Ecological Archives E087-055-A1

M. Zeiter, A. Stampfli, and D. M. Newbery. 2006. Recruitment limitation constrains local species richness and productivity in dry grassland. *Ecology* 87:942–951.

Appendix A. Habitat quality and soil conditions at the three study sites in southern Switzerland. All values were backtransformed after ANOVA, except for bare ground. Means not sharing lettered superscripts differed significantly (df = 2, 27; $P < 0.01$; except for productivity and bare ground $P < 0.05$). Soil samples from representative profiles in close vicinity of experimental plots (H. Pestalozzi, *unpublished data*).

	Negrentino	Poma	San Giorgio	*F*	*P*
Annual productivity (g/m^2)	331.6^a	285.4^b	207.3^c	27.43	< 0.001
Gaps (%)	70.9^a	56.4^b	64.9^b	14.15	< 0.001
Bare ground (%)	14.8^a	0.6^c	3.6^b	54.1	< 0.001
Radiation (W/m^2)					
annual mean	5686^c	7404^a	6179^b	21.84	< 0.001
summer mean	4081^b	4882^a	3887^b	14.64	< 0.001
within-site range	2352	1283	3159	.	.
Soil pH †	5.4-6.6	5.0-5.5	5.7-7.2	.	.
Clay content ‡ (%)	29	23	70	.	.
Available water capacity §(mm)	222	127	96	.	.
Adsorbed Al-cations ‖ (mg/kg)	2-21	179-492	0-4	.	.
Adsorbed Ca-cations ‖ (g/kg)	0.3-2.7	0.5-1.0	5.1-8.3	.	.
Annual precipitation sum (mm)	1731	2074	1871	.	.

† Range of samples across all layers containing roots (A, B, BC-strata), potentiometric measurements in water.

‡ Using pipette method, Gupta S., and H. Häni 1989. Methoden für Bodenuntersuchungen. Schriftenreihe der Eidg. Forschungsanstalt für Agrikulturchemie und Umwelthygiene, Liebefeld-Bern.

§ Estimates averaged by layers using tables from AG Bodenkunde 1982. Bodenkundliche Kartieranleitung. Third Edition, Hannover.

|| Range of samples across all layers containing roots (A, B, BC-strata), measured in a 1 N NH_4Cl extract using a IPC-atomemission spectrometer (Bausch & Lomb ARL 3580, New York, USA).

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Appendix B. The sown species, their provenances, results of seed mass measurements, methods and results of germination tests, and the occurrence of established populations in the study sites. Origin of seed from Negrentino (N), Poma (P) and San Giorgio (S), seed mass of the 1998 collection, and deviation in seed mass of the 1999 collection (asterisks indicating significant differences in seed mass between years). Conditions for germination tests in the laboratory: seeds placed on top of paper (t) or between pleated paper (p); temperature regime, dormancy breaking pre-treatments, chilling (chill), scarification (scar), gibberellic acid (GA), and duration (D) of test. G is the number of germinated seeds (out of 100) and L the number of living, but dormant seeds at end of testing in 1998 (98) or 1999 (99). Occurrence of species in established vegetation within plots of study sites (p), at study site but not within the plots studied (l, local species pool) or in the surroundings of sites (r, regional species pool).

Species	Origin	Seed mass		Laboratory test								Occurrence		
		1998	99-98	Conditions		Pre-treatment (98/99)	D	G98	L98	G99	L99			
		(mg)	(%)		(°C)		(d)	(%)	(%)	(%)	(%)	N	P	S
Agrostis capillaris	N	0.089	5*	t	20-30	chill 10° 7d; KNO_3	14	68	-	94	-	p	p	.
Anthyllis vulneraria	N	3.989	-2	p	20	scar	45	80	5	67	-	p	r	r
Asphodelus albus	P	13.579	-3*	p	20-30	chill 10° 7d	65	3	39	0	78	.	p	.
Brachypodium pinnatum	P	3.465	-7*	p	15-25	chill 10° 7d	42	56	12	54	-	p	p	p
Bromus erectus	NPS	5.329	9*	t	15-25	chill 10° 7d	14	92	2	93	-	p	l	p
Carex flacca	S	1.018	-31*	t	15-25	chill 5° 28d	21	0	61	3	45	.	.	p
Centaurea nigrescens	P	2.673	5*	t	15-25	.	28	80	12	67	16	l	p	r
Danthonia alpina	S	3.122	0	t	15-25	chill 10° 7d	42	2	79	12	47	.	.	p

Dianthus carthusianorum	P	0.824	5*		t	20-30	chill 10° 7d	14		88	9	94	-		p	r	.
Dorycnium herbaceum	S	1.551	-1		t	20	scar / -	42		21	-	6	64		.	.	r
Galium rubrum	P	0.523	4*		t	15-25	chill 10° 7d	42		41	10	74	-		p	r	.
Helianthemum nummularium	P	1.114	5*		t	20-30	KNO_3	28		4	88	5	-		p	l	p
Hypochaeris radicata	P	1.164	3		p	15-25	GA	28		91	7	94	5		p	l	.
Peucedanum oreoselinum	P	4.674	-9*		p	20-30	chill 10° 7d	42		16	67	24	-		r	p	p
Phyteuma betonicifolium	P	0.041	21*		t	20-30	chill 5° 7d; KNO_3	70		82	-	46	-		p	p	.
Plantago lanceolata	N	1.800	-5*		p	20-30	- / chill 5° 7d; GA	28		12	84	79	7		p	r	.
Primula veris	N	0.778	-4*		t	20-30	chill 10° 7d; KNO_3	21		0	100	0	100		p	.	.
Rhinanthus alectorolophus	N	2.573	11*		p	15-25	chill 5° 28d	45		0	82	5	86		p	r	r
Sanguisorba minor	N	5.129	3		p	15-25	GA	28		59	28	51	-		p	r	p
Scabiosa columbaria	N	1.902	8*		p	15-25	.	28		87	-	83	-		p	r	r
Silene nutans	N	0.442	14*		t	15-25	.	28		81	10	97	-		p	p	.
Thalictrum minus	N	1.662	13*		t	15-25	chill 5° 7d; GA	42		39	11	55	11		p	.	.

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Appendix C. Establishment success of seedlings emerged from the soil seed bank at the three study sites in southern Switzerland, (a) Negrentino, (b) Poma and (c) San Giorgio, two years after the beginning of the experiment in 1998 or 1999. Number of established individuals in the control plots (sum and median, *n* = 10 plots) and frequency of plots with spontaneously established individuals (*n* = 10 plots). An asterisk indicates species with underestimated number of established individuals.

(a) Negrentino

Species	Sum			Median			Frequency	
	1998	1999		1998	1999		1998	1999
Agrostis capillaris	0	7		0	1		0	6
Anthoxanthum odoratum	23	8		1	0.5		7	5
Anthyllis vulneraria	9	6		1	0		6	4
Ajuga reptans	1	0		0	0		1	0
Arabis ciliata	4	1		0	0		1	1
Helictotrichon pubescens	7	3		0	0		4	2
Bromus erectus	0	3		0	0		0	2
Campanula rotundifolia	9	9		0	0		3	4
Carex montata	1	0		0	0		1	0
Carex sp.	2	2		0	0		2	2
Centaurea nigrescens	7	1		0	0		3	1
Clinopodium vulgare	53	10		2.5	0		7	2
Danthonia decumbens	6	3		0	0		3	3
Daucus carota	2	1		0	0		2	1
Festuca sp.	4	7		0	0.5		2	5
Galium rubrum	1	0		0	0		1	0
Helianthemum nummularium	98	119		9.5	9		10	10

Hippocrepis comosa	16	6		0	0	3	2
Holcus lanatus	2	2		0	0	2	2
Hypericum perforatum	1	0		0	0	1	0
Hypochaeris radicata	10	12		0	1	2	6
Leontodon hispidus	5	5		0	0	4	3
Leucanthemum vulgare aggr.	13	9		0	0	4	4
Lotus corniculatus	7	16		0.5	1	5	6
Luzula campestris	1	0		0	0	1	0
Phyteuma betonicifolium	15	13		1	1.5	7	7
Pimpinella saxifraga	29	4		1	0	7	3
Plantago lanceolata	81	54		3.5	6	9	10
Potentilla erecta *	121	45		11.5	3.5	10	7
Potentilla pusilla	28	48		2	4.5	9	8
Primula veris	2	5		0	0	2	4
Prunella vulgaris	0	4		0	0	0	1
Prunella grandiflora	2	5		0	0	1	2
Ranunculus bulbosus	12	14		0	0.5	4	5
Rumex acetosa	21	10		0.5	1	5	6
Salvia pratensis	0	1		0	0	0	1
Sanguisorba minor	34	27		0.5	0.5	5	5
Scabiosa columbaria	0	2		0	0	0	1
Silene nutans	149	92		16.5	4.5	10	10
Solidago virgaurea	17	1		1	0	7	1
Taraxacum officinale	1	0		0	0	1	0
Trifolium pratense	6	6		0	0	3	2
Trifolium montanum	1	0		0	0	1	0
Trifolium repens	1	2		0	0	1	2
Thymus pulegioides	22	21		0	1	4	6
Viola hirta *	169	64		17.5	4	10	6
Viola riviniana	39	15		2	0.5	8	5
Veronica spicata	1	0		0	0	1	0

unknown	1	1		0	0		1	1
all species	1034	664		93	64.5		.	.

(b) Poma

Species	Sum			Median			Frequency	
	1998	1999		1998	1999		1998	1999
Ajuga reptans	0	4		0	0		0	2
Anthoxanthum odoratum	0	1		0	0		0	1
Carex montana	3	8		0	0		1	2
Centaurea nigrescens	5	1		0	0		3	1
Cirsium erisithales	0	2		0	0		0	2
Cruciata glabra	0	3		0	0		0	2
Dactylis glomerata	0	2		0	0		0	1
Genista tinctoria	2	0		0	0		1	0
Lotus corniculatus	2	1		0	0		2	1
Luzula campestis	0	7		0	0		0	3
Phyteuma betonicifolium	15	17		1	0.5		6	5
Potentilla erecta *	26	40		2.5	1.5		6	7
Rumex acetosa	1	4		0	0		1	3
Silene nutans	3	3		0	0		3	1
Solidago virgaurea	16	14		0	0		3	3
Stellaria graminea	0	2		0	0		0	1
Thesium bavarum	1	1		0	0		1	1
Thymus pulegioides	0	2		0	0		0	1
Trifolium pratense	1	0		0	0		1	0
Veronica officinalis	0	1		0	0		0	1
Viola hirta	8	16		0	0		4	3
unknown	0	2		0	0		0	2

all species	83	131		5	7		.	.

(c) San Giorgio

Species	Sum			Median			Frequency	
	1998	1999		1998	1999		1998	1999
Briza media	0	1		0	0		0	1
Bromus erectus	1	0		0	0		1	0
Carex montana	3	2		0	0		2	2
Centaurea bracteata	3	0		0	0		2	0
Centaurea nigrescens	0	2		0	0		0	1
Danthonia decumbens	2	37		0	3.5		2	8
Erica carnea	0	1		0	0		0	1
Genista sp.	2	0		0	0		2	0
Globularia punctata	1	0		0	0		1	0
Helianthemum nummularium	1	2		0	0		1	2
Hippocrepis comosa	0	1		0	0		0	1
Linum catharticum	6	5		0	0		4	3
Lotus corniculatus	3	0		0	0		3	0
Molinia arundinacea	0	1		0	0		0	1
Peucedanum cervaria	0	1		0	0		0	1
Polygala chamaedrys	4	2		0	0		3	1
Polygala pedemontana	35	25		3	2		9	8
Potentilla alba	7	21		0	1.5		4	6
Potentilla erecta	10	18		1	1		6	7
Prunella grandiflora	0	1		0	0		0	1
Sanguisorba minor	0	2		0	0		0	2
Viola hirta	4	1		0	0		3	1
unknown	1	1		0	0		1	1

all species	83	124		8.5	11.5		.	.

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Appendix D. Effects of sowing year and year × site interaction on the performance of the sown species three years after sowing. Year of significantly higher seedling emergence, survival, establishment and growth are indicated with the year × site interaction. Asterisks indicate significant differences at $P < 0.05$ (*), $P < 0.01$ (**) and $P < 0.001$ (***).

	Germination		Survival		Establishment		Growth	
	year	y × s	year	y × s	year	y × s	year	y × s
Agrostis capillaris	99*	*	.	.	98*	.	.	.
Anthyllis vulneraria	99**	*	.	.	.	.	.	***
Asphodelus albus	.	.	99*	*	99*	.	99*	*
Brachypodium pinnatum	.	.	.	*	.	.	.	**
Bromus erectus	.	.	.	.	.	.	.	.
Carex flacca								
Centaurea nigrescens	99***	.	.	.	99*	.	.	.
Danthonia alpina	.	.	.	.	.	.	.	.
Dianthus carthusianorum	.	.	98*	.	98**	.	98*	.
Dorycnium herbaceum	.	.	98***	.	98***	.	98**	**
Galium rubrum	.	.	98***	***	.	***	.	.
Helianthemum nummularium	99***	.	98***	.	.	.	.	***
Hypochaeris radicata	.	.	98***	.	98**	.	98**	.
Peucedanum oreoselinum	99***	***	98***	.	99*	***	.	.
Phyteuma betonicifolium	.	**	98**	.	98***	.	.	*
Plantago lanceolata	.	.	98***	***	98***	***	.	.
Primula veris	99**	.	.	*	.	.	.	*
Rhinanthus alectorolophus	99***	.						
Sanguisorba minor	.	.	98**	.	.	.	99*	.

Scabiosa columbaria	.	.		98*	*		98**	.		.	*
Silene nutans	.	*		98**	*		98*	.		.	**
Thalictrum minus	99***	.		.	.		99***	.		.	.

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Appendix E. Performance of 22 species three years after sowing in 1998 and 1999 at Negrentino. Number of established individuals per plot in autumn (mean, $n = 10$). Mass per individual (sum of summer and autumn means) and annual phytomass per plot (sum over all individuals harvested in summer and autumn).

	Number			Individual mass (mg)			Phytomass per plot (g)	
	1998	1999		1998	1999		1998	1999
Agrostis capillaris	6	3		161	150		1.31	0.69
Anthyllis vulneraria	16	15		2057	1487		36.02	29.98
Asphodelus albus	11	17		18	14		0.23	0.25
Brachypodium pinnatum	6	6		32	36		0.17	0.23
Bromus erectus	78	80		72	102		6.17	9.82
Carex flacca	0	0		.	.		0	0
Centaurea nigrescens	30	29		646	456		18.15	12.49
Danthonia alpina	4	4		16	24		0.07	0.10
Dianthus carthusianorum	39	30		91	72		3.79	2.31
Dorycnium herbaceum	1	0		19	1		0.01	0.00
Galium rubrum	15	18		285	237		4.67	4.40
Helianthemum nummularium	9	12		151	201		1.44	2.72
Hypochaeris radicata	21	15		1038	473		23.47	7.86
Peucedanum oreoselinum	13	6		125	113		1.44	0.49
Phyteuma betonicifolium	5	1		1	0		0.01	0.00
Plantago lanceolata	9	10		509	567		4.42	7.78
Primula veris	15	22		3	7		0.04	0.19
Rhinanthus alectorolophus	.	.		435	.		1.02	0

Sanguisorba minor	8	6		76	84		0.59	0.57
Scabiosa columbaria	26	15		666	637		16.84	10.03
Silene nutans	17	12		13	20		0.29	0.36
Thalictrum minus	8	14		2	7		0.02	0.12

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