Effects of grassland extensification on yield, forage quality and floristic diversity

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Abstract

Austrian farmers taking part in Agri-environmental programmes are obliged to reduce cutting frequency and fertiliser input on 5% of their total grassland area to improve biodiversity. Typically cultivated grasslands (three-cut regime + 150 kg N ha^{-1} and four-cut regime + 200 kg N ha^{-1}) were split up into subsets: a) unmodified as reference, b) two cuts + consistent fertilisation, c) two cuts + reduced fertilisation and d) two cuts + zero fertilisation, to find out how yield, forage quality and botanical parameters were affected by various management regulations. High fertiliser rates, combined with low cutting frequencies, resulted in high yields but accelerated plant maturation and poor forage quality. The proportion of valuable plants for insects decreased in the two-cut regime with consistent fertilisation and increased the most in the unfertilised two-cut regime plots during the observation period from 2010 to 2013. Unmodified reference plots showed a higher proportion of pollinator plants in the year 2013 compared to 2010 as well, which indicates a good environmental condition of such practice-relevant management systems.

Keywords: grassland, management intensity, forage quality, floristic diversity, pollination

Introduction

Intensification during the last decades has endangered species-rich grasslands which are characterising the small scaled agricultural landscape in less favoured regions in Austria. To counteract the loss of biodiversity, farmers joining the Austrian Agri-environmental programme must implement an environmentally friendly and biodiversity-promoting management on 5% of their total grassland (BMLFUW, 2015). The aim of the present study is to investigate how yield, forage quality, floristic diversity and pollination service are affected by these restrictions.

Materials and methods

Field trials were established at three different sites in Austria (Table 1) in 1999 and used for a previous fertilisation experiment until 2009. The sward was established with a seed mixture containing *Trifolium repens, Lotus corniculatus, Lolium perenne, Dactylis glomerata, Phleum pratense, Arrhenatherum elatius, Festuca pratensis, Festuca rubra, Poa pratensis* and *Trisetum flavescens*. In all sites, a three-cut and a four-cut regime was combined with either NPK, slurry or dung + liquid manure fertilisation, representing a wide range of grassland types at the end of the first decennial period in Austria. The nitrogen content of the organic fertiliser was calculated according to the EU nitrate directive less barn and storage losses. In 2010, the previous fourfold replicated, randomised block design was modified relating to cutting frequency (c) and fertilisation level (N), without changing the fertiliser type. One replicate block (three cuts and 150 kg N ha^{-1} respectively four cuts and 200 kg N ha^{-1}) was managed unmodified and used as a reference (3c150N, 4c200N), whereas in the second replicate block the number of cuts per year were reduced to two, without changing the level of nitrogen fertilisation (2c150N, 2c200N). In the third replicate block, cutting frequency was also reduced to two cuts per year and the fertilisation level lowered to 90 kg N ha^{-1} (2c90N), whereas in the fourth replicate block the reduction to two cuts per year was combined with zero fertilisation (2c0N). Forage samples were dried in hot-air cabinet at 60 °C, milled in a Cyclotech mill to

Table 1. Location, altitude and climatic conditions of the experimental sites.

Site name	Co-ordinates	Altitude (m.a.s.l.)	Average annual precipitation (mm)	Annual mean air temperature (°C)
Gumpenstein	47°29′39.4″N/14°06′04.8″E	710	1,010	6.8
Winklhof	47°42′14.1″N/13°05′54.1″E	490	1,400	8.2
Kobenz	47°14′48.2″N/14°50′51.7″E	627	856	8.2

pass a 1 mm sieve and chemically analysed to determine crude protein (CP) using Dumas method. The cover of vascular plants was recorded at the end of the experiment in 2013. Finally, the 'flowering value' (Crane *et al*., 1984; MLR, 2011) of each recorded plant species indicating their importance for honey bees, wild bees and hoverflies was multiplied with the individual species proportion and summed up to calculate the 'flowering-points' per treatment. R version 3.3.1 was used for statistical analysis and multiple comparisons of means with Tukey contrasts using the 'multcomp' (Hothorn *et al*., 2006) package were applied.

Results and discussion

Cutting frequency, N-level and fertiliser type showed a significant ($P < 0.05$) impact on DM yield. The highest DM yields were observed within treatment 2c150N in the three-cut regime and treatment 2c200N in the four-cut regime (Table 2). In all treatments the NPK fertilised plots showed the highest yields. Within treatment 2c0N, plots which were fertilised with dung + liquid manure in the pre-period, achieved the best DM yields. This result can be explained due to a high proportion of organically bound N in this fertiliser type, resulting in a slower but longer lasting N-availability for plants. Crude protein (CP) content of the first cut was again significantly affected by cutting frequency, N-level and fertiliser type. Due to different length of growing periods, treatments with three and four cuts were not statistically compared with the two-cut treatments (Table 3). As expected, the unmodified reference treatments provided the highest CP content. Due to slower phenological development without any fertilisation, treatment 2c0N showed a higher CP content compared to treatment 2c90N. Treatments 2c150 and 2c200 had higher CP contents compared to the treatment 2c90N, which can be explained by the appearance of volunteers during the first growth. Concerning the type of fertiliser, there is evidence of a higher CP content in the NPK fertilised plots, influenced by the faster nutrient availability.

Due to considerable different results, floristic diversity (FD) and flowering points (FP) were evaluated seperately for each experimental site. Compared to the last botanical survey in 2005, FD increased at all evaluated sites within treatment 3c150N. Treatment 2c0N within the three-cut regime showed a significant rise of FD in Gumpenstein and Kobenz but a decrease in Winklhof. In treatment 2c200N a significant decrease of FD occurred at all sites. The same appeared for treatment 2c150N with the exception of Kobenz, where FD stagnated. The highest rise in FD (+ 21%) was observed in Kobenz

Table 2. DM yield (Mg ha^{-1} $year^{-1}$) during the observation period (average of 2010-2013).[1]

Fertiliser type - three-cut regime				Fertiliser type - four-cut regime			
Treatment	NPK	Slurry	Dung + liquid manure	Treatment	NPK	Slurry	Dung + liquid manure
3c150N	$9.42^{a\ ij}$	$8.18^{b\ i}$	$7.76^{b\ i}$	4c200N	$9.15^{a\ j}$	$8.51^{a\ j}$	$9.23^{a\ i}$
2c150N	$9.94^{a\ i}$	$8.50^{b\ i}$	$8.03^{b\ i}$	2c200N	$10.58^{a\ i}$	$9.59^{b\ i}$	$9.87^{ab\ i}$
2c90N	$8.51^{a\ j}$	$7.25^{b\ j}$	$7.50^{ab\ ij}$	2c90N	$8.45^{a\ j}$	$7.38^{b\ k}$	$7.55^{ab\ j}$
2c0N	$5.20^{b\ k}$	$5.71^{ab\ k}$	$6.59^{a\ j}$	2c0N	$5.26^{b\ k}$	$5.57^{b\ l}$	$6.80^{a\ j}$

[1] Superscript letters (abc for fertiliser type and ijkl for treatments) indicate significant differences ($P < 0.05$).

Table 3. Crude protein content (g CP kg^{-1} DM) of the first cut (average of 2010-2013).[1]

Fertiliser type - three-cut regime				Fertiliser type - four-cut regime			
Treatment	**NPK**	**Slurry**	**Dung + liquid manure**	**Treatment**	**NPK**	**Slurry**	**Dung + liquid manure**
3c150N	101^{a}	87^{b}	85^{b}	4c200N	140^{a}	134^{ab}	129^{b}
2c150N	$79^{a\ i}$	$71^{b\ ij}$	$67^{b\ i}$	2c200N	$79^{a\ i}$	$74^{a\ i}$	$71^{a\ i}$
2c90N	$67^{a\ j}$	$66^{a\ j}$	$69^{a\ i}$	2c90N	$64^{a\ j}$	$66^{a\ j}$	$65^{a\ i}$
2c0N	$76^{a\ i}$	$75^{a\ i}$	$74^{a\ i}$	2c0N	$73^{a\ i}$	$72^{a\ ij}$	$72^{a\ i}$

[1] Superscript letters (ab for fertiliser type and ij for treatments) indicate significant differences ($P < 0.05$).

within treatment 2c0N in the former four-cut regime. By contrast, treatment 2c200N in Gumpenstein showed the highest reduction (- 36%). In total, FD at the initial situation was lowest in Winklhof and only one of the treatments showed a significant increase there. In Gumpenstein and Kobenz, where the initial situation already provided a broader variety of plants, two of the four tested treatments performed significantly better than the references with regard to FD. At all sites with the exception of Winklhof, FP were highest within treatment 2c0N. The reference plots 3c150N and 4c200N showed, on average, the second highest FP, whereas treatments with a reduction of the cutting frequency but with consistent or reduced fertilisation level performed worst. With regard to fertiliser types, slurry and dung + liquid manure increased FP more than NPK.

Conclusion

A reduced defoliation regime combined with a lower fertilisation level is a suitable measure to increase FD and the proportion of valuable plants for insects on grassland. Poor forage qualities and lower yields, mainly influenced by the fertilisation level, are the result of low cutting frequencies. A site-adapted defoliation regime with three cuts, combined with well adapted fertilisation levels, shows a positive impact with regard to FD and the proportion of valuable plants for insects as well.

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