

Supplementary information

Competitive effects of plant invaders on and their responses to native species assemblages change over time

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This supplementary file includes Table S1-S6 and Figure S1-S3.

Table S1 Alien and native invader species used in the experiment.

Pair	Species	Family	Origin	Native range	Sowing date	Seed source
1	<i>Lepidium virginicum</i> L.	Brassicaceae	alien	North America	17 Feb, 2020	University of Konstanz, Germany
	<i>Lepidium campestre</i> (L.) R. Br.	Brassicaceae	native	-	17 Feb, 2020	University of Konstanz, Germany
2	<i>Setaria faberi</i> RAW Herrm.	Poaceae	alien	Asia	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
	<i>Setaria viridis</i> (L.) P. Beauv.	Poaceae	native	-	17 Feb, 2020	University of Konstanz, Germany
3	<i>Lupinus polyphyllus</i> Lindl.	Fabaceae	alien	North America	17 Feb, 2020	University of Konstanz, Germany
	<i>Trifolium pratense</i> L.	Fabaceae	native	-	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
4	<i>Bromus carinatus</i> Hook. & Arn.	Poaceae	alien	North America	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
	<i>Bromus sterilis</i> L.	Poaceae	native	-	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
5	<i>Solidago gigantea</i> Aiton	Asteraceae	alien	North America	10 Feb, 2020	University of Konstanz, Germany
	<i>Senecio jacobaea</i> L.	Asteraceae	native	-	17 Feb, 2020	University of Konstanz, Germany

Table S2 A, Competitor species used in the experiment; **B**, Combinations of species to produce seven native competitor assemblages for each of the three species-richness levels. The species names are abbreviated as the first three letters of the genus name and the first three letters of the species epithet.

A Species	Family	Sowing date	Seed source
<i>Alopecurus pratensis</i> L.	Poaceae	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
<i>Anthoxanthum odoratum</i> L.	Poaceae	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
<i>Bromus hordeaceus</i> L.	Poaceae	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
<i>Lolium perenne</i> L.	Poaceae	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
<i>Poa pratensis</i> L.	Poaceae	17 Feb, 2020	Rieger-Hofmann GmbH, Germany
<i>Prunella vulgaris</i> L.	Lamiaceae	10 Feb, 2020	Rieger-Hofmann GmbH, Germany
<i>Plantago lanceolata</i> L.	Plantaginaceae	17 Feb, 2020	Rieger-Hofmann GmbH, Germany

B	One-species assemblage							Two-species assemblage							Four-species assemblage							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
<i>Alo.pra</i>	■							■						■	■				■	■	■	
<i>Ant.odo</i>		■						■	■						■	■					■	■
<i>Bro.hor</i>			■						■	■					■	■	■					■
<i>Lol.per</i>				■						■	■				■	■	■	■				
<i>Poa.pra</i>					■						■	■				■	■	■	■			
<i>Pru.vul</i>						■						■	■				■	■	■	■		
<i>Pla.lan</i>							■						■	■					■	■	■	■

Table S3 Effects of invader origins (alien or native), species richness of the competitor assemblage (1, 2 or 4 species), harvesting time (week 4, week 8 or week 12) and their interactions on proportional aboveground biomass of invader plants. For the factor Species richness, we created two orthogonal contrasts ($R_{\text{One-/Multi-species}}$: one-species assemblage vs. average of two- and four-species assemblages, $R_{\text{Two-/Four-species}}$: two-species assemblages vs. four-species assemblages).

	<i>df</i>	Proportional aboveground biomass of invader	
		χ^2	<i>P</i>
<i>Fixed effects</i>			
Initial leaf area of invader	1	17.446	<0.001
Origin of invader (O)	1	1.236	0.266
Species richness of assemblage (R)	2	0.799	0.671
$R_{\text{One-/Multi-species}}$	1	0.663	0.416
$R_{\text{Two-/Four-species}}$	1	0.145	0.704
Time of harvest (T)	2	1.618	0.445
O × R	2	2.643	0.267
O × $R_{\text{One-/Multi-species}}$	1	1.706	0.192
O × $R_{\text{Two-/Four-species}}$	1	0.965	0.326
O × T	2	1.851	0.396
R × T	4	5.276	0.260
$R_{\text{One-/Multi-species}} \times T$	2	2.893	0.235
$R_{\text{Two-/Four-species}} \times T$	2	2.369	0.306
O × R × T	4	0.906	0.924
O × $R_{\text{One-/Multi-species}} \times T$	2	0.129	0.938
O × $R_{\text{Two-/Four-species}} \times T$	2	0.782	0.676
<i>Random effects</i>		SD	
Invader family		0.090	
Invader species [†]		0.095	
Assemblage identity [†]		0.040	
Residual		0.073	

Values are in bold when $P < 0.05$. [†] Shown are the standard deviation (SD) of *Lepidium virginicum* and the SD of the one-species assemblage of *Lolium perenne*. The SDs of all invader species and assemblage identities are shown in Table S6.

Table S4 Effects of invader origins (alien or native), presence and species richness of the competitor assemblage (0, 1, 2 or 4 species) and their interactions on belowground biomass and root weight ratio (RWR) of invader plants at the first harvest time (week 4). For the factor Species richness, we created three orthogonal contrasts ($R_{\text{Without/With}}$: without competitors vs. average of one-, two- and four-species assemblages, $R_{\text{One-/Multi-species}}$: one-species assemblages vs. average of two- and four-species assemblages, $R_{\text{Two-/Four-species}}$: two-species assemblages vs. four-species assemblages).

	<i>df</i>	Belowground biomass		RWR	
		χ^2	<i>P</i>	χ^2	<i>P</i>
<i>Fixed effects</i>					
Initial leaf size of invader	1	11.541	0.001	0.850	0.357
Origin of invader (O)	1	0.283	0.595	0.239	0.625
Species richness of assemblage (R)	3	6.349	0.096	3.898	0.273
$R_{\text{Without/With}}$	1	6.267	0.012	0.872	0.350
$R_{\text{One-/Multi-species}}$	1	0.059	0.808	0.165	0.685
$R_{\text{Two-/Four-species}}$	1	0.007	0.932	2.863	0.091
$O \times R$	3	1.481	0.687	2.029	0.566
$O \times R_{\text{Without/With}}$	1	0.001	0.972	1.381	0.240
$O \times R_{\text{One-/Multi-species}}$	1	1.436	0.231	0.101	0.750
$O \times R_{\text{Two-/Four-species}}$	1	0.061	0.805	0.560	0.454
<i>Random effects</i>		SD		SD	
Invader family		0.106		0.034	
Invader species [†]		0.085		0.036	
Assemblage identity		0.015		0.000	
Residual		0.080		0.048	

Values are in bold when $P < 0.05$. [†] Shown is the standard deviation (SD) of *Lepidium virginicum*. The SDs of all invader species are shown in Table S6.

Table S5 Effects of invader types treatment (without invader, alien or native invader), species richness of competitor assemblage (1, 2 or 4 species) and their interactions on belowground biomass and root weight ratio (RWR) of the native competitor assemblage at the first harvest time (week 4). For the factor Invader, we created two orthogonal contrasts ($I_{\text{Without/With}}$: without vs. with invader, $I_{\text{Alien/Native}}$: with alien vs. with native invader). For the factor Species richness, we created two orthogonal contrasts ($R_{\text{One-/Multi-species}}$: one-species assemblages vs. average of two- and four-species assemblages, $R_{\text{Two-/Four-species}}$: two-species assemblages vs. four-species assemblages).

	<i>df</i>	Belowground biomass		RWR	
		χ^2	<i>P</i>	χ^2	<i>P</i>
<i>Fixed effects</i>					
Invader treatment (I)	2	0.468	0.791	3.527	0.171
$I_{\text{Without/With}}$	1	0.345	0.557	0.053	0.818
$I_{\text{Alien/Native}}$	1	0.127	0.721	3.497	0.061
Species richness of assemblage (R)	2	0.639	0.726	0.169	0.919
$R_{\text{One-/Multi-species}}$	1	0.609	0.435	0.028	0.868
$R_{\text{Two-/Four-species}}$	1	0.033	0.857	0.140	0.708
$I \times D$	4	2.491	0.646	4.822	0.306
$I_{\text{Without/With}} \times R_{\text{One-/Multi-species}}$	1	0.258	0.612	1.956	0.162
$I_{\text{Without/With}} \times R_{\text{Two-/Four-species}}$	1	0.095	0.758	0.475	0.491
$I_{\text{Alien/Native}} \times R_{\text{One-/Multi-species}}$	1	0.085	0.770	0.278	0.598
$I_{\text{Alien/Native}} \times R_{\text{Two-/Four-species}}$	1	2.143	0.143	2.128	0.145
<i>Random effects</i>		SD		SD	
Invader family		0.000		0.004	
Invader species		0.030		0.012	
Assemblage identity [†]		0.102		0.021	
Residual		0.055		0.015	

[†] Shown is the standard deviation (SD) of the one-species assemblage of *Lolium perenne*. The SDs of all assemblage identities are shown in Table S6.

Table S6 The SDs of the ten invader species and/or 21 assemblage identities from the models shown in Tables 1, 2, S3, S4 and S5.

		Table 1 [†]	Table 2 [‡]		Table S3 [§]	Table S4 [†]		Table S5 [‡]	
Invader species	<i>Lepidium virginicum</i>	0.314	-	-	0.095	0.085	0.036	-	-
	<i>Lepidium campestre</i>	0.303	-	-	0.083	0.057	0.026	-	-
	<i>Setaria faberi</i>	0.809	-	-	0.048	0.174	0.036	-	-
	<i>Setaria viridis</i>	0.618	-	-	0.057	0.136	0.044	-	-
	<i>Lupinus polyphyllus</i>	0.279	-	-	0.088	0.112	0.086	-	-
	<i>Trifolium pratense</i>	0.565	-	-	0.096	0.069	0.022	-	-
	<i>Bromus carinatus</i>	0.442	-	-	0.093	0.116	0.030	-	-
	<i>Bromus sterilis</i>	0.471	-	-	0.106	0.102	0.030	-	-
	<i>Solidago gigantea</i>	0.518	-	-	0.140	0.089	0.045	-	-
	<i>Senecio jacobae</i>	0.328	-	-	0.079	0.068	0.040	-	-
One-species assemblages	<i>Lolium perenne</i> (Lp)	-	0.083	0.048	0.040	-	-	0.102	0.021
	<i>Alopecurus pratensis</i> (Ap)	-	0.124	0.061	0.063	-	-	0.229	0.056
	<i>Bromus hordeaceus</i> (Bh)	-	0.154	0.085	0.052	-	-	0.251	0.040
	<i>Anthoxanthum odoratum</i> (Ao)	-	0.121	0.055	0.060	-	-	0.179	0.029
	<i>Poa pratensis</i> (Pp)	-	0.126	0.088	0.080	-	-	0.121	0.051
	<i>Prunella vulgaris</i> (Pv)	-	0.147	0.094	0.053	-	-	0.172	0.067
	<i>Plantago lanceolata</i> (Pl)	-	0.140	0.077	0.052	-	-	0.231	0.026

Competitor-assemblage identity	Two-species assemblages	<i>Lp-Pp</i>	-	0.115	0.063	0.056	-	-	0.248	0.069
		<i>Ap-Pl</i>	-	0.096	0.055	0.050	-	-	0.136	0.034
		<i>Bh-Ao</i>	-	0.097	0.078	0.059	-	-	0.205	0.047
		<i>Ap-Pv</i>	-	0.123	0.071	0.042	-	-	0.143	0.041
		<i>Bh-Pp</i>	-	0.091	0.060	0.055	-	-	0.256	0.071
		<i>Ao-Pl</i>	-	0.126	0.061	0.056	-	-	0.175	0.044
		<i>Lp-Pv</i>	-	0.113	0.061	0.073	-	-	0.148	0.049
	Four-species assemblages	<i>Lp-Bh-Ao-Pl</i>	-	0.079	0.052	0.043	-	-	0.149	0.033
		<i>Ap-Bh-Pp-Pv</i>	-	0.111	0.063	0.076	-	-	0.141	0.050
		<i>Lp-Bh-Pp-Pv</i>	-	0.108	0.051	0.059	-	-	0.133	0.037
		<i>Lp-Ap-Ao-Pl</i>	-	0.109	0.058	0.044	-	-	0.172	0.035
		<i>Ap-Ao-Pp-Pl</i>	-	0.093	0.045	0.054	-	-	0.126	0.056
		<i>Lp-Bh-Pv-Pl</i>	-	0.097	0.058	0.049	-	-	0.235	0.053
		<i>Ap-Ao-Pp-Pv</i>	-	0.122	0.065	0.068	-	-	0.193	0.056

Variance structure: † invader species were allowed to have different variances by using the *varIdent* function; ‡ assemblage identities were allowed to have different variances by using the *varIdent* function; § invader species and assemblage identities were allowed to have different variances by using the *varComb* and *varIdent* functions.

Figure S1 Belowground biomass (**A**) and root weight ratio (RWR, **B**) of invaders in the absence or presence of native competitor assemblages of different species richness at the first harvest (week 4). Shown are means (\pm SEs) of the raw data.

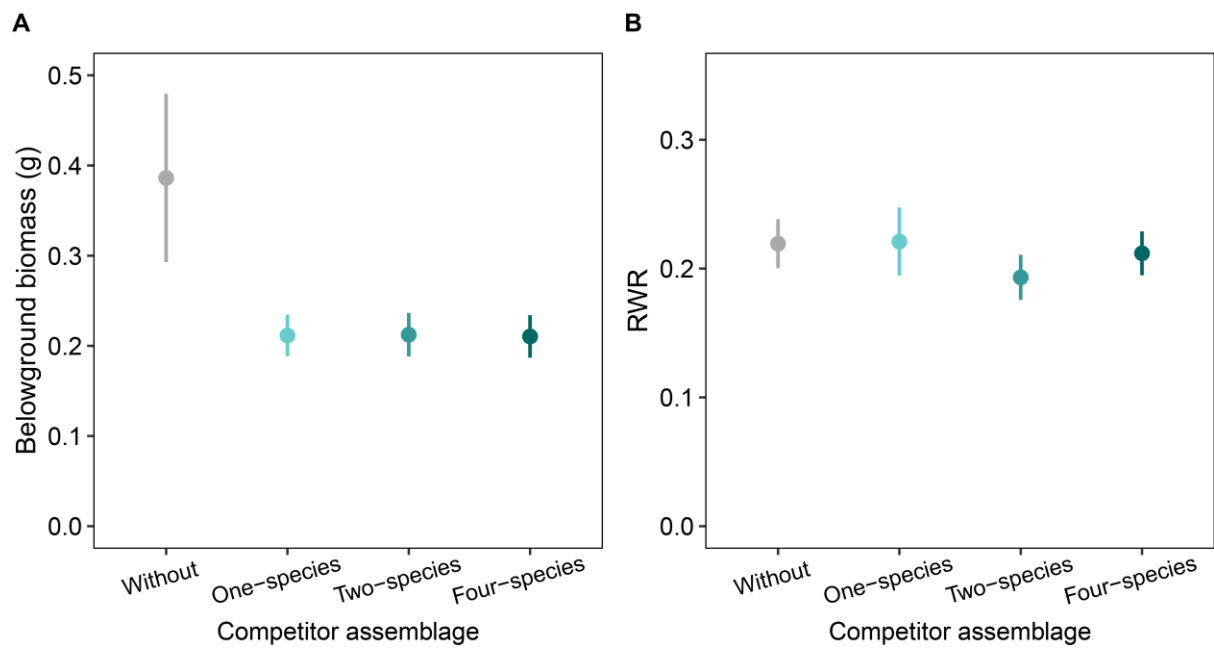


Figure S2 Belowground biomass (**A**) and root weight ratio (RWR, **B**) of the competitor assemblage in the absence or presence of alien and native invader species at the first harvest (week 4). Shown are means (\pm SEs) of the raw data.

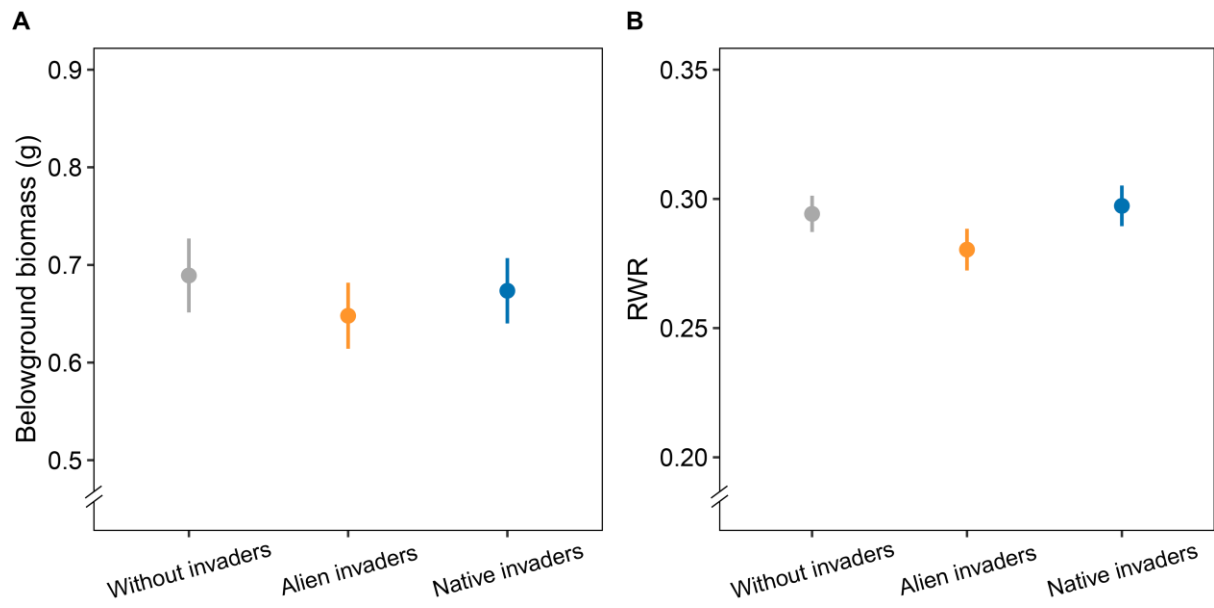


Figure S3 Aboveground biomass of each of 21 native competitor-assembly combinations in the absence or presence of alien and native invaders at each of the three harvests. Shown are means (\pm SEs) of the raw data.

