Sources of phenotypic variation of life history traits in an invasive species, *Senecio inaequidens* DC. (Asteraceae)

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Introduction
Introduction

• Alien species invade contrasted environments
Introduction

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Prunus serotina Ehrh.
Introduction

- Alien species invade contrasted environments
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Robinia pseudoacacia L.
• Alien species invade contrasted environments

⇒ *the variability within species* is crucial to most plant invasions!
Introduction

• Alien species invade contrasted environments

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Variability within the species
« phenotypic variability »
⇒ Germination
⇒ Growth
⇒ Reproduction
⇒ Etc.

Variability in invaded areas
• Alien species invade contrasted environments

➔ the variability within species is crucial to most plant invasions!

Variability within the species
« phenotypic variability »
➔ Germination
➔ Growth
➔ Reproduction
➔ Etc.

Variability in invaded areas

What mechanisms allow invasion in contrasted environments?
Introduction

• Alien species invade contrasted environments

⇒ *the variability within species* is crucial to most plant invasions!

• How to decompose the variability within species:
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\text{Phenotypic variability} = \text{Genetic variability} + \text{Environmental variability}
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4 evolutionary forces
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- Mutations
- Natural selection
- Genetic drift
- Population differentiation
- Gene flow
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- Environmental maternal effects
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Objectives
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Using *Senecio inaequidens* as a study model, within the invaded range, we ask:
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**Objectives**

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What is the importance of environmental maternal effects in relation to climate?
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**Objectives**

- Is phenotypic variation related to climate?
- Does this variation reflect a genetic differentiation?
- What is the importance of environmental maternal effects in relation to climate?
- If there is a genetic differentiation, is it adaptation to climate?
Study model
Study model: *Senecio inaequidens* DC.

- Perrenial herbaceous shrub
- Native to South Africa and Lesotho
- Pioneer species
Introducing to Europe as a wool alien in several locations linked to wool industries:

- Verviers (Belgium) : 1892
- Bremen (Germany) : 1896
- Mazamet (France) : 1936
- Verona (Italy) : >1940
Study model: *Senecio inaequidens* DC.

- During several decades, it was only found in the vicinity of wool-processing areas
Study model: *Senecio inaequidens* DC.

- From 1950-1970, it started to spread throughout Europe
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During ~50 years of invasion, *Senecio inaequidens* gradually encountered contrasted climatic zones.
Study model: *Senecio inaequidens* DC.

- From 1950-1970, it started to spread throughout Europe.

- During ~ 50 years of invasion, *Senecio inaequidens* gradually encountered contrasted climatic zones.

- Several independent colonizations in Europe.
Materials & methods + Results
1) Is phenotypic variation related to climate?

2) Does this variation reflect a genetic differentiation?
French transect:

- 5 altitudinal zones:
  Altitudinal range: 0 – 1600 m

- 2 populations per zone

Meteorological analysis:
Temperature and summer-drought gradient
Belgian transect:

- 4 altitudinal zones:
  Altitudinal range: 0 – 480 m

- 2 populations per zones

Meteorological analysis:

Temperature and rainfall gradient
Growth trait measurements in natural populations

10 individuals per population
Growth trait measurements in natural populations

Results:
Gradual decrease of plant traits with altitude
Is phenotypic variation related to climate?

Does this variation reflect a genetic differentiation?
Materials & methods + results

10 parent individuals per population

10 achenes per parent individual
Materials & methods + results

10 parent individuals per population

10 achenes per parent individual

1 descendant per parent individual
Materials & methods + results

Life history traits:
- Germination delay
- Flowering delay
- Height at maturity
- Final plant height
- Aboveground biomass
Replication of the whole experiment

Materials & methods + results

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Life history traits:
- Germination delay
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- Height at maturity
- Final plant height
- Aboveground biomass

Spatial replication: 2 study transects
Temporal replication: 2 years of experiment
Results:

- Clinal reduction of growth traits with altitude of source populations!
- Clearer in France
Materials & methods + results

1) Is phenotypic variation related to climate? ✓

2) Does this variation reflect a genetic differentiation? ✓
Materials & methods + results

1) Is phenotypic variation related to climate?

2) Does this variation reflect a genetic differentiation?

3) What is the importance of environmental maternal effects in relation to climate?

4) If there is a genetic differentiation, is it adaptation to climate?
Materials & methods + results
3 populations in the Pyrenean
3 populations in Mazamet (introduction site)
Life history traits

- Seed mass
- Time to germination
- Plant volume
- Cumulated flower heads
Life history traits

- Seed mass
- Time to germination
- Plant volume
- Cumulated flower heads

Fitness traits \(\rightarrow\) adaptation to climate?
Materials & methods + results

Life history traits

• Seed mass
• Time to germination
• Plant volume
• Cumulated flower heads

Environmental maternal effects ?

Fitness traits → adaptation to climate ?
Materials & methods + results

Results:
Results:

Environmental maternal effects depend on climate.
Materials & methods + results

Results:

Environmental maternal effects depend on climate

Mediterranean (Favourable climate)

Germination independent of seed mass

No influence on fitness
Results:

Environmental maternal effects depend on climate

Mediterranean (Favourable climate)

Germination independent of seed mass 

No influence on fitness

Mountain (Harsh climate)

Germination dependent on seed mass

Strong influence on fitness!

Materials & methods + results
Materials & methods + results

**Results:**

Environmental maternal effects depend on climate
Results:

Environmental maternal effects depend on climate
**Results:**

Environmental maternal effects depend on climate

Genetic differentiation: verified
**Materials & methods + results**

**Results:**

Environmental maternal effects depend on climate

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Genetic differentiation: verified

Plasticity in relation to climate
**Results:**

Environmental maternal effects depend on climate

Genetic differentiation: verified

Plasticity in relation to climate
**Materials & methods + results**

**Results:**

Environmental maternal effects depend on climate

Genetic differentiation: verified

Plasticity in relation to climate

Local adaptation to climate?

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**Mediterranean garden**

![Bar chart showing volume (cm³) for Mediterranean plants, Mazamet plants, and Pyrenean plants.](chart1)

**Pyrenean garden**

![Bar chart showing volume (cm³) for Mediterranean plants, Mazamet plants, and Pyrenean plants.](chart2)
Results:

Environmental maternal effects depend on climate

Genetic differentiation: verified

Plasticity in relation to climate

Local adaptation to climate? Mediterranean: yes!

Materials & methods + results
Environmental maternal effects depend on climate

Genetic differentiation: verified

Plasticity in relation to climate

Local adaptation to climate?
- Mediterranean: yes!
- Pyrenean: no clear pattern...

Results:

Materials & methods + results
Discussion

Invasion range

Temperature gradient
Discussion

➔ Clinal variation in natural populations
Discussion

- Clinal variation in natural populations

- Marked genetic differentiation:
  - Adaptation to climate in the Mediterranean, for growth traits
Discussion

- Clinal variation in natural populations
- Marked genetic differentiation:
  - Adaptation to climate in the Mediterranean, for growth traits

Invasion range

No clear local adaptation

Local adaptation in growth traits

Genetic differentiation

Temperature gradient
Discussion

- Clinal variation in natural populations
- Marked genetic differentiation:
- Phenotypic plasticity related to climate
  → *Not responsible for the clinal pattern* (> < genetic trend)

Invasion range

- No clear local adaptation
- Local adaptation in growth traits
Discussion

- Clinal variation in natural populations
- Marked genetic differentiation:
- Phenotypic plasticity related to climate
- Environmental maternal effects in harsh climate
  → *Functional importance of seed mass in mountains*

Invasion range

<table>
<thead>
<tr>
<th>Genetic differentiation</th>
<th>Local adaptation in growth traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>No clear local adaptation</td>
<td>No environmental maternal effects</td>
</tr>
<tr>
<td>Strong environmental maternal effects</td>
<td></td>
</tr>
</tbody>
</table>

Temperature gradient
Conclusions
Conclusions

- **Rapid evolution (time scale < 100 years)** can help plant invasion in contrasted environments.

- **Different mechanisms** can explain the success of aliens in warmer and colder areas.

- All the sources of phenotypic variation should be taken into account to understand the success of invasion in contrasted environments.
Thank you for your attention

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