Do rare herbs have large seeds?  
The seed size – distribution range trade-off hypothesis

Judit Sonkoly, Balázs Deák, Orsolya Valkó, Attila Molnár V., Béla Tóthmérész & Péter Török

14th Eurasian Grassland Conference
4-11 July 2017, Riga
Rarity

• the term ’rare’ can be used to define different patterns
• correlations between the different measures of rarity (range size is positively correlated to e.g. local abundance and niche breadth)
• geographical range size is the most frequently used measure is it
• range size has conservational importance (extinction risk, invasive species etc.)
There is a great variance in species’ range size

Possible general explanations:
• variance in environmental tolerance and/or habitat breadth
• differences in dispersal ability
• latitude of the geographical location

Explanations in case of plants:
• growth form or plant height
• seed size
• seed production patterns
• seed longevity

A generally acceptable and supported hypothesis for this great variance has not been established yet
Range size and dispersal ability

- Higher dispersal ability – better chance to colonise new habitats
- Poor dispersal capacity – rapid adaptation to local conditions – rapid speciation – smaller range size

Direct quantification of dispersal ability can be very difficult

Different proxies are often used instead of a direct measure of it

Seed size is the most usual proxy for dispersal ability

- Numerosity of small seeds (seed size/number trade-off)
- Smaller seeds are more easily transported by wind and also by other agents
Introduction

Contrasting results of previous studies
- The expected negative relationship has been demonstrated in previous studies (e.g. Guo et al. 2000; Walck et al. 2001; Morin & Chuine, 2006; Procheș et al., 2012)
- There are some counterexamples as well (Lavergne et al. 2003, 2004; Kolb et al. 2006)

Possible explanation:
Competition – colonization trade-off: smaller seeds have a greater chance to colonise new sites, but they have a lower probability of survival there, which acts against range expansion

A general relationship between seed size and range size has not been demonstrated yet
Introduction

Environmental conditions

Seed size – previous results
- Larger seeds in shaded habitats
- Smaller seeds in wet habitats
- Larger seeds at high soil pH
- Larger seeds in fertile habitats

Range size – previous results
- Much less information
- Larger range of wetland species
- Larger range of species of infertile habitats
We hypothesised that

i. Seed mass is negatively related to range size

ii. Seed mass is related to environmental factors (soil moisture, light intensity, nutrient supply)

iii. Range size is related to environmental factors (soil moisture, light intensity, nutrient supply)

Revealing underlying mechanisms that shape the rarity of plants
Checklist of plant species of the Pannonian Ecoregion
(2516 species; Flora Database – Horváth et al. 1995)

Excluding certain species groups
• Woody species (204 species)
• Adventive species (337 species)
• Aquatic plants (182 species)

Obtaining thousand-seed mass values from the literature

Obtaining soil moisture, light intensity and nutrient supply indicator values
(Flora Database – Horváth et al. 1995)
<table>
<thead>
<tr>
<th>Distribution</th>
<th>Range size category</th>
<th>Species number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpathian</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Dacic</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Illyric</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Pannonic</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>Alpine-Balcanic</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Balcanic</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Central-European</td>
<td>2</td>
<td>118</td>
</tr>
<tr>
<td>Central-European-Alpine</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>East-Submediterranean</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Pannonic-Balcanic</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Pontic</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Pontic-Mediterranean</td>
<td>2</td>
<td>79</td>
</tr>
<tr>
<td>Pontic-Pannonic</td>
<td>2</td>
<td>59</td>
</tr>
<tr>
<td>Turanian</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Alpine</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Atlantic-Submediterranean</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td>Boreal</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Continental</td>
<td>3</td>
<td>89</td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>167</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Sarmatian</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Subatlantic</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Submediterranean</td>
<td>3</td>
<td>138</td>
</tr>
<tr>
<td>Eurasian</td>
<td>4</td>
<td>400</td>
</tr>
<tr>
<td>Circumpolar</td>
<td>5</td>
<td>139</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>5</td>
<td>122</td>
</tr>
</tbody>
</table>

1600 species in total

- Flora Database
- eMonocot
- Encyclopedia of Life

- Global Biodiversity Information Facility
- PESI Portal
- Euro+Med PlantBase
Statistical analyses

Generalized Linear Mixed Models (GLMMs):

• Effect of species range, soil moisture, light intensity and nutrient supply on the thousand-seed mass of the studied species
• Effect of soil moisture, light intensity and nutrient supply on range size
• Genus nested in family as a random factor

Spearman’s rank correlations:

• Direction and steepness of relationships between variables
### Results

#### Effects on seed mass

<table>
<thead>
<tr>
<th>Factor</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range size</td>
<td>4.613</td>
<td>0.001</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>2.884</td>
<td>0.001</td>
</tr>
<tr>
<td>Light intensity</td>
<td>2.789</td>
<td>0.007</td>
</tr>
<tr>
<td>Nutrient supply</td>
<td>2.978</td>
<td>0.003</td>
</tr>
</tbody>
</table>

#### Effects on range size

<table>
<thead>
<tr>
<th>Factor</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil moisture</td>
<td>19.845</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Light intensity</td>
<td>6.747</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nutrient supply</td>
<td>14.273</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
1a – Seseli osseum
1b – Centaurea indurata
1c – Seseli leucospermum
2a – Echium maculatum
2b – Biscutella laevigata
2c – Lactuca quercina
3a – Bupleurum praehalum
3b – Vaccinium oxycoccos
3c – Prunella grandiflora
4a – Geranium dissectum
4b – Lepidium perfoliatum
4c – Marrubium peregrinum
5a – Briza media
5b – Ranunculus flammula
5c – Chenopodium botrys
Rank correlations (Spearman’s rho)

WB – soil moisture
LB – light intensity
NB – nutrient availability
A trade-off between seed mass and range size exists in the studied 1600 species

The key factor is dispersal ability,

BUT:
• High number of small seeds (seed size/number trade-off)
• Small seeds have a lower probability of being eaten
• Small seeds persist longer in the soil
• Narrow range – narrow habitat requirements –
  – bigger seeds are more advantageous
Accordance with some of the former results ↔ Contradiction with some other former results → Regional differences?

We used
  • the highest number of species to date
  • the global range size of species

Some factors counteract the effects of better dispersal ability of smaller seeds:
  • The competition – colonization trade-off
  • Effectively dispersed seed can get far away from the suitable habitat
  • Evolutionary age of a species
Plant species of dry grasslands have high conservation value.

- Light intensity and soil moisture increase, leading to
- Range size decrease, leading to
- Plant species of dry grasslands have high conservation value.

- Nutrient availability increases, leading to
- Range size increase, leading to
- Common species are mostly associated with fertile, degraded habitats, while rare species are associated with less fertile and less disturbed ones.
Widespread species have small seeds

Small, easily dispersed seeds are not always advantageous in isolated habitat

Widespread species may face more and more local extinctions in the future?
Thank you for your attention!

The authors were supported by OTKA K108992 (AMV), OTKA K116639 (BT), NKFIH K 119225 (PT) and OTKA PD 115627 (BD) projects. JS and OV were supported by the Human Capacities Grant Management Office and the Hungarian Ministry of Human Capacities (NTP-NFTÖ-16-0107). BD and OV were supported by the Bolyai János Research Scholarship of the Hungarian Academy of Sciences.