Effects of different plant parts of invasive *Solidago* species on the germination and growth of native grassland plant species

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Introduction

- Allelopathy involves the production of secondary metabolite biochemical substances by one plant that stimulate or inhibit the germination, growth, and development of adjoining or neighbouring organisms (Bachheti et al. 2020; Rice 1984).
- Allelopathy is an important factor influencing whether an invasive plant species can become successfully established in a new range through disrupting the germination and growth of native plant species (Uddin & Robinson 2017).
- *Solidago gigantea* Aiton (Giant goldenrod) and *Solidago canadensis* L. (Canadian goldenrod) are the most widespread invasive species of North American origin in Central Europe (Meyer 2022; Popay & Parker 2022).

Figure 2. a, *Solidago canadensis* L and **b**,*Solidago gigantea* Aiton (Photos: M Szymura)

Objective

- Analyse the effect of water extracts from *S. canadensis* and *S. gigantea* parts (roots, rhizomes, stems, leaves, and inflorescences) on the germination and initial growth of seedlings of 13 grassland species that typically grow in Central Europe.

Hypotheses

- Native grassland species differ in terms of seed germination and seedling growth under the allelopathic effects of invasive *Solidago* species.
- Impacts on germination and growth of native species vary depending on the *Solidago* plant part used to create extracts.
- *S. canadensis* and *S. gigantea* differ in terms of their allelopathic influence on native grassland species.

Conclusions

- ✓ To reduce the allelopathic effect of *Solidago* during habitat restoration, the aboveground parts should be removed, including fallen leaves, since the leaves have a strong allelopathic effect (Table 2, Fig. 2).
- ✓ Relatively resistant species such as *Daucus carota*, *Leucanhemum vulgare*, *Lolium perenne*, and *Trifolium pratense* should be favoured for site restoration (Fig. 3).
- ✓ Difference in allelopathic effects of leaves versus stems suggest that these two plant parts should be considered separately, and not mixed, in allelopathic trials (Table 2, Fig. 2).

References

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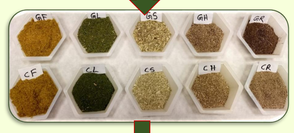
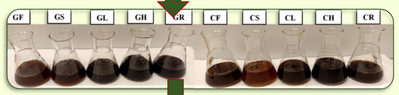
Methodology

1. Air-dried parts of *S. canadensis* and *S. gigantea.*



2. Ground plant material.

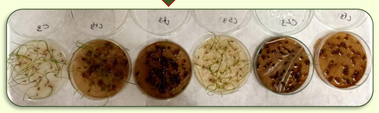
S. canadensis (C) and *S. gigantea* (G) [F = flowers; L = leaves; S = stems; H = rhizomes; R = roots]



3. Prepared 10% aqueous solutions.

4. 50 seeds were sown onto a Petri dishes and soaked with 8 ml of an extract based on *Solidago* plant part or with distilled water (control).

5. Petri dishes were closed and placed in a growth chambers for 21 days.
6. Four replications of a particular combination of grassland species (13) were prepared (572 Petri dishes in total) (Table 1).



7. Hypocotyl and root lengths (cm), and fresh mass of seedlings (g) were measured.

(Photos: PCD Perera)

Data analysis

- Germination percentage of seeds (GP) (ISTA 1985)

$$GP\ \% = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds plated}} \times 100$$

- Inhibition (EI) (Hsu & Chou 1992)

$$EI = \frac{C - T}{C} \times 100$$

where C is the measurement associated with the control for a particular species and T is the measurement associated with a particular treatment

- ➢ Analysed within a generalised linear model framework with glm2 package in the R environment, with assumed normal distribution and identity link.

Table 1. Common grassland species used for the experiment.

No	Species	Abbreviation	Family
1	*Daucus carota* L.	DC	Apiaceae
2	*Leucanthemum vulgare* Lam.	LV	Asteraceae
3	*Campanula patula* L.	CP	Campanulaceae
4	*Lychnis flos-cuculi* L.	LF	Caryophyllaceae
5	*Lotus corniculatus* L.	LC	Fabaceae
6	*Trifolium pratense* L.	TP	Fabaceae
7	*Trifolium repens* L.	TR	Fabaceae
8	*Festuca arundinacea* L.	FA	Poaceae
9	*Festuca pratensis* Huds.	FP	Poaceae
10	*Festuca rubra* L.	FR	Poaceae
11	*Lolium perenne* L.	LP	Poaceae
12	*Phleum pratense* L.	PhP	Poaceae
13	*Poa pratensis* L.	PoP	Poaceae

Results and Discussion

Table 2. Results of statistical comparisons (F and p) for seed germination (Germ_inhib), inhibition of seedling shoot (Shoot_inhib), root (Root_inhib), and weight (Weight_inhib), and their interactions ($p < 0.05$). [a]df = degree of freedom

		Germ_inhib		Shoot_inhib		Root_inhib		Weight_inhib	
	df	F	p	F	p	F	p	F	p
Solidago	1	6.3	0.012	13.3	<0.001	4.0	0.045	14.1	<0.001
Part	4	458.9	<0.001	148.8	<0.001	501.7	<0.001	474.4	<0.001
Species	12	149.5	<0.001	67.8	<0.001	98.3	<0.001	63.7	<0.001
Solidago × Part	4	12.5	<0.001	6.1	<0.001	15.5	<0.001	10.9	<0.001
Solidago × Species	12	4.6	<0.001	13.3	<0.001	3.2	<0.001	2.9	0.001
Part × Species	48	12.2	<0.001	6.8	<0.001	13.9	<0.001	8.4	<0.001
Solidago × Part × Species	48	3.4	<0.001	3.9	<0.001	3.7	<0.001	2.6	<0.001

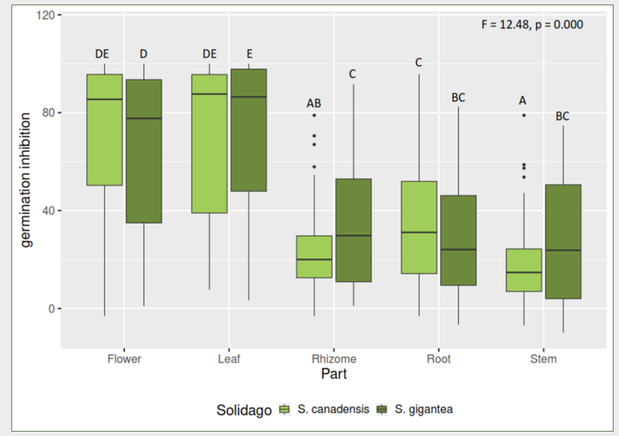


Figure 2. Inhibition of grassland species germination caused by leaf, flower, root, rhizome, and stem extracts of *Solidago* species, and results of tests (F and p). The different letters above boxes indicate significant differences detected by post hoc comparisons.

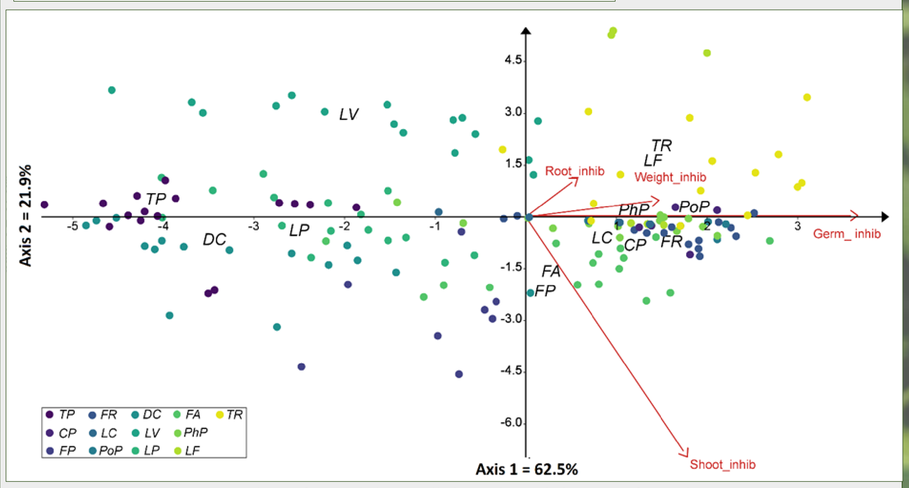


Figure 3. Discriminant analysis for *Solidago* allelopathy inhibition of seed germination, seedling root length, and shoot length and weight of tested grassland species. Species name abbreviations are presented in Table 1. The graph shows the results for merged leaf and flower extracts only.