Joint effects of biocontrol herbivory and plant competition greatly reduce the growth of *Rumex obtusifolius*

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Abstract

Augmentative biological control offers a potentially effective, but largely unexplored, opportunity to control native weeds with native phytophagous insects. Herbivore effects on the target weed may further be enhanced by interspecific competition with other plant species. We assessed the impact of root-boring larvae of the Sesiid moth *Pyropteron chrysidiforme* on the target weed *Rumex obtusifolius* for two groups of initially small and large plants, with or without competition from a *Lolium perenne* sward. In a field experiment, 106 *Rumex* roots were planted into plots with either pure *L. perenne* or bare soil, and *R. obtusifolius* plant performance was measured after one year. Overall, competition from the grass sward strongly reduced aboveground biomass and root mass of *R. obtusifolius*. Herbivory alone had little impact on *R. obtusifolius* growth. However, in combination with grass competition, herbivory negatively affected above- and belowground biomass of *R. obtusifolius* plants, but only when growing from initially smaller roots (agent × competition interaction: $P<0.05$ for each). Our results indicate that joint effects between augmentative biological control and plant competition can reduce the growth of a major grassland weed.

Keywords: augmentative biocontrol, *Pyropteron chrysidiforme*, weed control

Introduction

Rumex obtusifolius L. (broad-leaved dock) is one of the most problematic weeds in intensively managed permanent grasslands in Europe (Grossrieder and Keary, 2004) and is considered a major hindrance for conversion to organic farming in Switzerland. There is thus a need to develop effective non-chemical control measures against *R. obtusifolius*. The native European clearwing moth *Pyropteron chrysidiforme* (Esper) (Lepidoptera; Sesiidae) has been proposed as a candidate for augmentative biological control of *R. obtusifolius* (Grossrieder and Keary, 2004) as the root-boring larvae can promote degradation of the plant's storage organ (Scott and Sagliocco, 1991). However, in a previous study the impact of *P. chrysidiforme* was insufficient to significantly reduce the performance of established plants of *R. obtusifolius* in permanent grasslands (Hahn *et al.*, 2016). The effects of herbivory can possibly be enhanced by interspecific plant competition (Sheppard, 1996), and a potential competitor of *R. obtusifolius* is *Lolium perenne* L. (perennial ryegrass) (Keary and Hatcher, 2004; Niggli *et al.*, 1993). In this study, we assessed the impacts of herbivory by *P. chrysidiforme* and competition with *L. perenne* on small and large plants of *R. obtusifolius*.

Materials and methods

A field experiment was set up in June 2019 near Zürich, Switzerland. Field-collected, small and large roots of *R. obtusifolius* (106 roots in total) were planted into established, pure swards of *L. perenne* and plots with bare soil (16 plots in total: dimension 1.8×5 m; 3-4 roots of each size class per plot). The average mass of transplanted small and large roots was 2.9 g (standard error ±0.20 g) and 57.5 (±5.19) g, respectively. One half of the roots from each size class was inoculated with eggs of the biological control agent *P. chrysidiforme*, the other half served as the control with no application (split-plot design). Aboveground biomass of *Rumex* plants was harvested three times in autumn 2019 and twice in spring 2020, dried to constant weight and summed over harvests to obtain the cumulative aboveground biomass.

Roots were excavated in May 2020, washed free of soil and weighed. Data were analysed with generalized linear mixed-effects models (GLMMs) using a log link function. Explanatory factors were competition from *L. perenne* (2 levels), application of *P. chrysidiforme* (2 levels), and initial root mass of *R. obtusifolius* (2 levels), including all interactions. The split-plot structure was accounted for by a random intercept for plot (analyses done with software R, version 4.1.1, R Core Team, 2021).

Results and discussion

The aboveground biomass of all *R. obtusifolius* plants was significantly reduced by competition from *L. perenne* (main effect: χ^2=66.5, P<0.001; Figure 1); yet, plants from initially small roots were more suppressed by competition than plants grown from large roots (competition × init. root mass interaction: χ^2=23.8, P<0.001). While there was no effect of *P. chrysidiforme* application when *R. obtusifolius* plants grew without competition, *P. chrysidiforme* significantly reduced the aboveground biomass of initially small roots under competition from the *L. perenne* sward (z=3.9, P<0.001; compare contrasts Figure 1).

Similar to aboveground biomass, final root mass of all *R. obtusifolius* plants was negatively affected by competition from *L. perenne* (main effect: χ^2=39.3, P<0.001; Figure 2), and the competition effect was stronger for initially small roots (competition × init. root mass interaction: χ^2=20.6, P<0.001). Also, final root mass of initially small roots was significantly impacted by the application of *P. chrysidiforme* only under competition from the *L. perenne* sward (z=4.8, P<0.001; compare contrasts Figure 2B).

Our findings provide evidence that interspecific competition and herbivory cause interactive impacts on the growth of *R. obtusifolius* and that these effects were plant size-dependent. Competition from a grass sward has been shown to reduce resource availability for neighbour plants, thereby affecting their growth

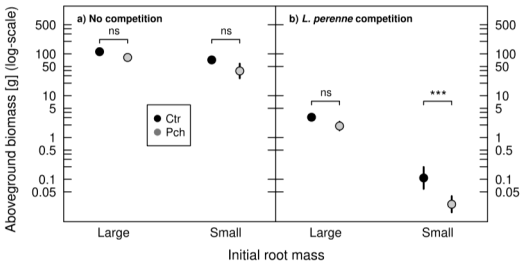

Figure 1. Aboveground biomass of *Rumex obtusifolius* plants grown under no competition (A) and competition from a *L. perenne* sward (B) depending on the initial root mass and *Pyropteron* treatments (no application [Ctr], *P. chrysidiforme* [Pch]). Displayed are means ± standard error. Non-visible standard errors are due to small values. The statistical inference is based on a GLMM. *** P<0.001, ns = not significant.

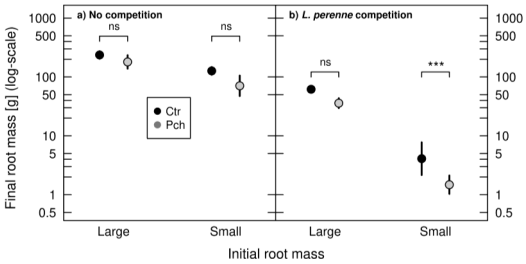

Figure 2. Final root mass of *Rumex obtusifolius* plants grown under no competition (A) and competition from a *L. perenne* sward (B) depending on the initial root mass and *Pyropteron* treatments (no application [Ctr], *P. chrysidiforme* [Pch]). Displayed are means ± standard error. Non-visible standard errors are due to small values. The statistical inference is based on a GLMM. *** P<0.001, ns = not significant.

(Jeangros and Nösberger, 1990). Yet, Niggli *et al.* (1993) have demonstrated a high regrowth potential of *R. obtusifolius* after cutting, even when grown in competition with *L. perenne* and other grass swards.

The high competitive ability of *R. obtusifolius* was attributed to its efficient use of nitrogen and its carbohydrate reserves (Niggli *et al.*, 1993). This finding may explain why in our study small *Rumex* roots had a lower potential to resist competition, as their reserves are small. The herbivory effect, although generally weaker than the competition effect, further suppressed initially small, but not the larger roots when subjected to competition from *L. perenne*.

Conclusions

Combining augmentative biological control and plant competition can reduce the growth of *R. obtusifolius* below its single effects, yet only for small plants. Such combined effects should more often be explored in integrated weed management.

Acknowledgements

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