Impact of plant diversity, with equal number of grass and legume species, on sward productivity and legume content under contrasted mowing management in a low input system

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Abstract

Studies have underlined the link between plant biodiversity and sward productivity. Higher production is associated with complementarities between the different functional groups involved. More especially, the occurrence of legumes seems to be a key point. In this context, this study aimed to validate the interest of improving species number in the sward on its productivity while controlling for the legume-occurrence effect, in a trial performed under organic farming and mowing schemes (3 and 4 cuts per year). To test the hypothesis, mixtures based on perennial ryegrass-white clover, cocksfoot-lucerne and *Lolium hybridum*–red clover, were diversified through the addition of grass-legume pairs until mixtures with six species of grass and six species of legumes were obtained. The performances of these mixtures (production in quantity and quality and plant composition) were followed during three full exploitation years. As reported previously by Sanderson (2010), our results underlined that there was no unique relationship between herbage yield and the complexity (number of species) of the mixture: everything is a function of the potential of the initial pair of species in the given soil-climate context and of its persistency. Legume content was also crucial, but did not, by itself, explain the performances recorded.

Keywords: functional diversity, mixture persistence, ryegrass-white clover, cocksfoot-lucerne, *Lolium hybridum*-red clover

Introduction

Faced with increased input costs, farmers want to reduce fertilizers and use of external feedstuffs while optimizing internal resources. This evolution in management of farming systems is in response to greater market instability and also to social demand. In such a context and for herbivores production systems, grassland agro-ecosystem productivity, in terms of quantity, quality and stability are key points to insure technico-economical performances and resilience of the farming system. Previous studies have shown the link between plant biodiversity and sward productivity, in terms of quantity (e.g. Hector and Loreau, 2001) and stability (Tilman *et al.*, 2006). Higher production is associated with complementarities between different functional groups involved, complementarities improving resources valorization. The occurrence of legumes seems to be the key point to improve and stabilized sward productivity (Sanderson, 2010).
In this context, the aim of this study was to validate the interest of improving species number in the sward on its productivity while controlling for the legume-occurrence effect. This trial was performed under organic farming and mowing schemes.

Materials and methods

In order to test the impact on grassland production and plant diversity evolution of plant species diversity in mixed grass-legume (60%: 40% of viable seeds) and of management schemes, the following experimental scheme was set up, in a four complete blocks design, in a organic field, converted in 1998, in Libramont, Belgium (49° 55' N 5° 35' E).

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Table 1. Mixtures compared u
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alexandrinum L.); sainfoin (*C*
clover (*Trifolium subterraneu*
L.).

Mixture basis
Four species mixtures
Eight species mixtures
Twelve species mixtures

The contrasted managem
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Results and discussion

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Mixtures, based either on perennial ryegrass (*Lolium perenne* L.) - white clover (*Trifolium repens* L.), on cocksfoot (*Dactylis glomerata* L.) – lucerne (*Medicago sativa* L.) and on *Lolium hybridum* – red clover (*Trifolium pratense* L.), were increased in complexity through the addition of grass-legume pairs until mixtures with six species of grass and six species of legumes were obtained (Table 1). Two modalities with, respectively, only grass (12) or legume (10) species were also included in the experimental scheme.

Table 1. Mixtures compared under contrasted cutting management schemes. Timothy (*Phleum pratense* L.); tall fescue (*Festuca arundinacea* Schreb.); meadow fescue (*Festuca pratensis* Huds.); smooth meadow-grass (*Poa pratensis* L.); red fescue (*Festuca rubra* L.); brome (*Bromus sitchensis* Trin); Egyptian clover (*Trifolium alexandrinum* L.); sainfoin (*Onobrychis sativa* Lamarck); yellow trefoil (*Medicago lupulina* L.); subterranean clover (*Trifolium subterraneum* L.); birdsfoot trefoil (*Lotus corniculatus* L.); alsike clover (*Trifolium hybridum* L.).

Mixture basis	Perennial ryegrass /White clover (**PW2**)	Cocksfoot /Lucerne (**CL2**)	*Lolium hybridum* /Red clover (**HR2**)
Four species mixtures	+ Cocksfoot /Red Clover (**PW4**)	+ Tall fescue /Red clover (**CL4**)	+ Perennial ryegrass /White clover (**HR4**)
Eight species mixtures	+ Tall fescue & Timothy grass /Lucerne & Yellow trefoil (**PW8**)	+ Perennial ryegrass & Timothy grass /White clover & Yellow trefoil (**CL8**)	+ Italian ryegrass & Tall fescue /Lucerne & Egyptian Clover (**HR8**)
Twelve species mixtures	+Smooth meadow-grass & Meadow fescue / Bird's-foot trefoil & Alsike (**PW12**)	+Brome & Red fescue /Bird's-foot trefoil & Subterranean clover (**CL12**)	+Timothy grass & Brome /Yellow trefoil & Sainfoin (**HR12**)

The contrasted management schemes applied during three seasons consisted of two cutting schemes reflecting intensive (4 cuts per year – 4C) or extensive (3 cuts per year – 3C) practices (fertilization with 35 t ha^{-1} of composted beef cattle manure).

Before each cut, proportions of grass and legumes species were quantified, on a weight basis, after hand sorting of a composite sample of the four replicates of the corresponding modality. Before the second cut, the proportions of each species in the mixture were also defined. Due to the difficulties of distinguishing between Italian and Hybrid ryegrasses, these different species were regrouped in an HI group.

Individual plots, measuring 1.5 × 11 m, were harvested using a Haldrup plot harvester. Green forage was weighed and a sample was collected from each plot and dried to quantify dry matter yield and to determine its feeding value (cellulase digestibility).

Data analysis (ANOVA including species richness and block parameters and multiple means comparison based on Student Newman Keuls method) were done using SAS 9.2. software.

Results and discussion

As expected, both the yield (10557±454 *vs* 9490±505 kg DM ha^{-1}) and quality (66.7±1.4 *vs* 70.2±1.6 %), for 3C and 4C respectively, were affected by the number of cuts. Statistical analyses, performed independently for both management schemes, highlighted a significant to highly significant effect of the mixture basis species number × year interaction on DM yields ($F_{3C}(12,105) = 12.3$; $P < 0.001$ and $F_{4C}(12,105) = 2.2$; $P = 0.01$). Table 2 integrates the results of the analyses performed per mixture basis and year.

These results show that once the binary mixture is able to exploit the production potential of this specific soil-climate-management situation (*c.* 12 t DM ha^{-1}) there was no further increase due to additional species: this was the case for HR-based mixtures in 2010 and CL-based mixtures across the three years (Table 2). In contrast, mixture complexity improved the productivity of PW-based mixtures: less aggressive in the sowing year than the HR and CL binary mixtures, across the three years and from less long-lasting HR-based mixtures, already the second and third year of production (Table 2). These trends were equivalent for both cutting frequencies. Sward quality was affected more by mixture basis and cropping year than by species richness (Table 2).

Table 2. Impact of species richness on DM yield (t ha^{-1}) and sward digestibility (%), per year and mixture basis. Means sharing a letter are not significantly different ($P > 0.05$).

		PW-3C		PW-4C		CL-3C		CL-4C		HR-3C		HR-4C	
Year	Nbr Sp	DM	DIG	DM	DIG	DM	DIG	DM	DIG	DM	DIG	DM	DIG
2010	2	8.3b	78a	8.8b	81a	11.5a	66c	9.8a	73	13.1a	72b	10.8a	77
2010	4	11.7a	73bc	10.8a	76b	11.8a	69cb	10.7a	73	11.7b	73b	10.5a	78
2010	8	12.0a	71cd	10.6a	75b	11.6a	71.2b	10.5a	75	11.7b	69c	10.1a	75
2010	12	12.4a	73bc	10.7a	77b	12.1a	70.3b	10.3a	76	12.1b	70c	10.0a	75
2010	12G	5.2c	76ab	5.5c	77b	5.2b	76a	5.5b	78	5.2c	76a	5.5b	77
2010	10L	11.4a	69d	9.9ab	74b	11.4a	69cb	9.9a	74	11.4b	69c	9.9a	74
2011	2	7.5c	72a	7.8c	71a	11.5a	64b	11.0a	65	9.3b	67a	9.5b	69ab
2011	4	9.1b	66b	8.8b	69ab	10.3b	64b	9.8b	68	9.8b	68a	9.4b	69ab
2011	8	9.8b	66bc	9.6a	67ab	10.9ab	65b	10.6a	68	11.2a	64b	10.4a	67ab
2011	12	10.5a	65bc	9.8a	68ab	10.6ab	65b	10.4ab	68	11.1a	66ab	10.4a	66b
2011	12G	5.5d	67b	5.1d	69ab	5.5d	67a	5.1d	69	5.5c	67a	5.1c	69ab
2011	10L	9.3b	64c	8.8b	66b	9.3c	64b	8.8c	66	9.3b	64b	8.8b	66b
2012	2	7.3d	68a	6.8b	72a	11.3a	59b	8.4ab	64	8.6c	66a	8.6a	69
2012	4	9.2b	62b	8.5a	66b	9.9b	62ab	8.0b	65	8.5c	66a	7.8b	69
2012	8	10.2a	63b	8.5a	66b	9.6b	61ab	8.5ab	66	11.0ab	62b	9.0a	66
2012	12	10.4a	63b	8.6a	66b	10.4ab	61ab	8.6a	66	11.6a	62b	9.0a	66
2012	12G	8.1c	63b	6.6b	67b	8.1c	63a	6.6c	67	8.1c	63b	6.6c	67
2012	10L	10.4a	62b	8.7a	67b	10.4ab	62ab	8.7a	66	10.4b	62b	8.7a	66

Even if legume content was significantly correlated to sward productivity (r = 0.6; N = 84), across the different mixtures and years, with an increase of 48 kg DM ha^{-1} year^{-1} per percentage increase in legume proportion, the classifications presented in the Table 2 were not modified by performing covariance analyses with the legume occurrence as co-variable (data not shown) confirming an interest improving species diversity in sward-mixture composition. This applies even without taking into account the legume effect, whether the mixture basis is not able to valorise fully the local productivity potential and/or whether it is not persistent enough. Nevertheless, including more than 8 species in the mixture appeared to be inefficient in the context of this trial.

Conclusions

As reported by Sanderson (2010), there was not a unique relationship between herbage yield and the complexity (number of species) of the mixture: everything is a function of the potential of the initial pair of species in the given soil-climate context and of its persistency. Legume content was also crucial but it did not, by itself, explain the performances recorded.

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HR-3C		HR-4C	
DM	DIG	DM	DIG
13.1a	72b	10.8a	77
11.7b	73b	10.5a	78
11.7b	69c	10.1a	75
12.1b	70c	10.0a	75
5.2c	76a	5.5b	77
11.4b	69c	9.9a	74
9.3b	67a	9.5b	69ab
9.8b	68a	9.4b	69ab
11.2a	64b	10.4a	67ab
11.1a	66ab	10.4a	66b
5.5c	67a	5.1c	69ab
9.3b	64b	8.8b	66b
8.6c	66a	8.6a	69
8.5c	66a	7.8b	69
11.0ab	62b	9.0a	66
11.6a	62b	9.0a	66
8.1c	63b	6.6c	67
10.4b	62b	8.7a	66

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