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The Impact of Two Different Cutting Regimes on Grassland Species Diversity

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ABSTRACT

Since 1995, a field experiment has been conducted on semi-natural grassland to compare the effects of different cutting regimes (2 cuts per year, 4 cuts per year) over several years (1998, 2002, and 2019) on the botanical composition of the swards. Each year (from 1995 to the present), vegetation inventories were inventoried before the first cut in May using the direct estimation technique. Species diversity was assessed using standard parameters (H - Shannon's diversity; D1 - Simpson's diversity; D2 - Simpson's dominance, E - Simpson's evenness). The total number of plant species was statistically different in the observed years. However, the different management measures had no significant effect on the total number of plant species. Based on the results, we found that the different cutting regimes also significantly influenced the proportion of grasses and legumes in the sward, while they did not significantly change the proportion of herbs. A less frequent cutting regime (2 cuts per year) was characterized by a higher proportion of legumes and a lower proportion of grasses. In contrast, the results for treatment with 4 cuts per year were just the opposite. The values of all examined species diversity indices showed that the less intensive grassland management (2 cuts per year) had a significantly higher species diversity than the more intensive one (4 cuts per year).

Key words: grassland, cutting frequency, botanical composition, diversity indices

INTRODUCTION

It is well known that semi-natural grasslands are among the largest ecosystems in the world (Suttie et al., 2005). In Europe, they cover up to two-thirds of the total agricultural land (Kramberger and Kaligarič, 2008). They serve as a source of forage for animal nutrition but also have an essential function in maintaining the cultural landscape and protecting biodiversity (Hopkins and Holz, 2006).

Historically, the biodiversity of semi-natural grasslands was mainly maintained by extensive grazing or haymaking during the seed maturation of the plants (Lukač et al., 2013). Since the mid-20th century, when significant changes in the use of grassland began, i.e. the use of large amounts of nitrogen fertilizers and herbicides, many previously semi-natural and natural grasslands have been converted into arable land consisting of sown grasses and legumes (Kramberger and Kaligarič, 2008).

Slovenia is characterized by a great diversity of plants and animals resulting from less intensive grassland management. However, grassland management is much more intensive in some western and north-western European countries. Intensive grassland management often improves forage production and quality but, on the other hand, often reduces the plant diversity of the sward (Hodgson et al., 2005; Plantureux et al., 2005; Hopkins and Holz, 2006). The relationship between the botanical composition of the sward and forage production is fundamental to the management of grassland and the maintenance of its biodiversity (Nösberger and Staszewski, 2002; Plantureux et al., 2005).

In the last decade, the negative consequences of the decline in grassland biodiversity have been recognised, and measures have been developed to end it (Lukač et al., 2013). Researchers have looked at different aspects of managing semi-natural grassland to facilitate its conservation and have studied the different cutting regimes and fertilizer applications on herbage production, botanical composition and sward structure. In this study, the effects of long-term different cutting frequencies of the sward on its botanical composition in all standard biodiversity parameters were investigated.

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MATERIAL AND METHODS

The trial sites

The botanical composition of the meadow was studied based on field plots in a long-term experiment established in 1995 in Maribor, Slovenia (46°28' N, 15°38' E; 300 m a.s.l.). The semi-natural wet grassland, dominated by the plant community Ranunculo repentis – Alopecuretum pratensis (Ellmauer and Mucina, 1993), was previously mowed three times a year under conditions of low fertilization (only mineral fertilizers were added in an annual amount of 80 kg N, 80 kg P_2O_5, and 120 kg K_2O per hectare, respectively). The soil type is district brown (Dystric Cambisol; FAO, 1989), with pH ($CaCl_2$) 5.9 and mean soil values of 17.5 mg ammonlactate-soluble P and 40.1 mg ammonlactate-soluble K per 100 g air-dried soil (Egnér et al., 1960).

The experimental design was a randomized block trial with four replications of two management treatments (different cutting frequencies). The size of each plot was 40 m^2 (5 m × 8 m). In treatment 1, cutting was done at six-week intervals (4 cuts per year), and the first cut was in mid-May. In treatment 2, only two cuts were made per year. The first cut took place in mid-June, the second in late August. Depending on mowing intensity, 180 kg N, 120 kg P_2O_5, and 180 kg K_2O were applied in treatment 1 each year, and 80 kg P_2O_5 and 120 kg K_2O in treatment 2. In treatment 2, however, no nitrogen was added to promote legume growth.

The average annual air temperature in the region during 1998–2019 was 10.8°C, the average monthly air minimum was -0.1°C in January, and the average monthly maximum was 21.3°C in July. The average annual precipitation in the region during 1998–2019 was 1045 mm. In the region, the growing season starts at the end of March and lasts until the end of October. Table 1 shows precipitation and average monthly air temperatures during the growing season from March to October for the observed years, measured at the nearest meteorological station Maribor (ARSO, 2022).

Measurements

The direct estimation technique was used to inventory the botanical composition of the sward, which was carried out by three estimators (Mannetje and Jones, 2000). In addition to the list of all identified plant species, we also estimated their coverage ratio in the sward, as Whalley and Hardy (2000) recommended. The vegetation inventory was carried out each year (from 1995 to the present) before the first cut in May. However, in this paper, only the botanical inventories after 3 (1998), 7 (2002), and 14 (2019) years of the experiment were included in the analysis. The most commonly used parameters for assessing the species diversity of the sward are listed in Table 2.

Table 1: Average air temperature (at 2 m; °C) and precipitation (mm) during the growing season of the observed years at the nearest meteorological station Maribor

	1998	2002	2019
	Air temperature (°C)		
March	4.2	7.2	8.0
April	10.8	9.7	11.2
May	15.1	17.3	12.8
June	19.2	20.8	22.8
July	20.1	21.2	21.7
August	20.0	19.7	21.8
September	14.8	14.1	16.1
October	10.7	10.8	12.5
	Precipitation (mm)		
March	4.2	7.2	8.0
April	10.8	9.7	11.2
May	15.1	17.3	12.8
June	19.2	20.8	22.8
July	20.1	21.2	21.7
August	20.0	19.7	21.8
September	14.8	14.1	16.1
October	10.7	10.8	12.5

Table 2: Formulas used to calculate diversity measures (according to Morris et al., 2014)

Metric	Traditional formula
Richness (S)	Number of species
Shannon's diversity (H)	$H = -\sum p_i \ln p_i$
Simpson's diversity (D1)	$D_1 = 1 - \sum p_i^2$
Simpson's dominance (D2)	$D_2 = \frac{1}{\sum p_i^2}$
Simpson's evenness (E)	$E = \frac{D_2}{S}$

p_1 – the proportion of individuals belonging to species

The effects of cutting frequency and year on the assessed parameters of plant composition were analyzed using a two-way analysis ANOVA. Means were separated using Fisher's LSD or Duncan's test, and statistical significance between them was indicated by a P-value ≤ 0.05. Results are reported as estimated means ± standard errors of the mean (SEM). All analyses were conducted using IBM SPSS Statistics (version 22).

RESULTS AND DISCUSSION

Botanical composition of the sward

The botanical composition of the sward is shown in Table 3. The species are divided into three functional groups: grasses (Poaceae), legumes (Fabaceae), and herbs (species of other botanical families). The number of species and the proportion of dominant species are determined for each functional group depending on the experimental years and management treatment.

Between 32 to 47 plant species were found in the different managed swards (Table 3). In the treatment with low cutting frequency (two cuts per year), the botanical composition clearly evolved towards tall grasses over time. Yorkshire fog (*Holcus lanatus L.*), meadow foxtail (*Alopecurus pratensis L.*), and yellow oat grass (*Trisetum flavescens P. Beauv.*) dominated among the grasses. The most frequently represented species among the legumes are red clover (*Trifolium pratense L.*) and white clover (*Trifolium repens L.*). The group of other herbaceous plants is dominated by hedge bedstraw (*Galium mollugo L.*), English plantain (*Plantago lanceolata L.*), yellow bedstraw (*Galium verum L.*), and meadow buttercup (*Ranunculus acris L.*). The high proportion of the herbs mentioned can be explained by their high response to NPK fertilizers and by their ecological properties (Paulie et al., 2002).

The commonly used method for determining the botanical diversity of grasslands is still to determine the total number of all plant species (Morris et al., 2014). The year statistically influenced sward species richness, while management (2 or 4 cuts per year) had no significant influence (Table 4). Cutting frequency had a significant influence only on the proportion of grasses and legumes; at the same time, it had no statistically significant influence on the proportion of herbs. Furthermore, there was no interaction between the year and the management treatment ($Y \times MT$; $p > 0.05$) on the total number of plant species and the proportion of the individual functional groups in the sward.

In 2002, the highest average number (37.5) of different plant species was present in the sward, while the total number of species in 1998 and 2019 (27.3 and 29.0, respectively) were comparable and showed no statistically significant differences (Table 4). The proportion of grasses (1998 – 59.1%, 2002 – 58.8% and 2019 – 56.9%), legumes (1998 – 15.0%, 2002 – 14.0% and 2019 – 14.5%), and herbs (1998 – 25.9%, 2002 – 27.3% and 2019 – 28.5%) did not differ significantly between the observed years. However, the highest proportion of grasses (65.3%) was found when the sward was cut four times per year; at the same time, the proportion of legumes (23.9%) appeared to be statistically higher when the sward was cut twice per year. The proportion of herbs is comparable for both types of management (24.9 and 29.5, respectively).

As Buchgraber and Gindl (2004) found, the ideal botanical composition of natural grassland consists of 50 to 70% grasses, 10 to 30% legumes, and 10 to 30% herbs. The results show that the experimental plots have almost the best possible botanical composition for forage production. The comparison by year and management of the sward corresponds to the requirements. The difference is only in the proportion of legumes in the treatment with four cuts per year (5.2%), which is too low given the ideal content. The low proportion of legumes in the sward cut four times a year results mainly from the high content of added N (180 kg/ha per year) and the frequent defoliation, as noted in our previous publications (Kramberger and Gselman, 2000). The results are similar to those of Harmens et al. (2004), who also used equal amounts of fertilizers to treat different cutting frequencies. However, as moderately high amounts of N fertilizers were used, high total amounts of N in the system stimulated the negative effects of mineral N in the soil on N fixation and competitiveness of legumes grown in the more frequently mown grassland community. The results underline the importance of plant nutrients, especially N (Soussana et al., 2012), for plant competition and grassland community dynamics.

Botanical diversity evaluated with different indices

Dominance and diversity are essential characteristics to describe communities. The most commonly used indices to assess plant diversity in the swards are listed in Table 5. The management treatment (MT) had a strong statistical influence ($P < 0.001$) on each diversity parameter calculated (H – Shannon's diversity; D1 – Simpson's diversity; D2 – Simpson's dominance). However, the year (Y) and the interaction between the factors ($Y \times MT$; $P > 0.05$) had no significant influence on them. Only in the case of Simpson's evenness (E) did both factors indicate that the average values were statistically different ($P < 0.05$).

Since a higher Shannon's index value means greater community diversity (Routledge, 1979; Morris et al., 2014), the main findings of the experiment were that the four-cut treatment significantly reduced sward diversity regardless of the year observed (H-value of 2.4±0.02 for the four-cut treatment versus 2.5±0.03 for the two-cut treatment).

The Simpson's diversity index value varies between 0 and 1. The higher the value, the higher the probability of diversity; the index represents the probability that two individuals randomly selected from a sample belong to different species (Routledge, 1979; Morris et al., 2014). The overall D1 value indicates significant differences in botanical composition between swards with different cutting frequencies and ranged from 0.88 for the two-cut treatment to 0.90 for the four-cut treatment. We can thus claim that species diversity is more pronounced in areas with less frequent cutting

Table 3: Botanical composition of the sward following the observed year (1998, 2002 and 2019) and management treatment

Management treatment	Plants	Composition % 1998		2002		2019	
2-cuts	Grasses	*Holcus lanatus L.*	21.5	*Holcus lanatus L.*	10.0	*Holcus lanatus L.*	18.0
		Alopecurus pratensis L.	8.5	*Alopecurus pratensis L.*	9.0	*Arrhenatherum elatius L.*	14.0
		Arrhenatherum elatius L.	7.5	*Poa pratensis L.*	7.0	*Alopecurus pratensis L.*	11.0
		∑ other grasses	12.5	∑ other grasses	23.0	∑ other grasses	11.0
		%±SE	50±7.1	%±SE	49±7.1	%±SE	54±4.8
		Richness	**8**	**Richness**	**13**	**Richness**	**10**
	Legumes	*Trifolium repens L.*	10.5	*Medicago lupolina L.*	11.7	*Trifolium pratense L.*	11.5
		Trifolium pratense L.	9.5	*Trifolium pratense L.*	8.7	*Trifolium repens L.*	8.5
		Trifolium dubium L.	5.0	*Vicia cracca L.*	1.6	*Lotus corniculatus L.*	1.0
		∑ other legumes	1.0	∑ other legumes	1.0	∑ other legumes	2.0
		%±SE	26±9.5	%±SE	23±12.0	%±SE	23±8.3
		Richness	**5**	**Richness**	**6**	**Richness**	**5**
	Herbs	*Galium mollugo L.*	5.3	*Ranunculus acris L.*	5.5	*Galium mollugo L.*	7.4
		Galium verum L.	5.2	*Galium mollugo L.*	4.8	*Galium verum L.*	3.6
		Ranunculus acris L.	2.1	*Plantago lanceolata L.*	4.4	*Plantago lanceolata L.*	2.9
		∑ other herbs	11.4	∑ other herbs	13.3	∑ other herbs	9.1
		%±SE	24±4.8	%±SE	28±10.4	%±SE	23±5.5
		Richness	**22**	**Richness**	**28**	**Richness**	**18**
Total number of species			35		47		33
4-cuts	Grasses	*Holcus lanatus L.*	26.5	*Holcus lanatus L.*	18.5	*Anthoxanthum odoratum L.*	22.0
		Alopecurus pratensis L.	15.0	*Alopecurus pratensis L*	18.0	*Trisetum flavescens P. Beauv.*	19.3
		Trisetum flavescens P. Beauv.	9.0	*Poa pratensis L.*	11.0	*Poa pratensis L.*	12.0
		∑ other grasses	17.5	∑ other grasses	20.5	∑ other grasses	6.7
		%±SE	68±6.4	%±SE	68±6.5	%±SE	60±4.0
		Richness	**10**	**Richness**	**13**	**Richness**	**8**
	Legumes	*Trifolium repens L.*	2.0	*Medicago lupolina L.*	3.0	*Trifolium dubium L.*	2.1
		Trifolium pratense L.	2.0	*Trifolium pratense L.*	1.0	*Vicia sativa L.*	1.7
		Trifolium dubium L.	+	*Lotus corniculatus L.*	1.0	*Vicia cracca L.*	1.2
		∑ other legumes	+	∑ other legumes	+	∑ other legumes	1.0
		%±SE	4±1.0	%±SE	5±1	%±SE	6±1.4
		Richness	**5**	**Richness**	**5**	**Richness**	**6**
	Herbs	*Galium mollugo L.*	8.0	*Galium mollugo L.*	7.6	*Plantago lanceolata L.*	6.3
		Galium verum L.	4.2	*Plantago lanceolata L.*	4.4	*Galium mollugo L.*	6.1
		Rumex acetosella L.	1.5	*Ranunculus acris L.*	4.1	*Achillea millefolium L.*	5.0
		∑ other herbs	14.3	∑ other herbs	10.9	∑ other herbs	16.6
		%±SE	28±5.7	%±SE	27±6.3	%±SE	34±3.3
		Richness	**17**	**Richness**	**25**	**Richness**	**20**
Total number of species			32		43		34

SE – standard errors; 2-cuts – two cuts per year; 4-cuts – four cuts per year; + – plant species are sparse and cover a small area

Table 4: *F*-statistics from ANOVA on the effects of year and management treatment on the total number of plant species and the proportion of the individual functional groups in the sward

Factor		Richness	Grasses	Legumes	Herbs
Year		***	n.s.	n.s.	n.s.
Management treatment		n.s.	***	***	n.s.
Year x Management treatment		n.s.	n.s.	n.s.	n.s.
		Mean ± standard error			
Year	1998	29.0 ± 0.5b	59.1 ± 4.1	15.0 ± 4.8	25.9 ± 1.9
	2002	37.5 ± 0.8a	58.8 ± 4.0	14.0 ± 4.2	27.3 ± 2.8
	2019	27.3 ± 0.6b	56.9 ± 1.9	14.5 ± 3.8	28.5 ± 2.4
Management treatment					
2-cuts		31.8 ± 1.4	51.2 ± 1.7b	23.9 ± 2.7a	24.9 ± 2.0
4-cuts		30.7 ± 1.5	65.3 ± 1.9a	5.2 ± 0.4b	29.5 ± 1.6

2-cuts – two cuts per year; 4-cuts – four cuts per year; *** corresponding to P < 0.001; n.s. – not significant; a-b Different letters indicate significant differences among treatments.

Table 5: *F*-statistics from ANOVA on the effects of year and management treatment on diversity parameters

Factor		H	D_1	D_2	E
Year		n.s.	n.s.	n.s.	*
Management treatment		***	***	***	*
Year x Management treatment		n.s.	n.s.	n.s.	n.s.
		Mean ± standard error			
Year	1998	2.5 ± 0.03	0.88 ± 0.04	8.6 ± 0.3	0.30 ± 0.01ab
	2002	2.5 ± 0.05	0.89 ± 0.07	9.8 ± 0.8	0.26 ± 0.03b
	2019	2.4 ± 0.04	0.89 ± 0.05	9.2 ± 0.4	0.34 ± 0.01a
Management treatment					
2-cuts		2.5 ± 0.03a	0.90 ± 0.004a	10.1 ± 0.5a	0.32 ± 0.02a
4-cuts		2.4 ± 0.02b	0.88 ± 0.003b	8.3 ± 0.2b	0.28 ± 0.01b

H – Shannon's diversity; D_1 – Simpson's diversity; D_2 – Simpson's dominance; E – Simpson's evenness; 2-cuts – two cuts per year; 4-cuts – four cuts per year; *, **, *** corresponding to P < 0.05, 0.01 and 0.001, respectively; n.s. – not significant; a–b Different letters indicate significant differences among treatments.

systems than in areas that are cut more frequently (Čop et al., 2009).

Simpson's dominance points us to the number of identical species that make up the Simpson index. The lowest possible value of this index is 1, and the highest value is identical to the number of species in the sample. The higher the value, the greater the diversity (Routledge, 1979; Morris et al., 2014). As expected (according to the above indices), a statistically significant higher D2 value was found for the two-cut treatment (10.1) than for the four-cut treatment (8.3). Since a higher value means greater species diversity, we can conclude that the sward cut twice per year has a more diverse species composition than the one cut more frequently (four cuts per year).

Simpson's evenness (also called equitability) is calculated from Simpson's dominance divided by the total number of species observed. Its values can be low (one or a few species dominate) or high (a relatively equal number of individuals belonging to each species) (Routledge, 1979; Morris et al., 2014). The results show that the year and management treatment have a statistically significant influence on this index. In 2002, evenness was lower than in 2019 (0.26 and 0.34, respectively), while 1998 is comparable to 2002 and 2019 (0.30). In addition, E-values are statistically significantly higher when the sward was cut twice a year compared to the four-cut treatment (0.32 and 0.28, respectively). This suggests that less frequent use (two cuts per year) is characterized by greater species diversity. On the other hand, more frequent use (four cuts per year) indicates a smaller number of different plant species, but they are more abundant.

CONCLUSIONS

The floristic diversity of the grassland, measured by species richness, varied across the years and sward-cutting regimes studied. In general, management treatment has no significant effect on the total number of plant species, whereas the number of species varies according to the year studied. Although cutting frequency has a characteristic effect on the proportion of grasses and legumes in the sward, its effect on the proportion of herbs was insignificant. With a more frequent cutting regime (four cuts), the proportion of grasses in the sward is higher, and the proportion of legumes (which are more sensitive to frequent defoliation) is lower. With less frequent mowing (two cuts), the proportion of legumes was higher, and the proportion of grasses was lower. The values of all the indices studied (Shannon's diversity, Simpson's diversity, Simpson's dominance, and Simpson's evenness) showed that the less intensive management treatment (two cuts) was characterized by greater botanical diversity of the sward than the more intensive treatment (four cuts). The most important conclusion of the experiment is that the more frequent cutting regime influences the botanical composition significantly more than the respective year. Thus, for favourable species composition of the sward, it is crucial to how intensive the management is. This study was based on data from a limited number of treatments. Further studies will be conducted to determine the optimal cutting frequencies for the best grassland diversity.

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Vpliv pogostnosti košnje na vrstno pestrost travinja

IZVLEČEK

Od leta 1995 poteka na Fakulteti za kmetijstvo in biosistemske vede poskus na polnaravnem travinju. Vpliv različnih načinov rabe travne ruše (2 košnji letno, 4 košnje letno) na njeno botanično sestavo smo primerjalno proučevali več let (1998, 2002 in 2019). Botanični popis smo izvajali vsako leto (od leta 1995 do danes) pred prvo košnjo v maju s tehniko neposredne ocene. Vrstno pestrost smo ocenili s splošno uporabljenimi parametri (H – Shannonov indeks vrstne pestrosti; D1 – Simpsonova raznovrstnost; D2 – Simpsonova dominanca; E – Simpsonova izenačenost). Skupno število rastlinskih vrst se statistično razlikuje po opazovanih letih, vendar različni načini rabe travne ruše ne vplivajo bistveno na skupno število rastlinskih vrst. Na podlagi rezultatov smo ugotovili, da pogostnost košnje pomembno vpliva tudi na delež trav in metuljnic v travni ruši, medtem ko se delež zeli bistveno ne spreminja. Za 2-kosno rabo je značilen večji delež metuljnic in manjši delež trav, za 4-kosno rabo pa velja ravno obratno. Vrednosti vseh proučevanih indeksov vrstne pestrosti so pokazale, da je za manj intenzivno rabo travinja (2 košnji letno) značilna bistveno večja vrstna pestrost kot za bolj intenzivno rabo (4 košnje letno).

Ključne besede: travinje, pogostnost košnje, botanična sestava, indeksi pestrosti