Does root morphology and nutrient acquisition explain life history traits in ecotypes of *Capsella bursa-pastoris*?

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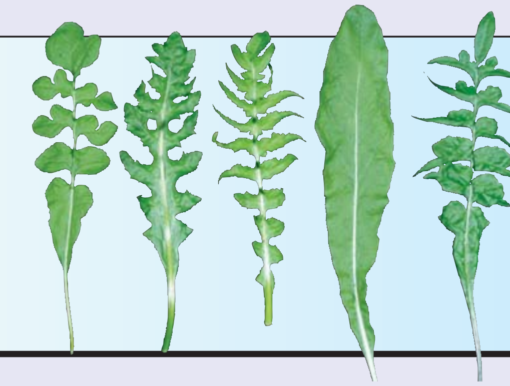
Detecting the existence and function of biodiversity in arable systems is of primary importance in agro-ecology. The aim of our research is to understand the role of intra-specific diversity in weed species in key processes of energy and nutrient flow through arable food webs, using *Capsella bursa-pastoris* as a model weed.

Background

Capsella bursa-pastoris, or Shepherd's purse, is a common and widespread weed of arable systems in the UK and throughout Northern temperate regions. Within-species variation in a number of traits has led to ecotype classification based on leaf morphology[1], life history traits[2] and molecular markers[3]. The physiological processes and molecular mechanisms underlying ecotype differences have not been characterised in detail.

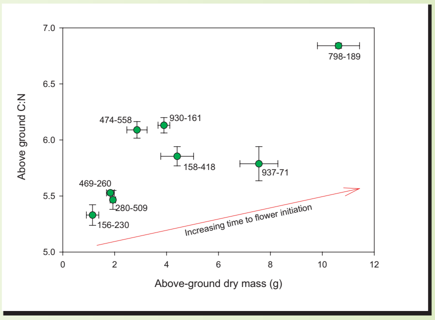


Results

Capsella ecotypes show differences in flowering time, pre-flowering mass and major element composition

Over 50 plant lines collected from arable fields across the UK have been phenotypically characterised at SCRI, and a subset of 8 plant lines or 'ecotypes', representing the full range of variation in life history traits, were selected for further physiological analysis.

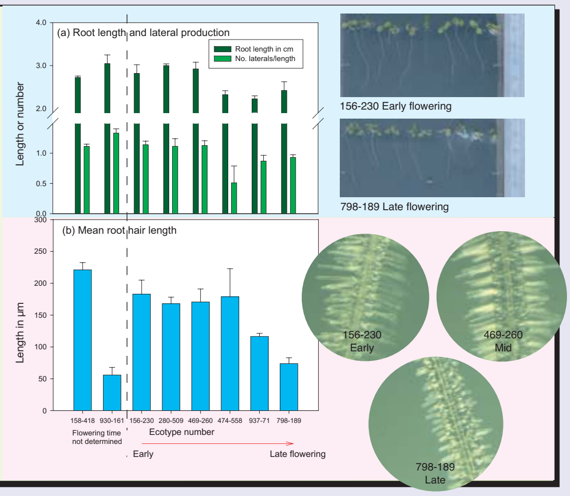
Plants with higher C:N values tend to have larger mass and later time to flowering. The C:N ratio of shoot tissue harvested at flower initiation varied significantly between ecotypes, even when biomass accumulation, which also varied significantly, was taken into account as a covariate (ANCOVA of C:N ratio: dry mass (covariate, ln-transformed): $F_{1,39}=5.29$, $p<0.05$; ecotype: $F_{7,39}=13.14$, $p<0.001$). Data points are mean values ± s.e. for n=5 plants, with ecotype numbers annotated.



Root morphology varies significantly between ecotypes

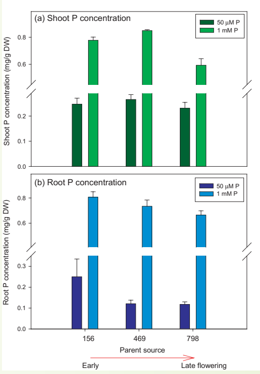
Root length, lateral production and root hair length were recorded for 10-12 d old seedlings of each ecotype grown in nutrient solution solidified with agar.

Later-flowering ecotypes tended to have shorter roots with few laterals per unit length and with short root hairs. Significant ecotype differences were detected in (a) root length ($F_{7,23}=5.06$, $p<0.005$) and the number of laterals per unit root length ($F_{7,23}=4.07$, $p<0.01$), and in (b) mean root hair length (F =8.05, $p<0.001$). Bars are mean values ± s.e. of n=3 plates, with between 3 and 10 observations per plate.



Ecotype nutrient relations: Phosphate acquisition

A pilot study of three ecotypes was initiated to assess the response of plants to changes in root phosphate supply. Sand-cultured plants exposed to low (50 µM) or high (1 mM) phosphate (P) until 66 d old were analysed for shoot and root P content.



Tissue P concentration (and dry mass: data not shown) responded positively to an increase in P supply, with lower concentrations in the late flowering ecotype.

(a) Ecotype differences in shoot P concentration were significant even when dry mass was included as a covariate (ANCOVA: ln-transformed shoot dry mass: supply: $F_{1,17}=22.09$, $p<0.005$; ecotype: $F_{2,17}=4.98$, $p<0.05$; interaction: $F_{2,17}=1.43$, $P>0.05$).

(b) Ecotype differences in root P concentration could be accounted for by the variation in root dry mass (ANCOVA: ln-transformed root dry mass: $F_{1,17}=19.97$, $p<0.005$; P supply: $F_{1,17}=6.03$, $p<0.05$; ecotype: $F_{2,17}=1.65$, $p>0.05$; interaction: $F_{2,17}=1.63$, $P>0.05$). Bars are mean values ± s.e. of n=3 plants.

Methods

- Above-ground mass was measured for compost-grown plants in non-limiting nutrient conditions and a randomised design in a glasshouse (18 h light, 20 °C). Shoot material was harvested prior to flower stem extension, freeze-dried and weighed. Subsamples of dried material were ball-milled for N and C analysis by continuous flow Dumas combustion coupled to a Europa Scientific 20-20 mass spectrometer.
- For root measurements, GA-treated seeds were germinated on 0.5 MS (Murashige and Skoog medium, with vitamins), 1% sucrose at pH 5.8-6 with NaOH, solidified with 0.7% phytoagar; after 3 days, seedlings were transferred onto medium in 100 mm square plates, with ten seedlings per plate. Plates were randomised within a plant growth cabinet (day/night conditions of 16/8 h and 15/16 °C). Images were acquired of 10 d old seedlings for root length and lateral analysis and of the region 10 mm behind the root tip of 12 d old seedlings for root hair length measurements. Length measurements were obtained using KZEISS image analysis software.
- The effect of P supply was assessed following transfer of GA-germinated seedlings to pots of washed sand. Plants were irrigated every two days with nutrient solution based on Hoagland's, but containing either 0.05 or 1 mM phosphate. Shoot and root material was harvested after 66 d, freeze-dried and weighed. Subsamples of dried material were ball-milled for acid-based P extraction and colourimetric analysis of phosphate based on reduction of the phosphomolybdate complex.

Summary

Significant intra-specific variation in *Capsella bursa-pastoris* can be detected for a number of physiological traits relating to plant growth and nutrient acquisition. Small, early-flowering ecotypes tend to accumulate higher N and P content, correlating with longer roots that have relatively more lateral branches and long root hairs.

We will extend the characterisation of root architecture and nutrient uptake, in particular to understand the molecular basis for ecotype differentiation.

Acknowledgements

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References

[1] Shull (1909) Carnegie Institution Publications 112, 1-57.
[2] Hurka & Neuffer (1997) Plant Systematics and Evolution 206, 295-316.
[3] Linde *et al*. (2001) Annals of Botany 87, 91-99.