How does root morphology and response to nutrients relate to life history traits in ecotypes of *Capsella bursa-pastoris*?

AJ Karley*, TA Valentine, J Greig, PPM Iannetta and GR Squire

Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA
*email: akarle@scri.ac.uk

Scottish Crop Research Institute

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

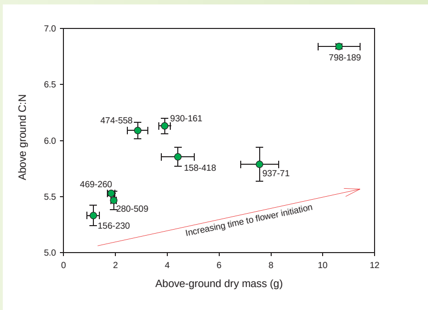
Capsella bursa-pastoris, or Shepherd's purse, is a common and widespread weed of arable systems in the UK and throughout Northern temperate regions. Within-species variation in a number of traits has led to ecotype classification based on leaf morphology[1], life history traits[2] and molecular markers[3]. 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

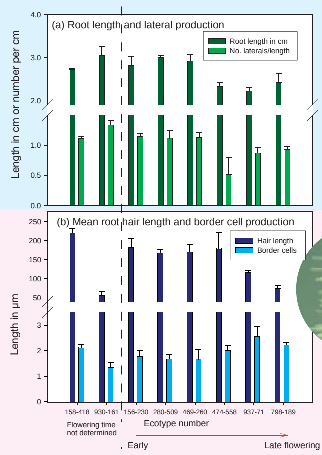
Over 50 plant lines collected from arable fields across the UK have been phenotypically characterised at SCRI, and a subset of 8 plant lines or 'ecotypes', representing the full range of variation in life history traits, were selected for further physiological analysis.

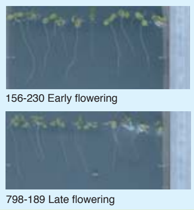
Plants with higher C:N values tend to have larger mass and later time to flowering. The C:N ratio of shoot tissue harvested at flower initiation varied significantly between ecotypes, even when biomass accumulation, which also varied significantly, was taken into account as a covariate (ANCOVA of C:N 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.

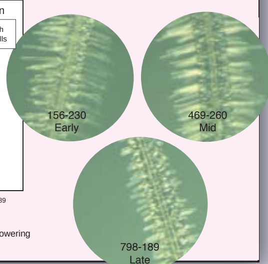


Root morphology varies significantly between ecotypes

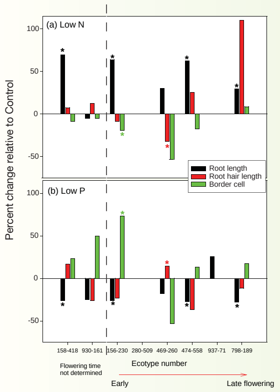
Root length, lateral production and root hair length were recorded for 10-12 d old seedlings of each ecotype grown in nutrient solution solidified with agar. Later-flowering ecotypes tended to have shorter roots with few laterals per unit length and with short root hairs. Significant ecotype differences 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 ($F = 8.05$, $p<0.001$); border cell coverage of root tips did not vary significantly between ecotypes ($F_{7,23}=2.39$, $0.05<p<0.1$). Bars are mean values ± s.e. of n=3 plates, with between 3 and 10 observations per plate.

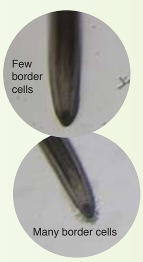






Differential responses to low nutrient supply amongst ecotypes





When N or P supply was low, ecotypes exhibited significant variation in root hair length and border cell coverage of root tips, but not in root length (analyses not shown).

Low N tended to promote root growth, while low P supply retarded root growth and led to greater tip coverage by border cells. Ecotype differentiation in response to low nutrient supply is indicated by the direction and significance of the change (indicates p<0.05 in ANOVA or Kruskal-Wallis analysis of untransformed data for each ecotype).

Root hair length responses to low nutrient supply varied between ecotypes.

Reduced sample size for two ecotypes (due to microbial contamination) prevented comparison of border cell production with ecotype flowering time.

Methods

- Above-ground mass was measured for plants grown in non-limiting nutrient conditions in compost using 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 of root tips were acquired using a Leica MZFLIII Microscope, Leica DC480 digital camera and Leica IM50 software, and border cell production was scored using a scale of 1-5 where 1=no cells and 5=root tip covered with cells.
- The effect of nutrient supply on root growth was assessed for 10-12 day old seedlings grown on Low N medium (nitrogen concentration reduced to 10% of 0.5 MS) and Low P medium (phosphate omitted from 0.5 MS medium).

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 content, correlating with longer roots that have relatively more lateral branches, longer root hairs and greater root tip coverage by border cells.

Root responses to low N and P supply were similar to those reported for other species, but the significant differences observed between ecotypes warrants further investigation, in particular to understand the molecular basis for root architecture and nutrient uptake

Acknowledgements

We thank Kirsty Binnie for assistance with image analysis, SCRI glasshouse staff for assistance with growth of plant material, and SEERAD for funding the research.

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.