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Species identity important to achieve benefits of diverse grassland mixtures

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Abstract

In semi-natural grasslands, plant diversity has shown to increase primary production and reduce weed invasion. To investigate whether such positive effects also apply to low input agricultural grasslands, a commercial grassland was sown with seven non-leguminous grassland mixtures. Diverse mixtures proved less susceptible for invading species three years after sowing. Yields were 11% higher for mixtures with two functional groups of grassland species compared with mixtures with only one functional group. Though overyielding was significant, transgressive overyielding was not apparent, due to the strong effect of one specific functional group: mixtures containing tussock grass had a 14% higher production than mixtures without tussock grass. Tussock grass also had a major effect on botanical composition. However, ground cover by invading species was mainly influenced by the number of functional groups present in the sown mixture. The results suggest that diverse grassland mixtures can improve agricultural production and reduce the susceptibility of sods for invading species, but that the specific composition of mixtures has a strong influence.

Introduction

In the last decades of agricultural intensification, species diversity has been largely ignored. In the Netherlands the main focus was on favouring and improving the most suitable, economical species, *Lolium perenne*. However, fertilization rates are increasingly limited, due to environmental legislation and the increased grassland area under nature conservation and organic production rules. Under these circumstances other grassland species might become more suitable. Mixing high productive species of leguminous herbs with grasses has been shown to increase primary production (Nyfeler *et al*, 2009). However, this effect is strongly related to increased N-availability, thus potentially conflicting part of the goals of environmental legislation and nature conservation, while grass-legume mixtures are rather unstable over years. Therefore, we tested the hypothesis that species diversity will improve grassland production (Hooper *et al*, 2005), with commercially available species of two different groups of grasses and one group of non-leguminous herbs.

Material and methods

In April 2009 an experiment was started with seven grassland mixtures (table 1) and three replications, as part of a larger trial (de Wit *et al*, 2013). We selected two groups of commercially available species (tussock grass and herbs) besides the standard sod grass (*Lolium perenne*), with two species in each functional group as we were uncertain which alternative grass and herb would be best suited for the agro-environmental conditions. A species rich mixture was added to assess the effects of higher species diversity. The trial was sown on a commercially used grassland with a shallow sandy soil in the south of the Netherlands. Plot size was 7 * 4 m. The plots were harvested four times in 2010 and 2011, but yield data of one replication in 2011 were lost. In both years weather conditions were rather unfavourable with severe drought periods during the first half of the growing season. Dry matter yield was determined by cutting a strip of 0.81m x 5m with a two-wheel tractor. After weighing the fresh biomass, a sub-sample was dried for 48h at 70°C and analysed for dry matter. In 2010, 2011 and 2012 the plots received cattle slurry in early spring (80, 61 respectively 75 kg total N ha^{-1}). In May 2011 and 2012 all sown and invading species were listed per plot and the percentage of cover by each species at the upper side of the biomass was visually assessed. This assessment of cover percentage is used as an indicator for the contribution of each species to the biomass production of the (fairly homogeneous) grass sod, though it may overestimate tall growing species slightly.

For the analysis of the diversity effect, the mixtures were clustered according to the number of functional groups. L (sod grass), DP (tussock grasses) and PC (non-leguminous herbs) were categorised as having one functional group, LDP and LPC as having two functional groups, and LDPPC and RICH as having at

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least three functional groups. Overyield was defined as the difference between the yield of the plot and the average yield of the constituent single functional groups (L, DP and/or PC), while transgressive overyield was defined as the difference between the yield of the plot and the highest yield of the constituent single functional group. The effects of mixture, number and type of functional groups on production and species presence were tested by an ANOVA using GENSTAT software.

Table 1. Composition of tested grassland mixtures.

Mixture	L	DP	PC	LDP	LPC	LDPPC	Rich
Number of functional groups	1	1	1	2	2	3	3
Species	--- seeding rate (kg ha^{-1}) ----						
Lolium perenne	40			20	35	19	15
Dactylis glomerata		10		5		5	4
Phleum pratense		30		15		14	8
Cichorium intybus			5		1,5	1,5	1
Plantago lanceolata			5		1,5	1,5	1
Festuca rubra							4
Festuca arundinacea							4
Festuca pratense							4
Daucus carota							1

Results and discussion

In autumn 2009 the newly sown grass mixtures were well established, though the establishment of *Phleum pratense* and *Festuca arundinacea* was disappointing, while *Festuca pratense* was virtually non-present. In spring 2011 the presence of the sown species was only slightly changed, except for a clear reduction of *Phleum pratense*. More importantly, unsown species invaded the plots (on average 10% of the ground cover), particularly the PC plots (42% of the ground cover). This process accelerated after the drought period of 2011. In spring 2012 *Cichorium intybus* had sharply decreased and nearly 29% of the soil was covered by invading species, mainly *Plantago lanceolata* (spreading rather evenly around the plots), *Poa annua* and *Trifolium repens* (see table 2). The successful invasion of species was significantly affected by the number of functional groups present in the mixture (table 3), but not by a single functional group. However, tussock grass (mainly the tall growing *Dactylis glomerata*) did affect the successful invasion of *Trifolium repens* ($P<0.05$): without tussock grass 19% of the surface was covered by *Trifolium repens*, while with tussock grass this was only 6%.

Table 2: Presence of species related to the mixture sown (May 2012; note: [a] is a species invaded from other plot).

Mixture	% of ground cover of most common species						Total number of different species
	Lolium perenne	Dactylis glomerata	Plantago lanceolata	Trifolium repens	Poa annua	Total by invading species	
L	52	0	23 [a]	17	2	46	16.0
DP	0	68	20 [a]	4	0	28	14.7
PC	12 [a]	0	45	23	7	49	19.3
LDP	22	43	23 [a]	7	0	33	14.7
LPC	38	0	30	17	5	28	15.3
LDPPC	18	44	30	5	0	6	14.3
RICH	20	37	28	9	0	11	19.7

Table 3. Presence of invading species related to the number of functional groups in grassland mixture. Values with different letters are significantly different (P<0.05) within each column.

Number of functional groups in mixture	% of ground cover (of species >1% of cover)	Number of different invading species
1	41.2 [b]	14.8 [b]
2	30.3 [b]	11.5 [a]
3	8.7 [a]	11.2 [a]

Average aboveground biomass production was limited to only 5.9 respectively 5.2 ton dry matter ha^{-1} in 2010 and 2011. Production was significantly affected by the mixture sown (table 4), related to the number of functional groups sown: mixtures with two functional groups were 11% more productive than mixtures with one functional group (table 5). Adding more diversity to the mixtures, however, did not further increase production. Besides this general diversity effect, there was one single functional group with a large individual effect: mixtures that included tussock grass (mainly the drought tolerant *Dactylis glomerata*) were more productive than the other mixtures (+0.7 ton DM ha^{-1}; P<0.05). Overyield is apparent (table 5) but relatively small compared to the results of e.g. Nyfeler *et al* (2009) and Finn *et al* (2012), possibly because in this current experiment no N-fixing herbs were included. Transgressive overyield was not achieved, even though the yield variation among the mixtures with one functional group was relatively small: the mixture DP was as productive as LDPPC and RICH. Thus, the agronomic value of species diversity in terms of production seems limited. However, the results do indicate that adding more palatable species, like *Lolium perenne,* is possible without decreasing the yield of the highest yielding species.

Table 4. Yields of mixtures (ton DM * ha^{-1} * year^{-1}), averaged for both years. Values with different letters are significantly different (P<0.05).

Mixture	L	DP	PC	LDP	LPC	LDPPC	RICH	Average
Yield	4.84 [a]	5.56 [ab]	4.83 [a]	5.99 [b]	5.29 [ab]	5.88 [b]	5.93 [b]	5.47

Table 5. Average yield and overyield per number of functional groups present in mixture. Values with different letters are significantly different (P<0.05).

Number of functional groups in mixture	1	2	3
Yield (ton DM* ha^{-1}*year^{-1})	5.08 [a]	5.64 [b]	5.90 [b]
Overyield (ton DM* ha^{-1}*year^{-1})	0 [a]	0.56 [b]	0.76 [b]
Transgressive overyield (ton DM* ha^{-1}*year^{-1})	0 [a]	0.34 [a]	0.18 [a]

The large effect of *Dactylis glomerata* on both yields and invasion rate by *Trifolium repens*, underlines the importance of species identity as indicated by Huyghe *et al* (2012). On the other hand, each species has a rather unique combination of functional characteristics and relevant agro-environmental conditions vary over years, making it difficult to select grassland mixtures with only few species. This was not only illustrated by the low presence of the drought tolerant (but also low productive) *Festuca rubra,* but also by the wide spreading of *Plantago lanceolata* simultaneously with the nearly disappearance of *Cichorium intybus*.

Conclusion

In this experiment diversity effects on productivity were modest. However, results indicate that possibilities exist to improve agricultural production and decrease weed invasion by using grassland mixtures with a diversity of species with functional types likely adapted to specific agro-ecological conditions.

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