Competitive forbs in high-producing temporary grasslands with perennial ryegrass and red clover can increase plant diversity and herbage yield

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Abstract

In highly productive temporary grasslands in Europe, plant diversity is usually low. Some non-leguminous species have shown a high competitive ability in temporary grasslands and can increase plant diversity without compromising yields. In an experiment, the competitiveness and productivity of three forb species: chicory (*Cichorium intybus*), ribwort plantain (*Plantago lanceolata*) and caraway (*Carum carvi*), grown in different proportions in mixtures including traditional sown grassland species, perennial ryegrass and red clover, were examined with slurry application as an additional factor. Dry matter (DM) yield and botanical composition were measured during one complete growing season. Annual DM yields were mostly similar when forbs were included in the grassland mixture. A three-species mixture (perennial ryegrass, red clover and ribwort plantain) had the highest yield potential, especially for the slurry application treatment. Chicory and ribwort plantain were highly competitive in the mixtures. The response in the DM yield of perennial ryegrass to slurry application was considerable, but no consistent trend was found in the forbs. In conclusion, forbs contributed to increased plant species diversity and herbage DM yield, and fertilisation had positive effect on herbage yield of grassland mixtures.

Keywords: plant diversity, forb, dry matter yield, competitiveness, fertilisation

Introduction

There is growing interest in increasing biodiversity in European agriculture to make a contribution towards increasing the sustainability of cropping systems. However, most high-producing grasslands are dominated by traditional sown grass and clover species. With the inclusion of forbs in high-producing grasslands, there is a potential for increasing biodiversity without decreasing the dry matter (DM) yield (Søegaard *et al.,* 2011), but high competitiveness is required to secure better establishment and productivity of the forbs. Therefore, a field experiment was established with high-diversity temporary grassland including three highly competitive forb species. The aim was to generate more knowledge on the competitiveness of forbs, including the herbage yield response to the application of fertiliser (slurry).

Materials and methods

Sixteen seed mixtures, composed of chicory (*Cichorium intybus*), ribwort plantain (*Plantago lanceolata*), caraway (*Carum carvi*), perennial ryegrass and red clover (Table 1), were established in plots of 1.5×8 m in spring 2013 in three replicates. Seed rates in pure stands were 15, 4 and 12 kg ha^{-1} for perennial ryegrass, red clover and the three forbs, respectively. The plots were supplied with two levels of cattle slurry, 0 or 200 kg total N ha^{-1}. Herbage mass was harvested twice in 2013 and four times in 2014 during the growing season between May and October to determine DM yield. Botanical composition was determined by hand separation of sub-samples. Results from 2014 are presented and discussed.

Results and discussion

Red clover had the highest DM yield in pure stands. The DM yield in mixtures, composed of perennial ryegrass, red clover and forbs (mixtures 6-15), ranged between 13.2 and 16.1, and 14.3 and 17.7 Mg ha^{-1}, without and with slurry application, respectively (Table 1). The majority of the mixtures, except the

Table 1. Annual dry matter (DM) yield and weighted botanical composition.[1,2]

Seed	Proportion of seed mixtures					Yield	Proportion of DM yield					
mixture	GR	RC	CI	PL	CA	(Mg DM ha^{-1})	GR	RC	CI	PL	CA	Weeds
Without slurry												
1	1.00					9.1^{g}	0.54^{a}					0.46^{a}
2		1.00				15.4^{abc}		0.94^{a}				0.06^{c}
3			1.00			8.8^{g}			0.85^{a}			0.15^{b}
4				1.00		11.2^{f}				0.79^{a}		0.21^{b}
5					1.00	8.0^{e}					0.51^{a}	0.49^{a}
6	0.20	0.20	0.60			13.8^{de}	0.07^{ef}	0.42^{de}	0.48^{b}			0.03^{c}
7	0.40	0.40	0.20			14.1^{cde}	0.19^{c}	0.46^{de}	0.28^{cd}			0.06^{c}
8	0.20	0.20		0.60		15.7^{ab}	0.06^{f}	0.53^{cd}		0.38^{b}		0.03^{c}
9	0.40	0.40		0.20		16.1^{a}	0.12^{de}	0.63^{bc}		0.24^{c}		0.01^{c}
10	0.20	0.20			0.60	13.2^{e}	0.25^{b}	0.56^{cd}			0.14^{b}	0.05^{c}
11	0.40	0.40			0.20	14.2^{bcde}	0.26^{b}	0.63^{bc}			0.08^{bc}	0.03^{c}
12	0.50	0.50				15.6^{abc}	0.25^{bc}	0.73^{b}				0.02^{c}
13	0.40	0.40	0.07	0.07	0.07	15.6^{ab}	0.13^{d}	0.61^{bc}	0.12^{e}	0.11^{d}	0.02^{c}	0.02^{c}
14	0.20	0.20	0.20	0.20	0.20	14.9^{abcd}	0.10^{de}	0.44^{def}	0.19^{de}	0.20^{cd}	0.03^{c}	0.04^{c}
15	0.10	0.10	0.27	0.27	0.27	14.5^{bcde}	0.06^{f}	0.33^{e}	0.28^{cd}	0.27^{c}	0.02^{c}	0.04^{c}
16			0.33	0.33	0.33	11.2^{f}			0.34^{c}	0.44^{b}	0.04^{c}	0.19^{b}
With slurry (200 kg N ha^{-1})												
1	1.00					11.9^{f}	0.74^{a}					0.26^{b}
2		1.00				15.7^{bcd}		0.95^{a}				0.05^{de}
3			1.00			11.3^{f}			0.94^{a}			0.06^{de}
4				1.00		14.0^{e}				0.82^{a}		0.18^{c}
5					1.00	9.7^{g}					0.64^{a}	0.36^{a}
6	0.20	0.20	0.60			14.3^{e}	0.14^{f}	0.30^{de}	0.54^{b}			0.03^{e}
7	0.40	0.40	0.20			16.3^{bc}	0.25^{de}	0.46^{bc}	0.28^{cde}			0.01^{e}
8	0.20	0.20		0.60		17.7^{a}	0.17^{ef}	0.41^{bcd}		0.39^{b}		0.02^{e}
9	0.40	0.40		0.20		15.9^{bc}	0.32^{cd}	0.42^{bc}		0.24^{c}		0.02^{e}
10	0.20	0.20			0.60	15.9^{bc}	0.30^{cd}	0.52^{b}			0.15^{b}	0.03^{e}
11	0.40	0.40			0.20	15.7^{bcd}	0.37^{c}	0.52^{b}			0.09^{c}	0.02^{e}
12	0.50	0.50				15.1^{cde}	0.49^{b}	0.49^{b}				0.02^{e}
13	0.40	0.40	0.07	0.07	0.07	16.4^{b}	0.29^{cd}	0.46^{bc}	0.12^{e}	0.10^{d}	0.02^{c}	0.02^{e}
14	0.20	0.20	0.20	0.20	0.20	16.6^{ab}	0.19^{ef}	0.35^{cd}	0.23^{de}	0.18^{c}	0.03^{c}	0.02^{e}
15	0.10	0.10	0.27	0.27	0.27	14.4^{de}	0.15^{f}	0.20^{e}	0.35^{cd}	0.21^{c}	0.05^{c}	0.04^{e}
16			0.33	0.33	0.33	12.5^{f}			0.40^{bc}	0.43^{b}	0.06^{c}	0.11^{cd}

[1] GR: perennial ryegrass; RC: red clover; CI: chicory; PL: ribwort plantain; CA: caraway.

[2] Within each column, values followed by the same letter are not significantly different *($P<0.05$)*.

three-species mixture of forbs (mixture 16) showed similar annual DM yields to that of the pure stand of red clover (mixture 2) and the standard mixture of red clover and perennial ryegrass (mixture 12). However, the three-species mixtures of perennial ryegrass, red clover and ribwort plantain produced relatively higher DM yields without slurry, and significantly higher yields with slurry application than the pure stand of red clover and the standard mixture (mixtures 2 and 12). The greater DM yield can be explained by the positive effect of plant species diversity on resource use (Pirhofer-Walzl *et al.,* 2013).

In mixtures, red clover contributed a higher proportion of the herbage than its proportion in the seed mixture (Table 1). The proportions of chicory and ribwort plantain were similar in the herbage and seed mixtures, and perennial ryegrass and caraway had a lower proportion in the herbage than in the seed mixtures. In the mixtures composed of one forb, perennial ryegrass and red clover, when the proportion of forbs was low (20% of seed mixture), the proportions of forbs in the herbage were higher than in the seed sown. With 60% of chicory and ribwort plantain seeds in the seed sown (mixtures 6 and 8), chicory appeared to have competed more successfully with red clover than plantain, which could be the reason for the lower DM yield with chicory and higher yield with plantain compared with the standard mixture (mixture 12), especially with slurry application. The more upright leaves of plantain might have allowed better light interception. In mixtures, slurry fertilisation (200 kg N) reduced the red clover content on average from 53 to 42%, while the grass content increased from 15 to 27% and the content of the three forbs was only slightly affected. This reflects a high ability of forbs to compete with grass for available resources. Caraway always constituted very low proportions of the DM yield in all mixtures and was a lower proportion of the herbage than in the seed mixture, demonstrating poor ability to compete for the available resources with companion species (Table 1). One explanation could be that the resources are being utilised to establish caraway's large root system and the herbage mass might be expected to be higher in subsequent years (Søegaard *et al.,* 2013). The abundance of weeds was significantly lower in mixtures, except the three-species mixture of forbs (mixture 16), compared to pure stands except the pure stand of red clover and that of fertilised chicory. It demonstrated a higher ability of mixtures to compete with weeds for better utilisation of resources and higher herbage production. White clover constituted a significant proportion of the unsown species present in the plots sown without red clover.

Slurry application increased DM yield, and was most pronounced in pure stands of perennial ryegrass and forbs, increasing the DM yield of perennial ryegrass by up to 31%; there were smaller increases for chicory, ribwort plantain and caraway. The DM yield of red clover did not increase with slurry application to the pure stand. In mixtures including red clover (mixtures 6-15), the change in DM yield varied between -3 and +20% as compared to that of the pure stand. This variation was not related to forb species or red clover content. Even in mixture 15, with the lowest red clover content, there was no effect of slurry fertilisation, indicating that the N_2-fixation of red clover was sufficient. In the mixture with all three forbs, slurry fertilisation increased yield by 12% compared to an increase of 21-28% in pure stands. This indicates better resource utilisation at a low fertiliser level.

Conclusions

The experiment demonstrated possibilities for increasing biodiversity in leys with a high content of non-leguminous forbs without a loss in DM yield. Herbage yield was increased by slurry application without affecting the competitiveness of non-legume species.

References

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