The potential of multispecies swards for eco-efficient dairy production in Northern Germany

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Abstract

Increased plant diversity in cultivated grassland possesses the potential to combine both environmental and agronomic benefits. The use of legumes reduces the need for N fertiliser whilst including herbs can have a positive impact on nutritive value of forages and benefit animal health. Mixed swards can increase herbage production if plants with diverse functional traits are combined. To prove whether this also holds true for intensive forage production with at least five defoliations per year, we conducted a two-year experiment, hypothesizing that the introduction of deep-rooting legumes and herbs into a binary mixture of perennial ryegrass and white clover will outperform the latter. Yield, forage quality and sward botanical composition were examined in an orthogonal experimental approach also considering defoliation (intensive rotational grazing versus mechanical harvesting). While integration of only red clover led to yield increases in all systems, a multispecies mixture also containing herbs, birdsfoot trefoil and red clover had only small additional effects on yield performance. When grazed in early growth stages the dairy cows preferred the complex swards, resulting in higher forage use efficiency. Under a high frequency of defoliation per year all seed mixtures tested were suited to provide high quality forage for lactating dairy cows.

Keywords: grazing, grass clover, zero-grazing, multi-species ley, defoliation frequency

Introduction

Several publications indicate that the inclusion of legumes and forbs into grass swards can reduce the environmental impact of milk production (Carlton *et al.*, 2019; Simon *et al.,* 2019) and simultaneously affect herbage yield, feeding quality (Roca-Fernández *et al.,* 2016), or agronomic traits (Hoekstra *et al.,* 2015) positively. The inclusion of chicory into grass-clover swards was found to increase dry matter (DM) intake and organic matter digestibility, leading to higher milk yields of the grazing dairy cows (Roca-Fernández *et al.,* 2016). However, if managed very intensively, only few species end up contributing to the harvested yields due to increased asynchrony in plant development with each new species. To validate the potential of diverse pastures under intensive grazing, zero grazing or cutting management systems, we conducted a two-year experiment with a minimum of 5 defoliations per year. We hypothesized that the introduction of deep-rooting legumes like red clover and birdsfoot trefoil, as well as of herbs, into a binary mixture of perennial ryegrass plus white clover will outperform the latter independent of the harvest regime.

Materials and methods

The field experiment was conducted at Kiel University's experimental farm for organic agriculture 'Lindhof' in Northern Germany (N 54°27; E 9°57; mean air temperature 8.7 °C; mean annual precipitation 785 mm) during two years (2017 and 2018). The experimental layout was an orthogonal split plot design with two experimental factors in four replicates: (1) seed mixture and (2) defoliation system. The seed mixtures used were (1) a binary mixture of 24 kg ha^{-1} perennial ryegrass (*Lolium perenne*, PR) + 4 kg ha^{-1} white clover (*Trifolium repens*, WC) (PR+WC), (2) a tertiary mixture of 24 kg ha^{-1} PR+ 2 kg ha^{-1} WC + 6 kg ha^{-1} red clover (*Trifolium pratense*, RC) (PR+WC+RC) and (3) a multi-species mixture of 16 kg ha^{-1} PR+ 1.5 kg ha^{-1} WC + 3 kg ha^{-1} RC that additionally contained herbs (1 kg ha^{-1} ribwort plantain (*Plantago lanceolata*) + 2 kg ha^{-1} of each chicory (*Cichorium intybus*), sheep's burnet (*Sanguisorba minor*), caraway (*Carum carvi*) and 5 kg ha^{-1} birdsfoot trefoil (*Lotus corniculatus*) (PR+WC+RC+Herbs). The 3 different defoliation systems were rotational grazing (8 times per year), zero grazing (harvested 8 times per year) and a silage cut system with 5 cuts per year. Grazing was performed with a pasture-based Jersey dairy herd. Mechanical harvest was carried out by a plot harvester. In each experimental year grass-clover swards in their first production year were used. Before machine harvesting at 5 cm and grazing at 4 cm residual height, forage yield had been determined by hand clipping 2 squares of 0.5 m^2 in each of the 4 plot replicates. Post-grazing biomass was sampled in the morning after day and night grazing. Forage quality was determined using NIRS spectroscopy. A linear mixed model with seed mixture and defoliation system as fixed and experimental year as random factor was used for statistical analysis with the statistical software R.

Results and discussion

Table 1 shows clear effects of both seed mixture and defoliation system on potential harvestable DM yield, forage quality and botanical composition of grass-clover leys at Lindhof. In all defoliation systems the integration of red clover led to yield increases compared to the binary mixture PR+WC. In none of the defoliation systems could yield differences be detected between the binary mixture and the multispecies mixture. Independent of seed mixture, grazing led to higher yields of potential harvestable biomass compared to the mechanical defoliated systems. This was accompanied by higher sward grass contents. No effects of seed mixture could be detected on the content of metabolizable energy (ME), while there were strong effects of the defoliation system on this parameter.

Table 1. Effect of seed mixture and defoliation system on potential harvestable DM yield, forage quality and sward grass-, legume- and herb-content of grass clover leys at Lindhof as average over 2 experimental years (2017 + 2018).[1,2]

Parameter (unit)	Defoliation system	Seed mixture					
		PR+WC		PR+WC+RC		PR+WC+RC+Herbs	
Potential harvestable DM (Mg DM ha^{-1})	Grazing	11.42	bA	13.26	aA	11.93	aA
	Zero-grazing	9.48	bB	10.87	aB	10.54	abB
	5-cut	9.41	bB	10.41	aB	9.19	bB
Forage ME content (MJ kg^{-1} DM)	Grazing	11.1	A	11.0	A	11.0	A
	Zero-grazing	11.0	A	10.9	A	10.9	A
	5-cut	10.6	B	10.7	B	10.7	B
Forage CP content (% of DM)	Grazing	22.5	aA	21.9	abA	21.3	bA
	Zero-grazing	21.9	aA	21.3	abB	20.0	bA
	5-cut	19.4	aB	19.4	aB	18.1	bB
Sward grass content (% of DM)	Grazing	40.0	A	38.8	A	33.4	A
	Zero-grazing	30.5	B	25.5	B	23.5	B
	5-cut	28.8	B	17.8	C	19.0	C
Sward legume content (% of DM)	Grazing	59.9	B	61.1	B	52.9	B
	Zero-grazing	68.3	A	73.8	AB	65.2	A
	5-cut	70.6	aA	81.8	aA	67.6	bA
Sward herb-content (% of DM))	Grazing	0.2	b	0.2	b	13.7	a
	Zero-grazing	1.2	b	0.7	b	11.4	a
	5-cut	0.6	b	0.4	b	13.4	a

[1] Different lower-case letters indicate significant differences between seed mixtures in the same defoliation system, different upper-case letters indicate significant differences between defoliation systems in the same seed mixture at $P<0.05$.

[2] DM = dry matter; ME = metabolizable energy; CP = crude protein; PR = perennial ryegrass; WC = white clover; RC = red clover.

An 8-time defoliation (grazing and zero grazing) led to higher ME concentrations compared to forage harvested in the 5-cut system. In all defoliation systems the multispecies mixture showed lower concentrations of crude protein (CP) compared to the binary mixture PR+WC. Despite lower legume contents, CP concentrations of the grazed swards were higher compared to material harvested in the 5-cut system. Table 2 shows potential effects of the factor seed mixture on amount and forage quality of different sward fractions of the grazed grass-clover leys. Despite statistical differences in pre-grazing biomass, all mixtures resulted in the same DM intake. Having free choice, cows seem to prefer the multispecies mixture to the tertiary mixture PR+WC+RC and left less post-grazing biomass. The results clearly indicate selective grazing in all mixtures. CP and ME contents in the rejected post-grazing biomass were lower than in the offered pre-grazing biomass. Thus, forage quality of the biomass chosen by the cows was higher than the quality of the offered pre-grazing biomass.

Table 2. Effect of seed mixture on pre-grazing, rejected post-grazing and eaten biomass, as well as on contents of metabolizable energy (ME) and crude protein (CP) of these biomass fractions as average over 2 experimental years at Lindhof (2017 + 2018).[1,2]

Parameter (unit)	Sward fraction	Seed mixture					
		PR+WC		PR+WC+RC		PR+WC+RC+Herbs	
Biomass (Mg DM ha^{-1})	Pre grazing	11.42	b	13.26	a	11.93	b
	Post grazing	3.01	ab	4.52	a	2.90	b
	Intake via grazing	8.42		8.74		9.04	
ME content (MJ kg^{-1} DM)	Pre grazing	11.1	A	11.0	B	11.0	B
	Post grazing	10.6	B	10.5	C	10.4	C
	Intake via grazing	11.2	A	11.3	A	11.2	A
CP content (% of DM)	Pre grazing	22.5	aB	21.9	abB	21.3	bA
	Post grazing	18.8	aC	18.1	a C	16.3	bB
	Intake via grazing	23.8	aA	24.4	a A	22.5	bA

[1] Different lower-case letters indicate significant differences between seed mixtures in the same biomass fraction, different upper-case letters indicate significant differences in forage quality between the biomass fractions of the same seed mixture at $P<0.05$.

[2] DM = dry matter; ME = metabolizable energy; CP = crude protein; PR = perennial ryegrass; WC = white clover; RC = red clover.

Conclusions

The addition of deep-rooted red clover to shallow-rooted grass-white clover leys can increase herbage production because of combination of diverse functional traits. Further addition of species had no positive yield effects. When grazed in early growth stages the dairy cows preferred the complex multispecies swards resulting in higher forage use efficiency. Under a high frequency of defoliation all seed mixtures tested are suited to provide high quality forage for lactating dairy cows. Under the conditions of Northern Germany, multispecies leys are a good measure to increase biodiversity without decreases in yield and forage quality.

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The effect of dairy cow feeding system on rumen function and milk production

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Abstract

Dairy cow feeding system is one of the main determinants of milk production. Good rumen function is essential to optimise animal performance and is influenced by what the cow consumes. The rumen function and milk production of cows offered one of three dietary treatments over a full lactation was examined. The three treatments were: (1) cows grazing grass-only swards receiving 250 kg N ha^{-1} $year^{-1}$ (Grass); (2) cows grazing grass-white clover swards receiving 250 kg N ha^{-1} $year^{-1}$ (Grass-Clover); and (3) cows housed indoors and offered a total mixed ration diet (TMR). Grass cows had the lowest MS production in all seasons. While treatment had no effect on rumen pH, it significantly altered the rumen volatile fatty acid (VFA), ammonia and lactic acid profiles. The Grass-Clover treatment had significantly greater (P<0.05) total VFA concentration as well as increased ammonia concentration compared with the Grass and TMR treatments. The increased ammonia concentration from the Grass-Clover treatment corresponded with the significantly greater milk urea content for the cows fed on Grass-Clover, indicating a greater excess of dietary protein in that treatment.

Keywords: rumen, grass white clover, total mixed ration, ammonia, volatile fatty acid

Introduction

Feed system is one of the main determinants of milk production (Bargo *et al.*, 2002). The ability to alter the diet to suit the cows' requirements (age, stage of lactation, etc.) gives total mixed ration (TMR) diets an advantage over pasture-based systems in terms of attaining maximum output per cow (Kolver and Muller, 1998). In temperate regions with a long grass growing season, low cost grass based systems are the most advantageous milk production systems from an economic perspective (Dillon *et al.*, 2016). White clover (*Trifolium repens* L.; clover) inclusion in the sward has been shown to improve pasture quality and animal performance compared to a grass-only sward (Egan *et al.*, 2018). The effect on rumen function and possible subsequent environmental effects of clover inclusion in the diet is poorly understood, particularly in comparison with TMR feeding systems. Differences in rumen characteristics, such as the quantity and proportions of volatile fatty acids (VFA), have been reported between animals fed clover (e.g. Dewhurst *et al.*, 2003) or mixed swards (Ribeiro Filho *et al.*, 2003) compared with perennial ryegrass only. While previous studies have compared grass-only with grass-clover diets (Egan *et al.*, 2018) or grass-only with TMR diets (Kolver and Muller, 1998), little work has been carried out simultaneously comparing both sward types with a TMR system. The objective of this study was to determine the effects, if any, of three different dietary treatments (Grass, Grass-Clover, TMR) on dairy cow milk production and rumen function.

Materials and methods

The experiment was undertaken at Teagasc, AGRIC, Moorepark, Fermoy, Co. Cork, Ireland (520 9' N; 80 16' W) in 2016. The experiment had three treatments: (1) cows grazing grass-only swards receiving 250 kg N ha^{-1} $year^{-1}$ (Grass); (2) cows grazing grass-white clover swards receiving 250 kg N ha^{-1} $year^{-1}$ (Grass-Clover); and (3) cows offered a total mixed ration diet and housed indoors (TMR). Swards in the Grass and Grass-Clover treatments were rotationally grazed and daily herbage allowance was 18 kg DM

cow^{-1} per day. No concentrate was fed. The TMR consisted of 7.15 kg DM grass silage, 7.15 kg DM maize silage and 8.3 kg DM concentrates. There were three seasons (spring, summer and autumn). Within each season a 3 (treatments) × 3 (periods) Latin square was carried out. Each period in the Latin square lasted two weeks, allowing 10 days for acclimatisation, with measurements taken in the final four days. Nine primiparous rumen-cannulated spring calving dairy cows (mean calving date 07 February 2016 ± 6.7 days) were used, three per treatment per period. The cannulated cows were blocked according to calving date, body weight, body condition score and milk production for the 3-week period prior to each measurement season and added to the three herds for each season and removed from those herds between seasons. Between seasons, cows grazed predominantly grass swards. There were 17 'intact' cows in each of the three treatment herds. Rumen samples were taken from each of the cows after morning (AM) and evening (PM) milking on days 11 and 12 of each period. Representative samples of both solid and liquid rumen contents were taken and strained through three layers of synthetic cheese cloth to separate solids from liquids. The liquid fraction was used for VFA and ammonia analyses. Milk yield was recorded daily and milk solids (MS; fat + protein) and milk urea weekly. Rumen VFA, ammonia, lactic acid and pH data are from the rumen-cannulated cows. Milk production results are from the herd fed each diet during the three seasons: spring (April/May), summer (June/July) and autumn (August/September). Data were analysed using SAS. Data were checked for normality using PROC UNIVARIATE. Data were analysed using linear mixed models that allowed for repeated measurements using the PROC MIXED procedure in SAS (2003).

Results and discussion

The TMR treatment had the greatest MS yield in summer and autumn, being significantly greater than Grass (Table 1). Grass-Clover and TMR had similar MS production in summer but TMR had significantly greater MS yield in autumn. The milk urea (MU) concentrations were similar on all treatments in spring (Table 1). They were significantly ($P<0.05$) greater on Grass-Clover in summer and autumn than Grass and TMR, while in autumn Grass had significantly greater MU concentration than TMR, indicating that there is surplus protein in the diet and inefficient N use (Roseler *et al.*, 1993). There was a significant ($P<0.05$) treatment × season interaction on rumen ammonia concentrations (Table 1). All treatments had similar rumen ammonia in the spring AM samples. Grass-Clover had significantly greater rumen ammonia than Grass and TMR in summer AM samples, and also than TMR in autumn AM samples. For the PM samples (Table 1), Grass-Clover had significantly greater rumen ammonia than TMR across all three seasons and greater than Grass in summer PM samples. Grass had greater rumen ammonia than TMR in the autumn PM. There was a significant ($P<0.05$) treatment × season interaction effect on total VFA concentration (Table 1). For the AM samples, in autumn Grass-Clover had a significantly greater

Table 1. Effect of treatment on milk production, milk urea concentration, and AM and PM total rumen VFA and ammonia concentrations in Spring, Summer and Autumn (n=9).[1]

	Spring			Summer			Autumn			SE	Treat	Season	Treat × Season
	G	GC	TMR	G	GC	TMR	G	GC	TMR				
Daily milk yield (kg cow^{-1})	26.7^{abc}	28.6^{a}	26.8^{ab}	20.9^{def}	23.9^{bcde}	24.4^{cd}	15.9^{g}	18.5^{fg}	21.6^{ef}	0.99	<0.05	<0.001	<0.001
Daily MS yield (kg cow^{-1})	1.95^{ab}	2.14^{a}	1.85^{bc}	1.61^{cd}	1.81^{bc}	1.90^{ab}	1.28^{e}	1.50^{de}	1.76^{bc}	0.072	<0.05	<0.001	<0.001
Milk urea (mg dl^{-1})	20.5^{a}	25.5^{ac}	22.7^{ad}	27.6^{dc}	34.3^{bg}	26.1^{dc}	41.1^{e}	46.7^{f}	29.5^{cg}	1.16	<0.001	<0.001	<0.001
Rumen measurements													
AM Total VFA (mmol l^{-1})	123^{abc}	122^{ab}	121^{ab}	126^{abc}	137^{c}	122^{abc}	124^{abc}	135^{ac}	111^{b}	4.0	<0.001	<0.05	<0.05
Ammonia (mmol l^{-1})	3.9^{a}	4.1^{a}	8.4^{abc}	9.1^{bc}	15.8^{d}	5.5^{ab}	11.6^{cd}	16.1^{d}	8.1^{abc}	1.01	<0.001	<0.001	<0.001
PM Total VFA (mmol l^{-1})	145^{abcd}	146^{abc}	123^{de}	128^{cde}	153^{ab}	132^{bcde}	152^{ab}	164^{a}	121^{e}	5.3	<0.001	<0.05	<0.05
Ammonia (mmol l^{-1})	4.5^{ab}	11.2^{bc}	3.2^{a}	11.9^{c}	21.9^{d}	9.5^{abc}	25.6^{de}	30.4^{e}	9.0^{abc}	1.63	<0.001	<0.001	<0.001

[1] G = grass only; GC = grass clover; TMR = total mixed ration, indoors; VFA = volatile fatty acids; MS = milk solids; AM <12:00 h; PM >12:00 h.

total VFA than TMR. For the PM samples, in spring Grass-Clover had a higher total VFA than TMR, in summer, Grass-Clover were higher than Grass and in autumn Grass-Clover and Grass had greater total VFA than TMR. On average, Grass-Clover had a significantly (P<0.05) greater total VFA than Grass and TMR (Table 1). The higher total VFA of Grass-Clover compared to Grass is similar to Dewhurst *et al.* (2003) and Ribeiro Filho *et al.* (2003). Grass resulted in a significantly greater total VFA than TMR.

Conclusions

The beneficial aspects of white clover inclusion in grazed grass swards were evident in this study through increased animal production compared with that of Grass; similar milk solids production to the TMR treatment; and the greater total rumen VFA concentration compared with the Grass and TMR treatments. However, the increased rumen ammonia and MU concentrations on the Grass-Clover treatment may be a cause of concern from an environmental perspective.

Acknowledgements

This research was funded by the Irish Dairy Levy administered by Dairy Research Ireland. The first author was in receipt of a Teagasc Walsh Fellowship.

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