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Diverse grassland mixtures for higher yields and more stable sward quality

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Abstract

In the last decades of agricultural intensification, species diversity has been largely ignored. However, in nutrient-poor grasslands, plant diversity has been shown to correlate with increased primary production. If such positive productivity effects also apply to agricultural grasslands, resource-use efficiency could be improved. To investigate whether other grassland species and diverse grassland mixtures could be more productive and nutrient efficient, a grassland on a shallow sandy soil in the south of the Netherlands was sown in April 2009 with seven non-leguminous grassland mixtures at three levels of N-fertilization (total N = 80, 200 and 320 kg ha^{-1}). Overyielding was significant, but unrelated to fertilization level: 8.0% overyielding for mixtures with two functional groups of grassland species and 14.4% for mixtures with three functional groups. Transgressive overyielding was not apparent; the DP mixture, containing only one functional group and dominated by the tall growing *Dactylis glomerata,* was equally productive as the more diverse mixtures. The results suggest that more digestible species can be included in the mixture without reducing maximum biomass production. Sward quality of diverse grassland mixtures remained better, having fewer invading species and more surface covered by sown species.

Keywords: grassland, *Dactylis glomerata*, overyielding, species diversity, species identity

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 economic species, *Lolium perenne*. Conventionally fertilized grasslands of the Netherlands are dominated by sown cultivars of *L. perenne*, with invading unsown species like *Poa trivialis, Poa annua, Stellaria media* and *Taraxacum officinalis*. Most grasslands on sandy soils are resown every 4-10 years due to botanical degradation often linked to drought periods; having negative effects on soil biodiversity, soil organic matter content and water retention (van Eekeren *et al.*, 2008). Fertilization rates have been reduced in conventional agriculture due to legislation, while the area of grassland that has restricted fertilization rates due to nature considerations and organic production rules is growing. Under these circumstances other grassland species might become more suitable. Moreover, in nutrient-poor grasslands plant diversity has been shown to correlate with increased primary production (Hooper *et al.*, 2005). If such positive productivity effects also apply to agricultural grasslands, grassland production could be improved using mixtures with a diversity of functional types.

Materials and methods

In April 2009 an experiment was started with seven grassland mixtures (Table 1), three levels of N-fertilization and 3 replications (63 plots). Plot size was 7×4 m. The trial was sown on commercially used grassland with a shallow sandy soil in the middle south of the Netherlands. In the year of sowing, all the plots received equal fertilization (138 kg N ha^{-1}) by mixed artificial fertilizer at the beginning of the experiment and two applications of cattle slurry at 20 m^{3} ha^{-1}. In 2010 all treatments received cattle slurry in early spring (80 kg total N ha^{-1}),

and the N2 and N3 fertilization treatments received an additional 120 or 240 kg N ha^{-1} (N2 and N3, respectively) of artificial fertilizer (CAN) in 3 equal parts before the first, second and third cut. The plots were harvested four times in 2010. Dry matter yield was determined by cutting a strip of 0.81×5 m, using 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 May 2011, all sown and invading species were listed per plot and the percentage of cover of each species in the upper surface of the biomass was assessed visually. 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 sward, 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 categorized as having one functional group, LDP and LPC as having two functional groups, and LDPPC and RICH as having 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 number of grassland functional groups and fertilization level 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
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 pratensis							4
Daucus carota							1

Results and discussion

In autumn 2009, the newly sown grass mixtures were well established, though the establishment of *P. pratense* and *F. arundinacea* was disappointing, while *F. pratensis* was virtually not present. In spring 2011 the presence of the sown species was only slightly changed, except for a clear reduction of *Plantago lanceolata* (a known autumn grower) while *P. pratense* had almost disappeared. Thus, the DP mixture was completely dominated by *D. glomerata* with only 2% of ground covered with *P. pratense*, while in the mixtures LDP, LDPPC and RICH its presence could only be noted but no percentage of ground cover could be assigned. Botanical composition was not affected by fertilization level, except for the type of invading species: *T. repens* was the main invader at fertilization level N1, while *P. annua* and *S. media* were the main invaders at levels N2 and N3. However, the number of invading species and the percentage of cover with sown species were affected by the number of functional groups sown (Table 2; $P<0.05$). The major part of this effect was caused by mixture PC, which had a very open sward, but also the cover with sown species of L and DP was 7-9% lower than of the mixtures LDPPC and RICH. Thus, this result does illustrate the effect of species diversity on resistance to weed invasion, while simultaneously indicating the importance of specific species in a mixture ('species identity') as was suggested by Huyghe *et al*. (2012).

Average aboveground biomass production was limited to only 7.8 t DM per hectare, and significantly affected by fertilization rate and the diversity of the mixture sown (P<0.001; Table 3). Besides a general diversity effect, there was one functional group with a large additional effect: mixtures that included tussock grasses, dominated by *D. glomerata,* were more productive than the other mixtures (+1.4 ton DM ha^{-1}; P<0.001).

Table 2. Presence of species with more than 1% of cover (average of all N-levels). Values with different letters are significantly different (P<0.05) within each column.

Number of functional groups in mixture	% of ground cover		Number of invading species
	Sown species	Invading species	
1	70^a	19	10.1^b
2	88^b	3	9.1^b
3	91^b	3	7.2^a

Table 3. Yields of mixtures at different fertilization levels (ton DM ha^{-1}). Values with different letters are significantly different (P<0.05) within each column or row.

	Number of functional groups in mixture	1	2	3	Average
Fertilization level	N1	5.5	6.0	6.5	5.9 ^{a}
	N2	7.9	8.3	8.9	8.3 ^{b}
	N3	8.6	9.3	10.0	9.2 ^{c}
	Average	7.3 ^{A}	7.9 ^{B}	9.2 ^{C}	7.8

There was significant (P<0.001) overyielding: 8.0% for mixtures with two functional groups and 14.4% for mixtures with three functional groups. This was relatively small compared Nyfeler *et al.* (2009) and Finn *et al.* (2012) and was possibly because here we deliberately did not include N-fixing herbs. The level of overyielding was not affected by fertilization level, contradicting the assumption that positive diversity effects are more important under resource-poor conditions. Transgressive overyielding was not apparent; the mixture DP was as productive as LDPPC and RICH. As these more diverse mixtures had only ± 40% of cover with *D. glomerata*, it indicates the possibilities to increase digestibility by adding more palatable species like *L. perenne,* without decreasing the yield of the highest yielding species. Again, the large effect of *D. glomerata* on yields stresses the importance of species identity.

Conclusion

In this experiment, diversity effects on productivity and resistance to weed invasion were modest and unrelated to the level of N-fertilization. However, results indicate that possibilities exist to improve agricultural production using grassland mixtures with a diversity of functional types adapted to specific agro-ecological conditions.

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