

Productivity and herbage quality in two-species grass-legume mixtures under cutting

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Abstract

Inclusion of legumes in grasslands could enhance N-use efficiency of forage production. Performance of 7 binary grass-legume mixtures was studied to examine companion species with contrasting attributes. Perennial ryegrass (PR) was sown alone and with each of four forage legumes: red clover (RC), birdsfoot trefoil (BT), lucerne (LU) and white clover (WC); WC was sown with each of four companion grasses: PR, hybrid ryegrass (HR), meadow fescue (MF) and timothy (TI). Mixtures were studied in a small-plot (1.5×8 m) cutting trial with 4 replications in Denmark to test the effect of species composition on herbage yield, contents of nitrogen (N) and neutral detergent fibre (NDF), and *in vitro* organic matter digestibility (IVOMD). Plots were fertilised with 300 kg N ha⁻¹ from cattle slurry and harvested five times from May to October in year 1 and four times in year 2. With different companion grasses, the WC proportion was similar in mixtures with HR and MF, which had a lower WC content than with PR and TI. Annual herbage yield was highest for PR/RC (15.6 Mg DM ha⁻¹) which had, on average, the highest legume proportion of DM, the highest N content (33 g N kg⁻¹ DM) and the highest N yield (505 kg N ha⁻¹) across both years. The mixture with the lowest values was PR/BT (9.6 Mg DM ha⁻¹; 25 g N kg⁻¹ DM; 243 kg N ha⁻¹). PR/RC had the lowest concentration of NDF (375 g kg⁻¹ DM) and pure PR the highest (437 g kg⁻¹ DM). IVOMD ranged from 730 g kg⁻¹ organic matter (OM) in PR/LU to 774 g kg⁻¹ OM in WC/HR. Choice of companion grass had less effects than that of companion legume in the examined mixtures. Red clover contributed most to N yield.

Keywords: companion species, functional group, fibre, grass-legume mixture, nitrogen, protein, yield

Introduction

Herbage is an important natural source of protein and fibre in ruminant diets. Inclusion of legumes in grass swards contributes to sustainable intensification as symbiotically fixed N₂ may replace fertilizer-N.

An optimal combination of suitable grass and legume companion species is needed to obtain high N-use efficiency, high herbage yield, a desirable seasonal production pattern and high contents of nutritive compounds in grass-legume mixtures. The impact of different grass-legume mixtures on the N contribution and effects of companion species have rarely been investigated under comparable soil and climatic conditions. Therefore a field experiment was conducted on a sandy soil with 7 two-species forage mixtures. N₂ fixation and residual N effects were reported earlier (Rasmussen *et al.*, 2012). The aim of this experiment was to study the effects of companion grasses and legumes in mixtures on annual and seasonal herbage yield, N production, and forage quality. We hypothesised in line with data of Smit *et al.* (2008) that red clover and lucerne would be most productive in terms of dry matter (DM) and N yield. As competition from the companion grass affects the growth of the forage legume we also hypothesised that under a silage cut regime, perennial ryegrass would allow a higher white clover proportion than other grass species.

Materials and methods

Perennial ryegrass (*Lolium perenne* L.; 'PR') was sown alone and with each of four forage legumes: red clover (*Trifolium pratense* L.; 'RC'), lucerne (*Medicago sativa* L.; 'LU'), and birdsfoot trefoil (*Lotus corniculatus* L.; 'BT'), and white clover was sown with each of four companion grasses: perennial ryegrass, hybrid ryegrass (*Lolium boucheanum* Kunth; 'HR'), meadow fescue (*Festuca pratensis* Huds.; 'MF') and timothy (*Phleum pratense* L.; 'TI'). Grass and mixtures were sown in 2006 in a small-plot (1.5×8 m) cutting trial with 4 replications in Denmark. Mixtures are abbreviated as PR/RC, PR/BT, PR/LU, PR/WC, MF/WC, TI/WC and HR/WC, respectively. Plots were fertilised with 300 kg N ha⁻¹ from cattle slurry divided into four applications during the growing season of 100, 80, 60 and 60 kg and harvested five times in 2007 and four times in 2008 with a Haldrup forage harvester at a residual stubble height of 7 cm. Herbage yield, contents of N and neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin, and *in vitro* organic matter digestibility (IVOMD) were determined in mixtures as reported by Rasmussen *et al.* (2012). Species composition was measured in May and August 2007 and in all harvests in 2008.

Results

In all mixtures, grass production was higher in the first harvest than in later harvests. MF and HR were the highest yielding grass species in the first harvest. MF/WC and HR/WC had similar high annual yields, and similar clover proportions that were slightly lower than in PR/WC as illustrated for 2008 in Figure 1. Regardless of companion grass species the seasonal WC production pattern was similar, the second harvest being most productive. The mean clover proportion in May and August was similar in MF/WC, TI/WC and HR/WC (Table 1). In contrast, legume proportions in mixture with PR differed ($P < 0.001$): RC > LU > WC > BT, as did legume yields and seasonal production patterns (Figure 1).

Annual herbage yield was highest for PR/RC that had the highest legume proportion of DM, the highest N content and the highest N yield averaged across both years (Table 1). The mixture with the lowest values was PR/BT. PR/RC had the lowest concentration of NDF and pure PR the highest. IVOMD ranged from 730 g kg⁻¹ organic matter (OM) in PR/LU to 774 g kg⁻¹ OM in HR/WC.

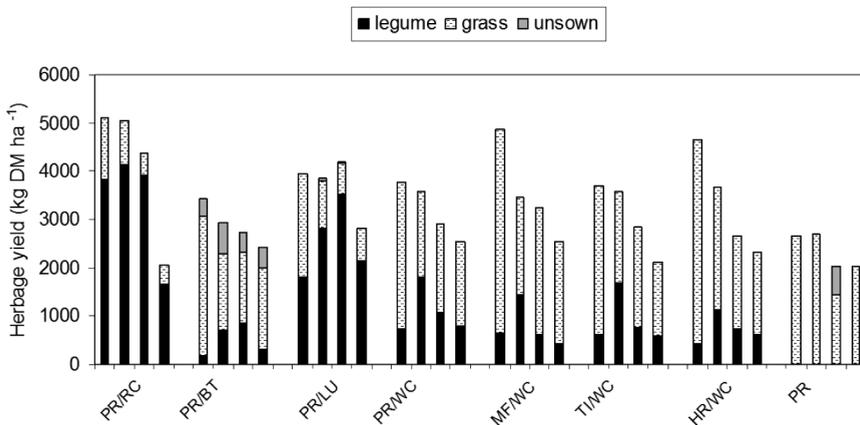


Figure 1. Seasonal dry matter (DM) production (harvests: 21 May, 2 July, 12 August and 9 October) from seven binary grass-legume mixtures and a pure-sown perennial ryegrass sward for 2008 (mean of four replicates). Mixture species abbreviations: perennial ryegrass (PR), red clover (RC), birdsfoot trefoil (BT), lucerne (LU), meadow fescue (MF), timothy (TI) and hybrid ryegrass (HR). Sown grass and legume species and unsown species are shown.

Table 1. Annual dry matter yield (DMY) and nitrogen (N) yield, *in vitro* organic matter digestibility (IVOMD), neutral detergent fibre (NDF), N content, and legume proportion of dry matter (DM).^{1,2} Average values of 4 replicate plots during 9 harvests in 2 years (n=72).

Mixture	DMY (kg ha ⁻¹)	N yield (kg ha ⁻¹)	IVOMD (g kg ⁻¹ OM)	NDF (g kg ⁻¹ DM)	N (g kg ⁻¹ DM)	Legume ³ (%)
PR/RC	15,581 a	505 a	737 f	375 g	32.5 a	81 a
PR/BT	9,571 e	243 d	758 d	421 c	25.3 g	18 e
PR/LU	13,374 b	396 b	730 g	421 c	29.7 d	69 b
PR/WC	12,635 c	388 b	763 c	386 f	30.7 c	34 c
MF/WC	13,303 b	378 b	752 e	430 b	28.5 e	22 de
TI/WC	11,835 d	380 bc	758 d	393 e	32.2 b	30 cd
HR/WC	13,073 b	365 c	774 a	394 d	27.8 f	22 de
PR	7,572 f	170 e	773 b	437 a	21.9 h	-
SE	229	6.8	0.7	0.6	0.07	4.2

¹ Abbreviations: perennial ryegrass (PR), red clover (RC), birdsfoot trefoil (BT), lucerne (LU), meadow fescue (MF), timothy (TI) and hybrid ryegrass (HR). SE = standard error. - = not applicable.

² Within a column, values without a common superscript are significantly different ($P < 0.001$).

³ Legume proportion of DM in 2008.

Discussion

Our hypothesis that perennial ryegrass would allow a higher clover proportion than other grass species was not confirmed: PR/WC and TI/WC had similar clover proportions and N yields, but N content was lower and annual yield higher in PR/WC. MF/WC and HR/WC had similar annual yields and clover proportions while N content and N yield were slightly higher in MF/WC. White clover had a high proportion of N derived from atmosphere for all companion grasses despite significant differences in clover proportion (Rasmussen *et al.*, 2012). Frame and Harkess (1987) studied white clover, red clover and lucerne with each of five companion grasses: diploid and tetraploid perennial ryegrass, timothy, meadow fescue and sweet brome (*Bromus carinatus* Hook & Arn.). Companion grass species did not affect annual DM production levels or N production in any of the three harvest years.

Choice of companion legume had major effects. As hypothesised, red clover and lucerne were more productive in terms of DM and N yield than birdsfoot trefoil which is in line with data of Smit *et al.* (2008). Even with slurry application of 300 kg N ha⁻¹, red clover and lucerne fixed >300 kg N ha⁻¹ (Rasmussen *et al.*, 2012). Frame and Harkess (1987) highlighted the high production levels achievable from red clover in the short term. This study showed that during the first two harvest years, red clover contributed most to N yield in forage mixtures under a silage cut regime.

References

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