B levels in the invaded range?

A multi-species approach with native and exotic origins of introduced species in New Zealand

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Background

UV-B radiation intensity fundamentally differs between the northern and the southern hemisphere due to human impact, but also in consequence of historical differences in overall solar radiation intensity and solar elevation angles (Fig. 1).

Consequently, exotic species originating from the northern hemisphere are exposed to higher amounts of UV-B when colonizing the southern hemisphere. This setting provides a suitable platform to study mechanisms of plasticity and recent adaptation in plant invasions. Successful invaders may cope with a higher UV-B intensity in the new range due to a broad UV-B radiation tolerance by displaying higher phenotypic plasticity or as a result of being pre-adapted to high levels of UV-B radiation.

Here, we investigated the effect of natural southern hemisphere UV-B radiation on exotic plant species from the northern hemisphere in multi-species common garden experiments in New Zealand and Germany. Specifically, we tested for the presence of local adaptation to stressful UV-B environments by growing individuals from the native and the introduced range.

Conclusions

We found evidence for...

• overall limiting effects of UV-B on growth and productivity in the native and invaded range
• rapid evolution of species in the invaded range, resulting in maladapted exotic genotypes when being retransferred in the native range
• higher plasticity of invasive genotypes in response to UV treatments, probably due to improved or even newly developed protection measures against photoinhibition by UV-B radiation

→ might be beneficial during the invasion process in high-UV-B environments

Experimental design & data collection

We conducted two reciprocal multi-species common garden experiments in the native and the invaded range. In Germany and New Zealand, respectively, we exposed native (German) and exotic (New Zealand) origins of eight herbaceous species to three radiation treatments: (i) natural sunlight, (ii) exclusion of UV-B while allowing natural UV-A, and (iii) exclusion of both UV-B and UVA. We used 18 experimental units, six equipped with Acrylic, PETG or Polycarbonate sheets, respectively (Fig. 4, Tab. 1). One individual per species was placed under each frame, resulting in 6 replicates per species and treatment. For each species native (DE) and invasive (NZ) individuals were equally allocated to the three treatments resulting in 3 replicates per origin and treatment.

Species were harvested depending on their developmental climax, i.e. the moment of maximum biomass production. For each individual, leaf traits such as specific leaf area (SLA), leaf dry matter content (LDMC), as well as aboveground and belowground biomass were determined. We standardized all data within species and analyzed the resulting z-scores.

Results

Limiting effect of UV radiation:

• maximum expansion and maximum leaf length was reduced under UV exposure, regardless of origin (Fig. 1, PUV < 0.05)

Plastic response of invasive genotypes:

• maximum expansion of invasive individuals was gradually reduced by exposure to UV radiation, whereas native individuals showed no clear response pattern to UV treatments (Fig. 2, Pexp < 0.05)

• LDMC and SLA of native individuals were comparable between experiments, whereas invasive individuals responded plasticity to the experimental site (Fig. 3b+c, Pexp < 0.05)

Mal-adapted invasive genotypes back in the native range:

• max. expansion, max. leaf length and aboveground biomass were higher for native individuals than for invasive individuals in the native range (DE) but comparable between origins in the invaded range (NZ, Fig. 3a, Pexp < 0.05)

Figure 3 (a-c): Significant origin/site interaction effects

Table 1: Transmittance properties of UV filter sheets

<table>
<thead>
<tr>
<th>Sheet material</th>
<th>UV-A</th>
<th>UV-B</th>
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<tbody>
<tr>
<td>Acrylic</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>PETG</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Polycarbonate</td>
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Data were analyzed using linear mixed models to test for effects of experimental site, UV treatment and origin.