Biomass production and forage quality in multispecies swards

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Abstract

Multispecies mixtures of legumes and grasses offer potential advantages over the perennial ryegrass monocultures and binary white clover-perennial ryegrass mixtures usually sown in temperate pastures. These include greater productivity, increased resistance to unsown species invasion and improved forage quality. An experiment comprising eight experimental communities containing different proportions of birdsfoot trefoil (*Lotus corniculatus*), red clover (*Trifolium pratense*), a high-sugar perennial ryegrass (*Lolium perenne*) and timothy (*Phleum pratense*) was established and results are presented from three years of measurements.

Keywords: birdsfoot trefoil, perennial ryegrass, red clover, timothy, yield, forage quality

Introduction

The importance of species diversity may be underestimated if only one of several ecosystem services is considered (Hector and Bagchi, 2007). Analysis of the true functional benefit of diversity therefore requires simultaneous measurement of many ecosystem processes in swards. These could include biomass productivity, resistance to invasion by unsown species, efficiency of use of environmental resources, soil structuring processes and the provision of forage of high nutritive quality. There is already clear evidence that multispecies mixtures of forage legumes and grasses offer yield advantages over the perennial ryegrass monocultures and binary white clover-perennial ryegrass mixtures usually sown in temperate pastures (Kirwan *et al.*, 2007). This research highlighted the importance of species evenness (i.e. relative abundance) in producing positive diversity effects in agronomically relevant mixtures of four species. The aim of the current experiment was to analyse the effect of contrasting initial levels of species evenness in multispecies mixtures on a range of ecosystem processes. To achieve this, evenness in a group of four temperate forage species was manipulated to create eight mixtures: four near-monocultures (low evenness) and four near-centroids (high evenness). This paper discusses the development of the mixtures over time in terms of biomass production, unsown species presence and forage quality, but other processes were also measured.

Materials and methods

32 field plots (6 m^2) containing eight multispecies mixtures (comprising different sown proportions of perennial ryegrass (PRG) (high sugar variety cv. AberDart), timothy (cv. S48), red clover (cv. AberRuby) and birdsfoot trefoil (cv. Leo)) were established in 2008 in a randomised block design with four replicates (Table 1). The experiment was managed under an agronomically realistic conservation cutting regime, i.e. 3 cuts per year (late spring, mid-summer, late summer) at a height of 4 cm. The plots received a total of 90 kg N ha^{-1} yr^{-1} applied in three equal doses. Harvested biomass was subsampled and separated into its sown and unsown species components, oven-dried at 80°C and weighed. Representative sub-samples were also collected from each plot at each harvest, oven dried at 60°C and finely milled in preparation for standard chemical analyses of the major forage quality parameters. This

paper focuses on DOMD (digestible organic matter content) and relationships between concentrations of WSC (water soluble carbohydrate) and CP (crude protein). Results were analysed by ANOVA, focusing on species evenness effects on annual dry matter yield, and on mixture effects for forage quality. Results of sward yield are presented for 2009 (Year 1), 2010 (Year 2) and 2011 (Year 3). Forage quality results are presented for 2009 and 2010.

Results and discussion

The yield of both low and high evenness mixtures decreased sharply after Year 1 but remained stable in subsequent years (Table 2). High evenness mixtures were significantly more productive in all years. Over the three years of the experiment the yield of unsown species increased substantially (36, 297 and 1194 kg ha^{-1} in Years 1, 2 and 3), but did not differ significantly between the evenness treatments, except in Year 2 in which it was lower in the high-evenness mixtures. Forage quality results are presented in Table 3.

Table 1. Composition of mixtures presented as proportions of the standard monoculture sowing rate for each species. Standard monoculture sowing rates used were: lotus = 10 kg ha^{-1}; red clover = 10 kg ha^{-1}; PRG = 20 kg ha^{-1}; timothy = 20 kg ha^{-1}

Mixture	Evenness	Lotus	Red clover	PRG	Timothy
1	Low	0.91	0.03	0.03	0.03
2	Low	0.03	0.91	0.03	0.03
3	Low	0.03	0.03	0.91	0.03
4	Low	0.03	0.03	0.03	0.91
5	High	0.34	0.22	0.22	0.22
6	High	0.22	0.34	0.22	0.22
7	High	0.22	0.22	0.34	0.22
8	High	0.22	0.22	0.22	0.34

Table 2. Annual sown species yield (kg ha^{-1})

Evenness	Year 1	Year 2	Year 3
Low	10869	5397	6144
High	14235	6582	7085
F prob.	0.002	0.046	0.03

In Year 1 there was no significant effect of mixture on DOMD at any harvest. The overall mean values in cuts 1, 2 and 3 were 59.38%, 63.71% and 63.93% respectively. There were significant differences between mixtures for herbage CP in all harvests in Year 1. Highest levels were found in mixtures containing a high proportion of legumes (1 and 2), whilst mixtures dominated by grasses (3 and 4) contained the lowest amounts. There were significant differences between mixtures in herbage WSC in all harvests. This parameter was strongly influenced by the presence of the high sugar PRG cv. AberDart, and was therefore highest in mixture 3. The second grass in the experiment, timothy, was chosen to provide a functional contrast to the high sugar PRG, as this species is naturally relatively low in WSC. This contrast was evident in the results, in which lower WSC levels were observed in mixture 4 (dominated by timothy). In Year 2 the mixtures did not differ in DOMD in cut 1 and the overall mean was 64.8%. In cut 2 there was a significant mixture effect, with the highest value (66.9%) found in the Lotus near-monoculture (mixture1), and the lowest (63.8%) in the timothy near-monoculture (mixture 4). DOMD values were substantially lower in all mixtures in cut 3 and there was a significant mixture effect. The highest value (62.6%) was in mixture 8 and the lowest in mixture 4 (58.5%). Overall, the DOMD values

reported here are low: expected average values for a monoculture of PRG cv. AberDart in Aberystwyth would be about 71%. The ratio between WSC and CP in forage is important in terms of ruminant nutrition. The ideal ratio has been calculated as around 2.4:1, but this was not achieved by any treatment in either Year 1 or Year 2. In both years the highest ratios were observed in mixture 3 in cut 1, showing the benefit of the high sugar trait. However, all other mixtures and cuts were deficient in WSC due to the low yield of the high sugar PRG relative to the high yield of timothy (results not shown).

Table 3. Forage quality parameters (% DM) for each mixture

Year 1

Forage quality	Mixture								F prob.
Cut 1	1	2	3	4	5	6	7	8	
DOMD	58.82	59.07	61.03	56.85	60.21	58.05	58.69	59.38	0.284
WSC	8.58	6.65	13.59	6.91	6.55	6.86	6.64	6.36	<0.001
CP	9.82	12.2	9.51	9.24	11.86	11.11	11.26	12.43	0.002
Cut 2									
DOMD	63.3	63.57	64.76	63.98	63.7	64.4	63.9	62.07	0.086
WSC	4.16	5.13	8.99	6.92	5.34	5.74	5.72	4.99	<0.001
CP	16.91	16.21	14.1	14.76	16.58	16.12	16.0	16.12	0.002
Cut 3									
DOMD	62.62	67.32	64.7	58.96	66.37	65.68	66.06	63.93	0.072
WSC	9.44	7.03	13.07	10.64	9.38	9.22	9.89	10.75	<0.001
CP	16.69	18.54	13.91	13.31	16.58	17.64	16.18	16.09	<0.001

Year 2

Forage quality	Mixture								F prob.
Cut 1	1	2	3	4	5	6	7	8	
DOMD	66.17	64.39	65.85	64.41	64.22	64.37	64.67	64.52	0.236
WSC	7.78	9.15	13.31	10.24	14.29	11.14	13.69	13.37	0.030
CP	16.52	13.67	12.33	13.67	12.44	12.62	11.94	11.66	<0.001
Cut 2									
DOMD	66.92	64.43	64.58	63.85	65.53	64.61	65.31	65.51	0.020
WSC	7.25	7.0	9.07	8.27	7.77	7.4	7.89	8.35	0.176
CP	18.59	15.8	14.8	15.34	16.44	15.72	16.16	15.94	0.017
Cut 3									
DOMD	60.78	61.27	58.57	58.56	61.06	60.75	59.5	62.64	0.002
WSC	6.59	7.5	9.09	8.03	8.72	7.99	8.46	7.26	0.007
CP	15.59	15.02	12.91	13.23	14.38	14.23	13.77	15.33	0.016

In conclusion, there were distinct yield gains in high evenness mixtures in terms of sown species, but increased resistance to unsown species invasion was not a stable characteristic of these mixtures. The nutritive value of harvested forage did not differ markedly between the two levels of species evenness.

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