Productivity and feeding value of species-rich grassland mixtures vs ryegrass

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Summary

Vegetation dynamics, sward productivity, and mineral composition and feeding value of herbage of two species-rich grasslands and a *Lolium perenne* sward were studied from 2006 to 2010. To this end three seed mixtures were sown: 1) nine grass species, three legumes and four herbs; 2) nine grass species mixed with native seeds harvested from an *Arrhenatheretum elatioris* community; 3) four grass species dominated by *L. perenne.* Each seed mixture was combined with three different fertilization treatments: a) no fertilization; b) application of cattle slurry; c) application of potassium (K). It was concluded that the sowing of species-rich seed mixtures could speed up the creation of a species-rich vegetation. Under low-fertilized conditions, species-rich grasslands can compete with *L. perenne* dominated swards for productivity and mineral composition of the herbage, but not for herbage feeding value.

Key words: Species-rich grassland, reintroduction, vegetation dynamics, productivity, feeding value, mineral composition

Introduction

During the last decades, the biodiversity of grasslands has decreased dramatically primarily due to intensification of farming (Tscharntke *et al.*, 2005; Isselstein *et al.*, 2005). After a long period of intensive grassland management with frequent grassland reseeding, rotation of grassland with maize, high fertilization rates and the use of pesticides, most species of semi-natural vegetation types have disappeared. Reducing soil fertility is generally not sufficient for the restoration of species-rich grasslands, since seeds of species of the original vegetation are often absent. Restoration management by refraining from fertilizer inputs and stimulating natural generation could be successful, but it may take many years before the desired vegetation will be achieved (Olff & Bakker, 1991; Oomes *et al.*, 1996). To speed up the regeneration, re-introduction of seeds could be an option (Korevaar *et al.*, 2004). Previous experiments showed a successful establishment of introduced seeds and a good persistence of most species (Korevaar & Geerts, 2009).

It has been observed by Fisher *et al.* (1996); Hopkins & Holz (2006); Van Ruijven & Berendse (2003); Korevaar & Geerts (2007) and Pirhofer-Walzl *et al.* (2011) that under more extensive conditions, due to the performance of legumes and herbs in those swards, the productivity, feeding value and mineral composition of species-rich swards could be fairly high compared to swards dominated by *L. perenne*, which is the most common grass species on grassland farms in Western Europe. To study the value of species-rich swards for biodiversity and nutritional quality of herbage we conducted a field experiment to compare species-rich swards with a *L. perenne* sward.

Materials and Methods

In October 2005 three grass mixtures were sown to compare productivity, feeding value and mineral composition of species-rich swards with a *L. perenne* sward. The field experiment was established in St Anthonis on a dry sandy soil which had been used for many years for maize production. The organic matter content of the topsoil (0-10 cm) was 2.1%, the pH-KCl was 4.7 and nitrogen supplying capacity of the soil (the amount of nitrogen released in the growing season by soil organic matter mineralization) was 47 kg N ha^{-1}. Three different seed mixtures were sown: SM1: a seed mixture of nine grass species, three legumes and four herbs; SM2: seeds of nine grass species mixed with native seeds harvested from an *Arrhenatheretum elatioris* community: SM3: a seed mixture of four grasses dominated by *L. perenne*.

To each seed mixture three different fertilization treatments were applied: a) no application of fertilizer (control); b) application of cattle slurry after the first cut (20 tonnes ha^{-1}; calculated effective fertilization from the slurry for grass production: 24 kg N, 10 kg P and 74 kg K ha^{-1}); c) application of 83 kg ha^{-1} potassium (K) after the first cut, no phosphorus (P) was applied in this treatment as the P content of the soil was already very high (8.1 mg P kg^{-1} analyzed as plant available phosphorus (P-PAE) by means of 0.01 M CaCl2 extraction (Houba *et al.*, 2000)). Plot size was 9 m x 10 m with three replicates per treatment. The swards were cut twice or three times per year from 2006 to 2010. The fresh grass was weighed and analyzed for dry-matter content, chemical composition and a number of feeding value parameters. Botanical composition was monitored yearly before the first cut on 25 m^2 of each plot according to the Braun-Blanquet cover-abundance scale (Braun-Blanquet, 1964).

The data for 2008 were excluded from the statistical analyses, because in that year only the dry-matter production was measured without further analyses of the grass composition. Most plots suffered in 2009 from an outbreak of *Phyllopertha horticola* (Garden Chafer) larvae, followed by a *Meles meles* (European Badger) searching for the larvae and damaging the sward. In combination with drought this resulted in parts of the experiment with an irregular vegetation cover and a low production in years 2009 and 2010. We therefore decided to analyze the data of 2009 and 2010 separately from the data of 2006 and 2007.

Results

The botanical composition showed an overall increase in plant species numbers between 2006 and 2010, with the largest species diversity for SM2 (21.9 species per 25 m^2) compared to SM3 and SM1 with 13.9 and 15.5 species per 25 m^2, respectively (Table 2). In all treatments the proportion of *L. perenne* decreased markedly and the proportion of *Holcus lanatus, Anthoxanthum odoratum, Poa pratensis, Leucanthemum vulgare, Centaurea jacea* and *Rumex acetosella* increased. The latter species are all typical for more extensive grassland management without grazing (Table 3).

Table 1. Sown species in the three seed mixtures. SM2 contains seeds harvested in a nature reserve, the composition of this mixture is not known in detail.

Scientific name	Common name	Seed mixture		
		SM1	SM2	SM3
Seed quantity		20 kg ha^{-1}	22 kg ha^{-1}	35 kg ha^{-1}
Grasses (% of seed quantity)		**73**	**85**	**100**
Festuca pratensis	Meadow Fescue	10	7	14
Lolium perenne	Perennial Rye-grass	30	22	69
Holcus lanatus	Yorkshire-fog		4	
Arrhenatherum elatius	False Oat-grass	3	3	
Trisetum flavescens	Yellow Oat-grass	3	2	
Cynosurus cristatus	Crested Dog's-tail	7	25	
Dactylis glomerata	Cock's-foot		1	
Anthoxanthum odoratum	Sweet Vernal-grass	1	2	
Festuca rubra	Red Fescue		2	
Phleum pratense subsp. pratense	Timothy	7	5	14
Poa pratensis	Smooth Meadow-grass	6	6	3
Poa trivialis	Rough Meadow-grass	6	6	
Legumes (% of seed quantity)		**24**	**5**	
Lotus corniculatus var. corniculatus	Common Bird's-foot-trefoil		x[1]	
Trifolium dubium	Lesser Trefoil		x	
Trifolium pratense	Red Clover	4	x	
Lotus corniculatus cv. Agrosan+Leo	Common Bird's-foot-trefoil	19		
Trifolium repens	White Clover	1		
Herbs (% of seed quantity)		**2**	**10**	
Prunella vulgaris	Selfheal		x	
Cerastium fontanum subsp. vulgare	Common Mouse-ear		x	
Leucanthemum vulgare	Oxeye Daisy	sp[2]	x	
Hypochaeris radicata	Cat's-ear		x	
Achillea millefolium	Yarrow	sp	x	
Crepis biennis	Rough Hawk's-beard		x	
Leontodon saxatilis	Lesser Hawkbit		x	
Ranunculus bulbosus	Bulbous Buttercup		x	
Centaurea jacea	Brown Knapweed		x	
Bellis perennis	Daisy		x	
Rumex acetosella	Sheep's Sorrel		x	
Plantago lanceolata	Ribwort Plantain	1	x	
Rumex acetosa	Common Sorrel		x	
Leontodon autumnalis	Autumn Hawkbit	sp		

[1] x = seeds of species in seed mixture but quantity not known.

[2] sp = sown species, seed quantity less than 1%.

SM1 had a significantly higher productivity (averaged over the fertilization treatments 4,991 kg dry matter ha^{-1} yr^{-1}), than SM2 and SM3 with 4,166 and 3,770 kg ha^{-1} yr^{-1}, respectively. As a result of the higher dry-matter production the uptake of N, P and K by the herbage was also higher for SM1. Also the N content of the herbage of SM1 (17.51 g dry matter kg^{-1}) was higher than the N content of the herbage of SM2 and SM3. The P and K contents showed no significant differences among the mixtures. The mineral content of herbage of SM1 was higher for Na, Ca, Mg and Zn than of SM3. The S content was highest for SM3 and the Mn content for SM2.

Application of cattle slurry or potassium resulted in a significantly higher dry-matter production, but not in differences in species numbers (Table 2). Slurry application resulted in a higher P and K uptake by the herbage, but not a higher N uptake. It resulted also in a higher K content of the herbage. However, the mineral content of the herbage was higher for Na, Ca, Mg and S on the unfertilized (control) plots. The lower dry-matter production in 2009 and 2010 resulted in higher herbage contents of Na, Ca, Mg, MN, Zn and Fe and lower contents of N, P, K and S.

The net energy yield, expressed in MJ ha^{-1}, was significantly higher for SM1 as a result of the high dry-matter production, but net energy content of the herbage was higher for SM3 (5.33 MJ kg^{-1} dry matter) than that of SM1 and SM2 with 4.97 and 4.87 MJ kg^{-1} dry matter, respectively. Also for intestinal digestible protein (PDI), sugar and lysine herbage of SM3 had the highest quality. Fertilization resulted in a higher net energy production, but the fertilization had no impact on the feeding value parameters of the herbage.

Discussion

In the first year (2006) after sowing, *L. perenne* was by far the most common species on all treatments, but its presence decreased rapidly on the plots of SM1 and SM2. The reduction on plots of SM3 was less sharp; on these plots *L. perenne* remained the dominant species. On all treatments we observed an increase of *Holcus lanatus*, *Anthoxanthum odoratum*, *Poa pratensis*, *Leucanthemum vulgare*, *Centaurea jacea* and *Rumex acetosella*, species which are common under more extensive grassland management without grazing (Table 3). The abundance of *Trifolium repens* and *Trifolium pratense* showed a negative trend on the plots of SM1. Herbs showed an increase on most plots even on those of SM3, probably due to invasion of seeds from neighbouring plots of SM1 and SM2. SM1 is the most productive mixture in terms of dry-matter production and uptake of N, P and K. The production on plots with this mixture is likely to be stimulated by the legumes, especially *Lotus corniculatus,* that were included in this mixture. The herbage of SM1 and SM2 has a higher content for most minerals than the herbage of SM3. This is in agreement with findings of Fisher *et al.* (1996) and Pirhofer-Walzl *et al.* (2011).

Due to the high dry-matter production, the net energy production of SM1 was significantly higher than the yields of SM2 and SM3. However, per kg dry matter, the net energy content of the herbage of SM3 was 7–9% higher than the net energy content of herbage of SM1 and SM2. Also, in terms of feed quality, the grass dominated herbage of SM3 had the highest content of intestinal digestible protein, sugar and lysine .

We conclude that introduction of species-rich mixtures could speed up the creation of a species-rich vegetation. Under low-fertilized conditions, species-rich grasslands can compete with *L. perenne* dominated swards for productivity and mineral composition of the herbage, but not for the feeding value of the herbage. Limited fertilizer use does not reduce species numbers.

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Table 2. Number of plant species, dry-matter production (d.m.), N, P and K uptake, mineral composition and feeding value of herbage for three seed mixtures, three fertilization applications and two periods.

	Seed mixture				Fertilization				Year			SM x fert	SM x year	Fert x year	SM x fert x year
	SM1	SM2	SM3	*P*	Control	Slurry	K	*P*	2006/07	2009/10	*P*				
Species	15.5	21.9	13.9	***				NS	15.7	18.4	***	NS	***	*	NS
per 25 m^2	b	c	a						a	b					
d.m.	4991	4166	3770	***	3865	4680	4382	**	4579	4038	**	NS[2]	NS	NS	NS
kg ha^{-1}	b[1]	a	a		a	b	b		b	a					
N	89.4	62.6	60.1	***				NS	82.4	59.0	***	NS	*	NS	NS
kg ha^{-1}	b	a	a						b	a					
P	17.8	14.7	13.4	***	14.0	16.8	15.0	**	17.9	12.7	***	NS	NS	NS	NS
kg ha^{-1}	b	a	a		a	b	a		b	a					
K	102.7	83.1	78.4	***	68.1	106.2	90.0	***	110.8	65.4	***	NS	*	NS	NS
kg ha^{-1}	b	a	a		a	c	b		b	a					
N	17.51	15.07	16.00	**				NS	17.80	14.58	***	NS	NS	NS	NS
g kg^{-1} d.m.	b	a	a						b	a					
P				NS				NS	3.98	3.15	***	NS	***	**	NS
g kg^{-1} d.m.									b	a					
K				NS	17.22	22.50	20.61	***	24.48	15.74	***	NS	NS	NS	NS
g kg^{-1} d.m.					a	c	b		b	a					
Na	0.70	0.69	0.52	***	0.81	0.60	0.49	***	0.39	0.88	***	NS	*	***	NS
g kg^{-1} d.m.	b	b	a		c	b	a		a	b					
Ca	6.89	5.51	5.16	***	6.41	5.27	5.87	***	5.21	6.50	***	NS	**	NS	NS
g kg^{-1} d.m.	b	a	a		c	a	b		a	b					
Mg	2.52	2.11	2.07	***	2.42	2.23	2.05	***	2.18	2.29	*	NS	*	***	NS
g kg^{-1} d.m.	b	a	a		c	b	a		a	b					
S	2.09	2.20	2.41	***	2.37	2.16	2.17	**	2.82	1.64	***	NS	***	NS	NS
g kg^{-1} d.m	a	a	b		b	a	a		b	a					
Mn	221.0	288.8	209.4	***				NS	219.2	260.3	**	*	NS	NS	NS
mg kg^{-1} d.m.	a	b	a						a	b					

Zn	93.2	62.6	61.4	***	71.4	76.9	69.0	*	63.0	81.8	***	**	***	NS	NS
mg kg^{-1} d.m.	b	a	a		ab	b	a		a	b					
Fe				NS				NS	76.8	87.7	**	NS	NS	NS	NS
mg kg^{-1} d.m.									a	b					
Net energy	24.48	20.33	20.11	***	19.51	23.52	21.89	**	23.78	19.49	***	NS	*	NS	NS
GJ ha^{-1}	b	a	a		a	b	b		b	a					
Net energy	4.97	4.87	5.33	***				NS	5.27	4.84	***	NS	NS	NS	NS
MJ kg^{-1} d.m.	a	a	b						b	a					
PDI[3]	50	45	52	*				NS	56	42	***	NS	NS	NS	NS
g kg^{-1} d.m.	ab	a	b						a	a					
Sugar	88.8	106.0	120.0	***				NS			NS	NS	*	NS	NS
g kg^{-1} d.m.	a	b	c												
Lysine	3.3	3.1	3.5	*				NS	3.7	2.9	***	NS	NS	NS	NS
g kg^{-1}d.m.	ab	a	b						b	a					
Methionine	1.3	1.2	1.3	*				NS	1.4	1.1	***	NS	NS	NS	NS
g kg^{-1} d.m.	a	a	a						b	a					

[1] Same letters within treatments seed mixture, fertilization or year: species numbers are not significantly different from $P \leq 0.05$

[2] NS: not significant

[3] PDI or ‘intestinal digestible protein' is a measure of the amount of protein which is available to the dairy cow from the feed.

Table 3. Botanical composition in 2010 according to the Braun-Blanquet cover-abundance scale (Braun-Blanquet, 1964) and trend in development of individual species between 2006 and 2010.

Seed mixture	SM1						SM2						SM3					
Fertilization	control		slurry		potassium		control		slurry		potassium		control		slurry		potassium	
	2010	trend	2010	trend	2010	trend	2010	trend	2010	trend	2010	trend	2010	trend	2010	trend	2010	trend
Grasses																		
F. pratensis				-						-				-				
L. perenne	2m[1]	- -[2]	2a	- -	2a	- -	2m	- -	2m	- -	2m	- -	4	-	3	- -	4	-
H. lanatus	2m	+	1	+	1	+	2a	+	2b	+	2a	+	2m	+	2a	+	2a	+
A. elatius		-		-					+	+	r	+						
T. flavescens	1	-	2m	+	2a	+	r	+	r	+	r	+	r	+	+	+		
C. cristatus	+	+	+	=	1	+	+	+			r	+						
D. glomerata			r	+			1	-	2a	+	2a	+	r	+	+	+	1	+
A. odoratum	4	++	3	++	2b	++	2b	+	2a	+	2b	+	2m	+	1	+	1	+
F. rubra	1	+	r	+			2b	=	2a	-	2b	=						
P. pratense subsp. pratense	2a	=	2a	=	2a	=	1	-	2m	-	+	-	3	++	2b	+	2b	+
P. pratensis	1	=	2a	+	2m	+	+	+	1	+	+	=	2m	+	2a	+	2m	-
Legumes																		
L. corniculatus var.corniculatus								-		-		-						
T. dubium	r	+	r	+			2m	+	+	+	2m	+	1	+			1	+
T. pratense		-	r	-	r	-	1	=	r	=	2m	+	+	+			r	+
L. corniculatus var.Agrosan+Leo	2m	-	2m	=	3	++	r	r			+	+						
T. repens		-	r	-		-	1	=	r	=	2m	+	+	=	1	+	2a	+
Herbs																		
P. vulgaris										-								
C. fontanum subsp. vulgare	r	+	r	+	+	+	1	=	1	+	1	=	1	+	+	+	1	+
L. vulgare	3	++	3	++	3	++	2a	+	2a	+	2a	+	2a	+	2b	++	2a	+
H. radicata	r	+			r	+	2a	+	1	+	2m	+	2a	+	r	+	2m	+
A. millefolium	2a	+	2b	++	2a	+			+	=	r	=	+	+			+	+
C. biennis					r	+	r	=	1	+	+	+	1	+			+	=

L. saxatilis							1	+			r	+	+	+			+	+
R. bulbosus							r	+			r	+						
C. jacea	r	+	r	+	r	+	2a	+	2a	+	2m	+	+	+	+	+	+	+
B. perennis							1	+	1	+	+	+	+	+			+	+
R. acetosella	+	+	r	+	1	+	2b	+	2b	+	2a	+	2m	+	2m	+	+	=
P. lanceolata	2a	=	2a	=	2a	=	2a	+	2a	+	2a	+	1	+	1	+	1	+
R. acetosa	r	+					+	=	+	=	+	-			r	+		
L. autumnalis	+	-	+	-	+	-							+	+				

[1] According to Braun-Blanquet (1964) percentage cover/number of individual plants:

r	< 5%, 1 plant	2m	<5%, >50 plants	3	25-50%
+	< 5%, 2-5 plants	2a	5-12% cover	4	50-75%
1	<5% 6-50 plants	2b	13-25%	5	75-100%

[2] Trend between 2006 and 2010: - - strong decrease; - decrease; = stable; + increase: ++ strong increase