Clinal differentiation during invasion: *Senecio inaequidens* (Asteraceae) along altitudinal gradients in Europe.

Arnaud Monty and Grégory Mahy

Gembloux Agricultural University, Laboratory of Ecology, Passage des Déportés, 2, 5030, Gembloux, Belgium.

Correspondace: monty.a@fsagx.ac.be ; Tel: 0032(0)81622546

INTRODUCTION

Senecio inaequidens DC. (Asteraceae) is a perrennial herbaceous shrub. It was introduced from South Africa to Europe more than one hundred years ago, in a few precise locations linked to wool industry. It progressively extended its distribution throughout Europe, coming across contrasted climatic conditions. In a context of global warming, the potential evolution of the species was studied in relation to altitude and climate.

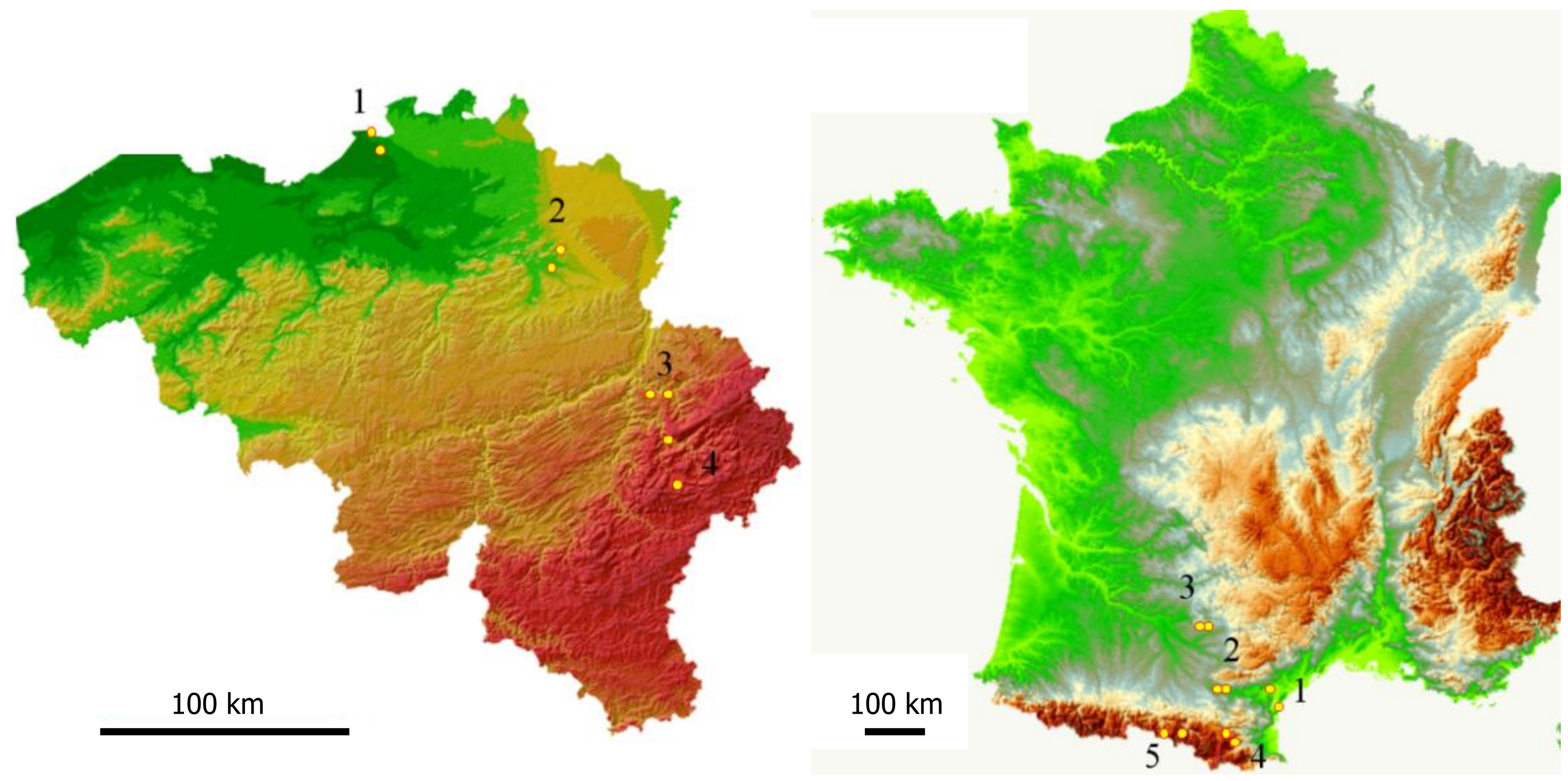

Fig.1: Belgian (left; altitudinal range: 0-480 m) and French (right; altitudinal range: 0-1700 m) transects for seed collection. Numbers represent climatic/ altitudinal zones. Dots represent populations.

Fig.2: Common garden experiment (random block design)

MATERIAL AND METHODS

Seeds were collected along two transects, both altitudinal and climatic, in Belgium and France (Fig.1). Respectively four and five climatic zones per transect, two populations per zone and ten randomly selected individuals per population were sampled in November 2005. Along each transect, zone number 3 correspond to the first introduction area (Fig.1)

Ten seeds per parent individual were sown in pots in a common garden experiment in Gembloux, in 2006 (Belgium)(Fig.2). In November 2006, ten other individuals per population were sampled along the transects and a repetition of the common garden experiment was performed in 2007.

Seeds were sorted in order to reduce potential maternal effects. In 2007, the mass of the ten seeds per pot was used as a covariate in the analysis. Germination was checked every two days. Blooming was checked everyday. At the end of each experiment, plant height and aboveground biomass (after drying 48h at 60°C) were measured.

Days to germination, days to flowering (since germination), height at maturity (first flower appearance), final height and aboveground biomass were correlated to altitude of source populations (Pearson's r and corresponding regressions).

A PCA analysis was performed on the measured life history traits for each transect, each year. The first axis was kept and is referred to as PCA 1 PLANT TRAIT.

Temperature and rainfall data from climatic stations along the transect were analysed using a PCA. The first axis was kept along each transect and is referred to as PCA 1 CLIMATE.

The scores of the four PCA 1 PLANT TRAIT axes were regressed against the corresponding PCA 1 CLIMATE scores.

RESULTS

Fig. 3 shows the correlations between plant traits and altitude of source populations, for both years, along the two transects. Along the Belgian gradient, a reduction of plant height and biomass with increasing elevation was observed in 2006, but not statistically confirmed in 2007. The general pattern of variation is however similar both years.
Along the French (more contrasted) transect, a clearer differentiation of the species was shown: both years, plants from higher elevations tended to grow smaller (in height and biomass) and to bloom at a lower height. In 2007, including seed mass as a covariate did not change the outcome of the analysis.

Over the two years of experiment, days to germination and days to flowering did not show consistent patterns of variation with respect to altitude.

According to climatic station data, the French altitudinal transects followed a temperature and summer-drought gradient, with the warmest and most summer-dry zones at lower altitudes. The Belgian transect followed both a decrease in temperature and an increase in rainfall levels with increasing elevation.
Fig.4 shows the regressions of PCA 1 PLANT TRAIT scores against PCA 1 CLIMATE scores. Global plant differentiation along both transect, but especially in France, is correlated to climate.

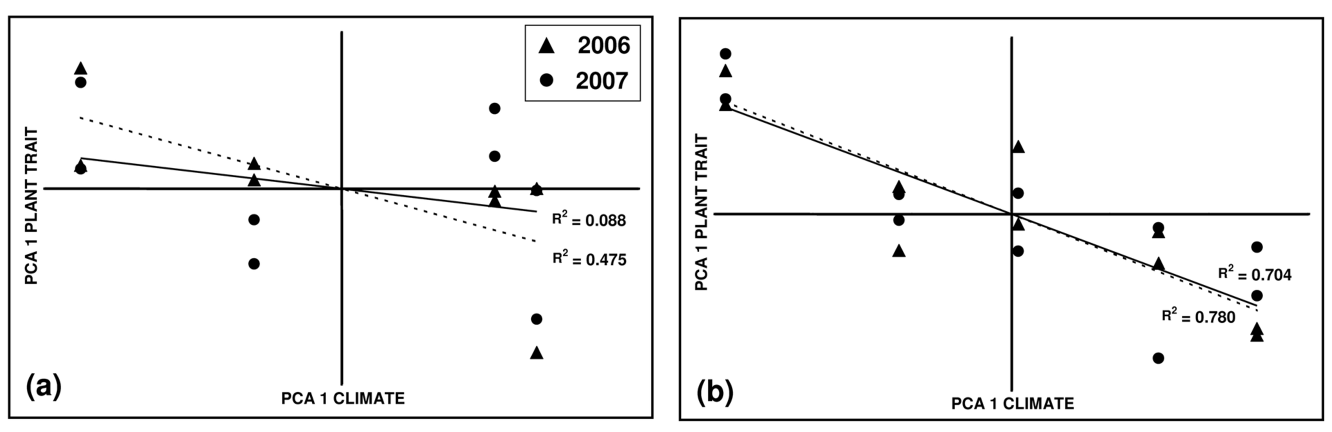

Fig. 4: PCA 1 PLANT TRAIT scores against PCA 1 CLIMATE scores for (a) the Belgian transect and (b) the French transect. Lines represent regressions. Triangles and dotted lines: 2006; circles and plain lines: 2007.

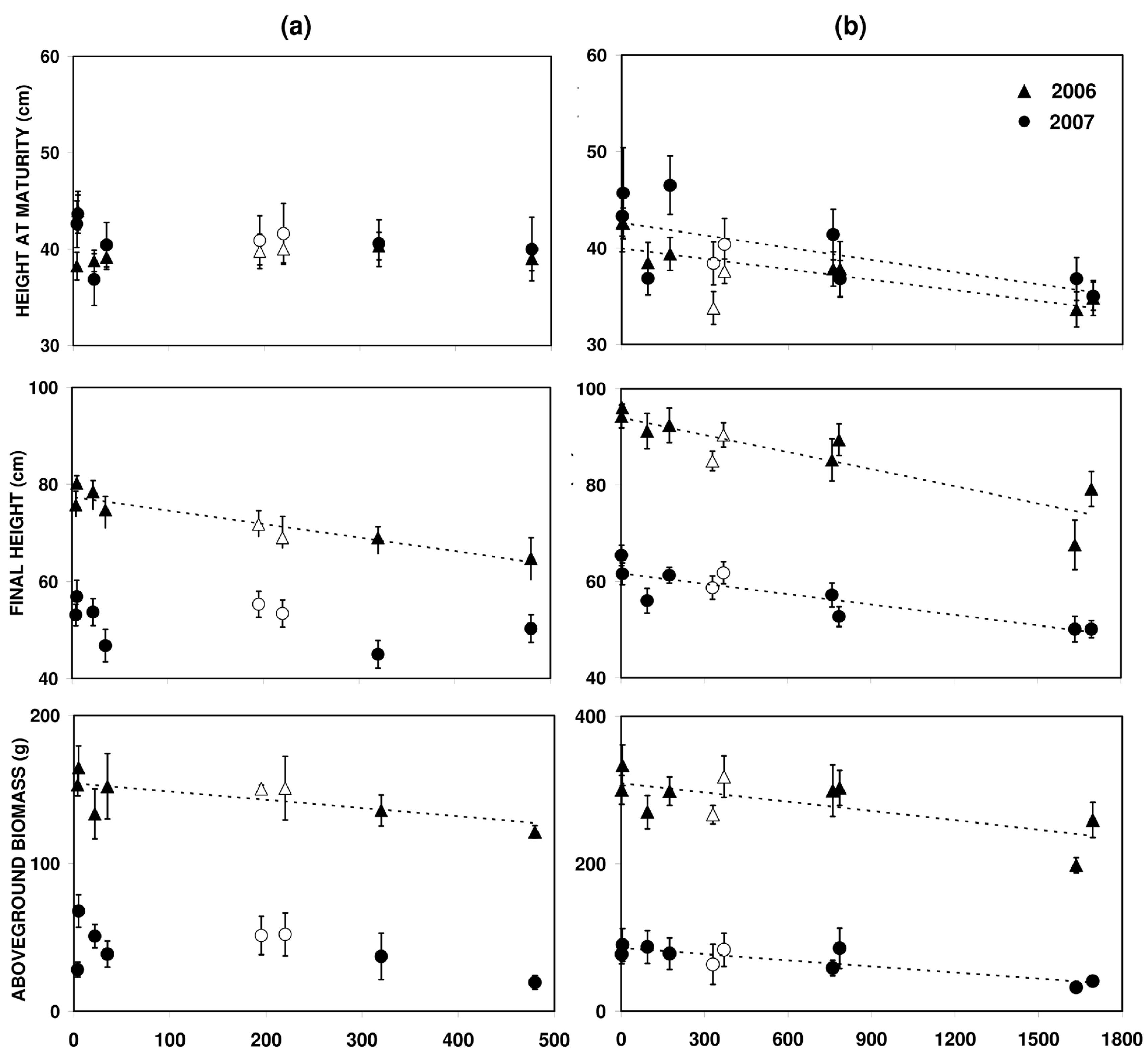

Fig. 3: Senecio inaequidens populations in the common garden experiments in 2006 and 2007: height at maturity, final height and aboveground biomass against altitude of source populations along the French transect. Symbols represent population trait means, with standard errors. Dotted lines represent significant regressions (P < 0.05) along the transects. Open symbols represent populations from the first introduction site (Verviers and Mazamet).

CONLUSIONS

This study showed that *S. inaequidens* encountered genetic differentiation during its invasion in Southern France, and to a lesser extent in Belgium. Several lines of evidence lead to conclude that this differentiation is the result of adaptive processes: (a) the same trends are found both in Belgium and France, whereas the two invasion areas are still disjunct; (b) a reduced height is a common feature in mountainous plants; and (c) the differentiation is clearly correlated to climate, and climate is a potential selection agent on this species.

However, the observed cline can also originate from demographic and stochastic processes. Notably, repeated founder events may have occurred during invasion from the first colonists, and enhanced plant differentiation. Environmental maternal effects may have also played a role in our results, even though including seed mass as a covariate did not change the pattern of variation.

Reciprocal transplants and/or phylogenetic analysis are needed to fully understand the adaptive benefit of the differentiation and the role of genetic drift during invasion.

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