Tuexenia 41: 395–410. Göttingen 2021.
doi: 10.14471/2021.41.016, available online at www.tuexenia.de

Consumption rate and dietary preference of cattle in species-rich mesic grasslands

Verzehrrate und Ernährungspräferenzen von Rindern im artenreichen, mesischen Grasland

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Abstract

For the improvement and maintenance of the desirable ecological value of semi-natural grasslands, it is necessary to manage them in a way which maintains their structure and their long-term functioning. This way is the extensive grazing in the case of the majority of grasslands situated on the Eurasian lowlands. Defoliation and biomass removal are among the most important effects of grazing on the vegetation, while the sufficient quantity and quality of plant biomass is an important ecosystem service for animal husbandry. In order to maintain the long-term functioning of pastures, it is important to gather information about the amount of consumed biomass and the dietary choice of the livestock. Therefore, we studied the direct effects of grazing on species-rich meadow steppes in Central-Hungary and the underlying mechanisms of dietary choice of cattle, using a trait-based approach. We asked the following questions: (1) What are the direct effects of grazing on the various biomass fractions (litter, mosses, forbs and graminoids)? (2) Which traits distinguish the preferred and non-preferred vascular plant species? The studied pastures were divided into two adjacent sites, which were managed differently in the study year: the grazed sites were managed by grazing for three months before the sampling date, while the control sites remained ungrazed until the sampling. In the previous years, the whole study area (i.e., each site) was grazed with moderate grazing intensity. We collected above-ground biomass samples, and measured leaf traits and shoot nitrogen concentration of the plants. The consumption of the litter and moss biomass was negligible, while the reduction of the live biomass of vascular plants was 65%. Grazing significantly decreased the flowering success of plants. Cattle consumed species characterized by high specific leaf area and high nitrogen concentration. Based on our results, we emphasize that in order to ensure the reproduction of most plant species in the long term, it is unfavourable

Manuscript received 18 March 2021, accepted 12 August 2021
Published online 31 October 2021
Co-ordinating Editor: Thomas Becker

to graze an area every year in the same period. Instead, it is recommended to use grazing in a mosaic spatial and temporal pattern. The livestock carrying capacity of an area and the long-term management of grasslands can be carefully planned based on measurements of biomass and the nutritional value of plants, which is well indicated by some easily measurable plant properties such as specific leaf area and the nitrogen concentration of species.

Keywords: biomass, grazing, leaf traits, litter, nitrogen concentration, palatability, rangelands, specific leaf area

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

The management of grasslands has undergone dramatic changes over the last centuries worldwide. Both agricultural intensification and abandonment of traditional management practices led to the decline of their conservation value (VALKÓ et al. 2018, DENGLER et al. 2020). Moreover, the former area of grasslands has been fragmented and their ecological functions have been deteriorated, which makes them vulnerable (BAKKER & BERENDSE 1999, KELEMEN et al. 2013). Thus, for the improvement and maintenance of the desirable ecological value of the grasslands it is necessary to manage them in a way which maintains their structure, diversity and their long-term functioning (KELEMEN et al. 2014, TÖRÖK et al. 2014, TÄLLE et al. 2016, GODÓ et al. 2017). Former studies proved that grazing adapted to the grassland type can be a proper tool to fulfil this aim (TÖLGYESI et al. 2015, TÄLLE et al. 2016, MOLNÁR et al. 2020). Maintaining the appropriate management of pastures is much more efficient than the reconstruction of the degraded stands both from a nature conservation and a financial point of view (TÖRÖK et al. 2011). Even after the restoration of a degraded grassland an appropriate management is needed to maintain the restored stage. Extensive grazing plays a crucial role in the seasonal removal of biomass and prevents litter accumulation and shrub encroachment (ELIAS & TISCHEW 2016, PÁPAY et al. 2020). Grazing animals influence vegetation via several mechanisms; they disperse the propagules by endo- and epizoochory and create colonization gaps for the establishment of many plant species (EICHBERG & DONATH 2018, LABADESSA et al. 2020, KISS et al. 2021). Defoliation and biomass removal are among the most important effects of grazing, while the sufficient quantity and quality of plant biomass is an important ecosystem service for animal husbandry (MOLNÁR et al. 2020). In order to maintain the functioning of pastures in the long run, it is important to fine-tune grazing regimes according to the consumed biomass, the nutritional requirements of the grazing animals and the annual weather conditions.

Selective grazing may change the species composition and the trait distribution of the vegetation; species with particular trait syndromes may become more abundant while others may be suppressed (TÖRÖK et al. 2016, TÓTH et al. 2018). The scientific methods of vegetation studies have changed over time; recently the trait-based approaches became favoured over the former species identity-based approaches (RAEVEL et al. 2012). The trait-based approach offers an opportunity for the broad generalization of the findings, enabling the global-scale comparisons of results from habitats with distinct species pools (WESTOBY 1998, LEPŠ et al. 2011, KELEMEN et al. 2016). Several studies have shown that cattle prefer the nutrient-rich plant species, since their strategy is to maximise their energy intake rate with the lowest possible energy investment (ILLIUS et al. 1992, RUTTER et al. 2004, SODER et al. 2007). For this reason, plant species favoured by cattle generally have a high specific leaf area (SLA), high nitrogen and phosphorus concentration, and are often large-sized species that are visible from afar (COPPOCK et al. 1986, DÍAZ et al. 2001). Non-preferred species are often characterized by high dry matter content, high carbon/nitrogen ratio, and they are often hairy or thorny species (MORETTO & DISTEL 1997, PÁLKOVÁ & LEPŠ 2008).

In many cases the efficient management of high-diversity pastures is hampered by the lack of knowledge about the functioning of these habitats. To fill this knowledge gap, it is crucial to reveal the biomass consumption rate and dietary preference of grazers in these habitats. For this purpose, we studied the following questions: (1) What are the direct effects of grazing on the various biomass fractions (litter, mosses, forbs and graminoids)? (2) Which traits distinguish the preferred and non-preferred vascular plant species?

2. Methods

2.1 Study area and the studied communities

Two meadow steppe stands were sampled in the central part of the Great Hungarian Plain (Central-Hungary), in the Kiskunság National Park (coordinates for the centre: 47°06'N, 19°16'E). The climate in the region is continental, the mean annual temperature is 10 °C and the mean annual precipitation is 520 mm (VADÁSZ et al. 2016). There are huge continuous ancient grasslands which cover several thousand hectares in this region. The studied meadow steppes usually originated from *Molinion* meadows and are dominated by *Molinia caerulea*, *Chrysopogon gryllus* and *Agrostis stolonifera* (MOLNÁR et al. 2008, VADÁSZ et al. 2016). These meadow steppes can be considered as the members of the *Succiso-Molinietum* association, which belongs to the *Molinio-Arrhenatheretea* class. In natural landscape of the studied region these meadow steppes (i.e., *Succiso-Molinietum*) forms a wide transition zone between *Molinia* meadows (*Molinion caeruleae*) and pannonic sand steppes (*Astragalo-Festucetum rupicolae*). In the last centuries the area of meadow steppes enlarged at the expense of *Molinia* meadows. The main reason of this process, which is still going on, is mainly the desiccation by drainage canals. Therefore, now the meadow steppes represent the grassland type with the largest extent in the study region. This habitat type is characterized by a unique species pool and high diversity, harbouring more than ten orchid species (e.g. *Anacamptis pyramidalis*, *Ophrys oestrifera*, *O. sphegodes*, *Orchis coriophora*) and several other plants protected in Hungary (e.g. *Centaurea scabiosa* subsp. *sadleriana*, *Gentiana pneumonanthe*, *Iris sibirica*, *I. spuria*, *Koeleria javorkae*, *Ophioglossum vulgatum*, *Schoenus nigricans* and *Veratrum album*). The nomenclature of plant species follows KIRÁLY (2009).

The soils of the studied communities are meadow soils characterized by high humus content. The meadow steppe stands have been managed by grazing for decades, nowadays extensive beef cattle (mainly Limousin cattle) grazing is typical with moderate grazing from April to November, with 0.4 livestock unit/ha. Both studied meadow steppes were located in a five thousand hectares large pasture system approximately 7 kilometres far from each other. The two studied stands did not differ in their abiotic conditions and in their management history.

2.2 Study design and data collection

Both meadow steppe stands were divided into two adjacent sites (grazed and control) which were managed differently in the study year (2015), giving an opportunity to use split-plot design (Fig. 1). The grazed sites were grazed for three months before the sampling while the control sites remained ungrazed in the study year until the sampling (late June 2015). In the previous years the management of the grazed and control sites was similar as both of them grazed with moderate grazing intensity. Within each site 35 above-ground biomass samples were collected from 20 cm × 20 cm plots in late June 2015, at the peak of biomass production (Fig. 1). We collected the above-ground biomass with scissors by cutting plants at the soil surface. After drying, all 140 samples [2 stands × 2 management types (grazed/control sites) × 35 samples] were separated to litter, mosses and living biomass of vascular

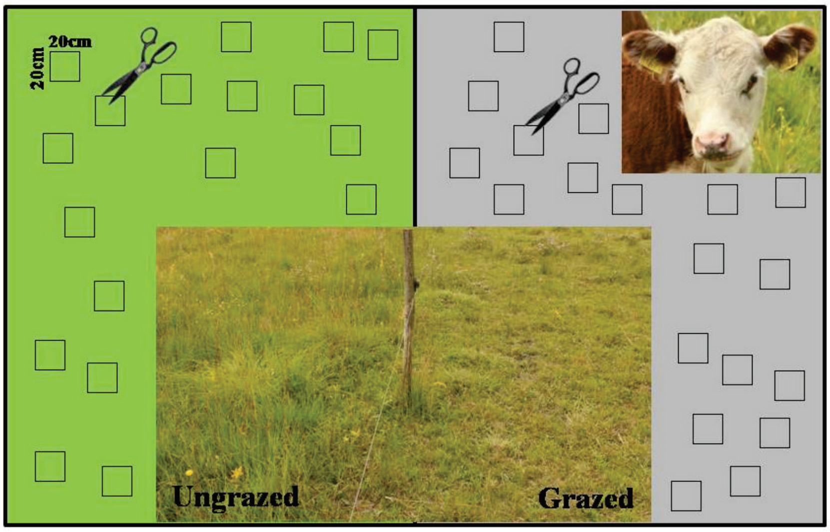

Fig. 1. Our *split-plot* sampling design. The studied pastures were divided into two adjacent management types i.e., ungrazed (control) and grazed sites. Within each site, 35 above-ground biomass samples were collected from 20 cm × 20 cm plots.

Abb. 1. Das verwendete *Split-Plot*-Design innerhalb der beweideten und unbeweideten Weiden. Auf jeder Fläche wurden auf 20 × 20 cm-Flächen 35 oberirdische Biomasse-Proben gesammelt.

plants, and the latter fraction was sorted to species. Dry weights of all fractions and species were measured with 0.01 g accuracy. The numbers of flowering shoots of each flowering species were also counted for each species in the biomass samples.

2.3 Data analyses

2.3.1 Community-level analyses

In the community-level analyses, we considered all the vascular plant species detected in the living biomass. We used linear mixed-effect models (LME) for exploring the effect of grazing on the dependent variables, where the management type (grazed/control sites) was set as fixed factor and the studied stands as random factor. Dependent variables were species density (species number/0.04 m²), amount of litter (g/m²), moss biomass (g/m²), living biomass of vascular plants (g/m²), living biomass of graminoids (g/m²), living biomass of forbs (g/m²), total number of flowering species (species/0.04 m²), number of flowering graminoid species (species/0.04 m²), number of flowering forb species (species/0.04 m²), total number of flowering shoots (shoot/m²), flowering shoot number of graminoids (shoot/m²) and flowering shoot number of forbs (shoot/m²).

2.3.2 Trait-based analyses

In order to reliably estimate species level biomass loss, we considered the species that occurred in more than 10% of the samples in each study site. Altogether 100 vascular species were detected in the samples from which 29 species complied with this criterion, adding up to 92.5% of the total living biomass of vascular plants. To compare the biomass of these 29 species in the grazed sites and controls, we used parametric and non-parametric pairwise tests (i.e., *t*-test, Welch *t*-test or Mann-Whitney *U* test) depending on the results of the normality test (Shapiro-Wilk test) and the F-test of the equality of variances. We classified these 29 species into three preference categories based on their biomass loss showed by the results of the pairwise test as follows: (i) non-preferred: no significant differences in their biomass between the grazed and control sites, (ii) moderately preferred: significantly higher biomass in control sites, but with biomass loss lower than the average reduction of the living biomass of vascular plants (65%), (iii) highly preferred: significantly higher biomass in control sites, with biomass loss greater than the average reduction of the living biomass of vascular plants. For the leaf trait measurements, we collected three individuals of each species and measured the following traits: leaf dry matter content (LDMC; %), leaf area (LA; mm²) and specific leaf area (SLA; mm²/mg) using Kjeldahl method. Moreover, we measured the nitrogen concentration of shoots (N; mg g^{-1}). We assigned shoot hairiness (present/absent) and shoot height of the species based on KIRÁLY (2009).

We applied one-way ANOVA with Fisher LSD post-hoc test to reveal the differences in the trait values characteristic to the three preference categories. We performed Principal component analysis (PCA) to study the covariance amongst traits. We tested the correlation between the species traits using Pearson correlation. We used R for the statistical analyses (R CORE TEAM 2017).

3. Results

3.1 Community level analyses

LME did not reveal significant differences in the species richness of the grazed and control sites. However, there were some short-lived species which were found only in the controls (e.g. *Bromus hordeaceus*, *Cerastium dubium*, *C. vulgare*, *Capsella bursa-pastoris* and *Myosotis stricta*). The differences between the control and the grazed sites in the amount of litter and moss biomass were non-significant (Table 1). The living biomass of vascular plants decreased by 65.2% in grazed sites compared to the controls. The reduction was similar for graminoid (65.5%) and forb (64.2%) biomass (Fig. 2). LME showed that these reductions were significant, and there were no significant effects of the studied stands (Table 1). Grazing significantly decreased the number of flowering species, both for graminoids and

Table 1. The effects of grazing on the biomass fractions and flowering success. The results of LME, where the management type (grazed *vs*. ungrazed) was set as fixed factor and the study site as random factor. *** $p \leq 0.001$, *n.s.* not significant.

Tabelle 1. Auswirkungen von Beweidung auf die Reduktion von Biomassefraktionen und den Blüherfolg. Ergebnisse linearer gemischter Modelle mit Managementtyp (beweidet *vs*. unbeweidet) als festem Faktor und Untersuchungsfläche als Zufallsfaktor. *** $p \leq 0{,}001$; *n.s.* nicht-signifikant.

	F	*p*
Biomass fractions		
Total biomass	79.21	***
Litter	2.57	*n.s.*
Moss	0.01	*n.s.*
Living vascular plants	230.90	***
Graminoids	152.71	***
Forbs	54.36	***
Flowering success		
Number of flowering species	85.33	***
Graminoids	60.60	***
Forbs	13.97	***
Number of flowering shoots	40.14	***
Graminoids	31.41	***
Forbs	18.24	***

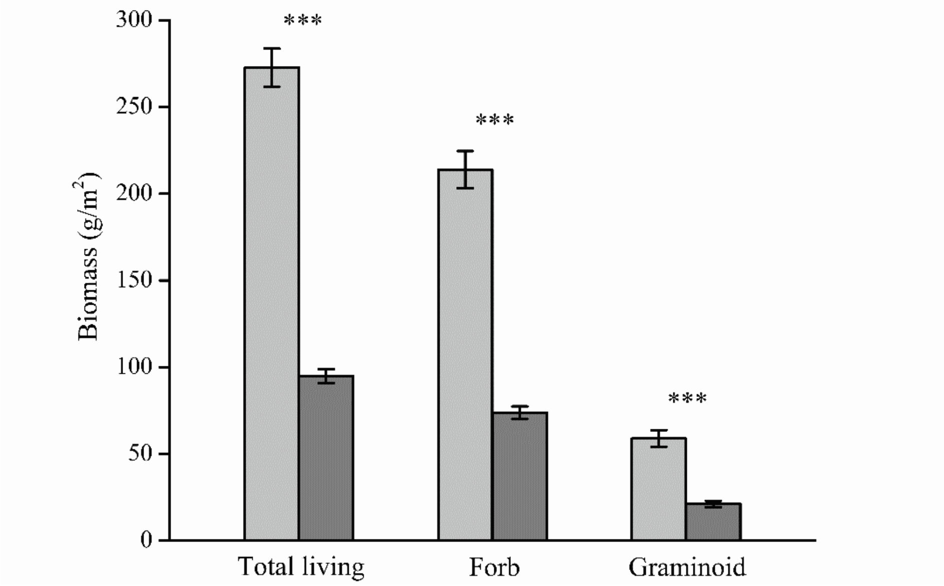

Fig. 2. Total living biomass and biomass fractions of forbs and graminoids in ungrazed (light grey bars) and grazed sites (dark grey bars). Mean ± SE. LME statistics revealed significant grazing effects in all cases at *** $p < 0.001$.

Abb. 2. Lebendbiomasse, gesamt und unterschieden nach der Kraut- und Grasfraktion, von unbeweideten = Kontrolle (hellgraue Balken) und beweideten Flächen (dunkelgraue Balken). Mittelwerte ± Standardfehler. In allen Fällen zeigte die LME-Statistik signifikante Unterschiede auf dem Level von *** $p < 0{,}001$.

forbs (Table 1, Fig. 3). The number of flowering shoots was reduced by 85.5% in the grazed sites compared to controls; the reduction was 85.6% and 84.7% for graminoids and forbs, respectively (Table 1, Fig. 3). There were no significant effects of the studied stands in the case of flowering species and shoot numbers.

3.2 Trait-based analyses

We classified the most frequent species into preference categories based on their biomass loss (Table 2) and compared the functional trait values of species belonging to different categories. The species of different categories significantly differed in their SLA (ANOVA: $F = 7.47$, $p < 0.05$) and nitrogen concentration (ANOVA: $F = 10.67$, $p < 0.001$); cattle preferred species with high SLA and nitrogen concentration (Fig. 4). There were no significant differences in other traits (LDMC, LA, plant height, hairiness) between the preference categories.

We revealed the association between the functional traits using PCA and Pearson correlations (Fig. 5). SLA was positively correlated with nitrogen concentration (Pearson: $r = 0.47$, $p < 0.05$) and negatively with LDMC (Pearson: $r = -0.49$, $p < 0.01$), and there was a negative correlation between LA and LDMC (Pearson: $r = -0.46$, $p < 0.05$).

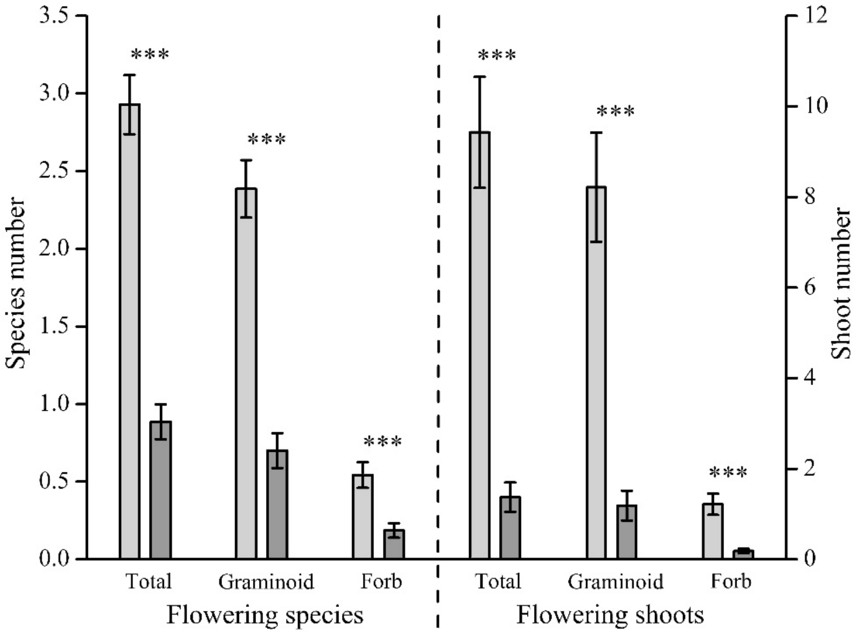

Fig. 3. Differences in flowering success (flowering species and shoot number per 0.04 m²) between the ungrazed (light grey bars) and grazed (dark grey bars) sites. LME revealed significant grazing effects at *** $p < 0.001$ in all cases.

Abb. 3. Unterschiede im Blüherfolg (Anzahl blühende Arten und Anzahl Blütentriebe pro 0,04 m²) zwischen unbeweideten (hellgraue Balken) und beweideten (dunkelgraue Balken) Flächen. Mittelwerte ± Standardfehler. In allen Fällen zeigte die LME-Statistik signifikante Unterschiede auf dem Level von *** $p < 0{,}001$.

4. Discussion

There are lot of studies about grazing effects on grasslands with contradictory results regarding its impact on species richness and biomass (MATCHES 1992, FERRARO & OESTERHELD 2002). One of the main reasons for the various results is the different temporal scale of the studies. The direct effects of grazing (i.e., the consumption of plants), the short-term effects of grazing (i.e., the vegetation properties in the next year after grazing) and the long-term effects of grazing (i.e., changed species composition and vegetation structure) necessarily differ from each other (ASNER et al. 2004). In this paper, we studied the direct effects of grazing, which can lead to a more detailed understanding of the rate of biomass consumption and the dietary strategies of cattle.

In this study, we expected and found that the species richness scores did not differ between the grazed and control sites, because the long-term usage of the studied sites has been the same as they have been managed by grazing for decades. Therefore, we focused on the direct effects of grazing on the biomass and flowering success of plants.

In moderately grazed grasslands, PLACHTER & HAMPICKE (2010) detected a decrease of approximately 45% in litter amount, while other studies typically found greater (70–85%) decreases in the long run (KAUFFMAN et al. 2004, BORK et al. 2012). Our results correspond with the findings of CARILLA et al. (2011) and BORK et al. (2012) who demonstrated that not

Table 2. Biomass reduction of the most frequent plant species. To compare their biomass between the grazed sites and ungrazed sites, Welch *t* test (W) or Mann-Whitney *U* test (M) were used. Species were classified into three ate preference categories based on their biomass reduction and on the results of the pairwise tests. *** $p \leq 0.001$, ** $p < 0.01$, * $p < 0.05$, *n.s.* not significant.

Tabelle 2. Biomassereduktion der häufigsten Pflanzenarten durch Beweidung. Die Arten wurden nach dem Ausmaß der Biomassereduktion in drei Fraßpräferenz-Kategorien (gering, mittel, hoch) eingeteilt. Welch *t*-Test (W) oder Mann-Whitney *U*-Test (M). *** $p \leq 0{,}001$; ** $p < 0{,}01$; * $p < 0{,}05$; *n.s.* nicht-signifikant.

Species	Preference category	Biomass reduction (%)	Test
Achillea asplenifolia	low	– *n.s.*	M
Deschampsia caespitosa	low	– *n.s.*	M
Festuca pseudovina	low	– *n.s.*	M
Juncus articulatus	low	– *n.s.*	M
Koeleria cristata	low	– *n.s.*	M
Plantago lanceolata	low	– *n.s.*	M
Plantago media	low	– *n.s.*	M
Poa angustifolia	low	– *n.s.*	M
Potentilla recta	low	– *n.s.*	M
Schoenus nigricans	low	– *n.s.*	M
Scirpoides holoschoenus	low	– *n.s.*	W
Agrostis stolonifera	medium	34.2 *	M
Carex flacca	medium	64.8 *	M
Carex panicea	medium	63.3 **	W
Carex tomentosa	medium	64.1 *	W
Chrysopogon gryllus	medium	9.8 *	M
Dactylis glomerata	medium	63.9 **	W
Festuca pratensis	medium	13.5 **	M
Inula britannica	medium	10.3 **	M
Serratula tinctoria	medium	56.1 ***	M
Centaurea jacea	high	79.5 ***	M
Daucus carota	high	95.4 ***	M
Elymus repens	high	77.0 **	W
Galium verum	high	91.1 ***	M
Leontodon hispidus	high	87.2 **	M
Lotus corniculatus	high	81.8 *	M
Molinia caerulea	high	92.6 ***	M
Picris hieracioides	high	77.4 *	W
Tetragonolobus maritimus	high	81.9 *	M

much litter is directly consumed by cattle. Our results also correspond with the finding that the lower amount of litter observed on pastures is mainly due to the effects of the trampling and consumption of living biomass (Xiong & Nilsson 1999, Welker et al. 2004).

The effect of grazing on mosses has been studied mainly focusing on the long-term effects of grazing (Boch et al. 2018a, 2018b) or concentrating on moss-dominated alpine vegetation or tundra (Memmot et al. 1998, Virtanen 2000). Memmot et al. (1998) demonstrated that spring grazing reduced moss cover by 50% in temperate cold deserts with open vegetation. Based on our study, we can assume that in habitats where herbaceous vegetation is abundantly available for the cattle the consumption of mosses is negligible (Rupprecht et al. 2016). This is consistent with the results of Oldén & Halme (2016) as they found that bryophytes are generally not eaten by large herbivores.

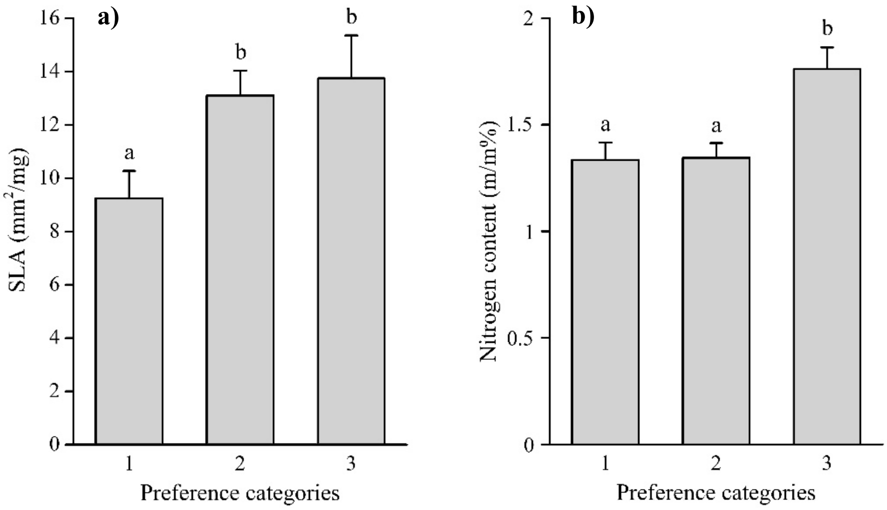

Fig. 4. Differences **a)** in SLA and **b)** nitrogen content between the preference categories: 1 = non-preferred, 2 = moderately preferred, 3 = highly preferred. Means + SE are shown. Different lowercase letters denote significant differences revealed by one-way ANOVA and Fisher LSD post-hoc test at $p < 0.05$.

Abb. 4. Unterschiede zwischen **a)** der spezifischen Blattfläche (SLA) bzw. **b)** dem Stickstoffgehalt der Arten der drei Präferenzkategorien: 1 = nicht-präferiert, 2 = moderat-präferiert, 3 = hoch-präferiert. Mittelwerte und Standardfehler. Unterschiedliche Kleinbuchstaben zeigen signifikante Unterschiede ($p < 0,05$) nach einfacher ANOVA und Fisher-LSD Post-hoc-Tests an.

Studies about the direct effects of moderate intensity grazing on vascular plants' biomass have come to similar results to ours; grasslands showed a 60–70% reduction in living biomass due to the direct effect of grazing (HOFSTEDE et al. 1995, AMIAUD et al. 2008). However, in the literature, we found examples for biomass consumption rates different from what we detected, for example CARILLA et al. (2011) reported 4 to 10% consumption of the living biomass of vascular plants under moderate grazing intensity.

The knowledge on the productivity of grasslands and the dietary preferences of the livestock supports the planning of sustainable livestock farming. However, from the ecological viewpoint, we have to consider that the decrease of the flowering success due to grazing can be disproportionately higher than the rate of biomass loss as we detected in the present study. Although grazers often avoid consuming flowering individuals (particularly flowering graminoids), cattle repeatedly graze the majority of palatable plants before they reach the flowering state; thus, they decrease the efficiency of the generative propagation (OESTERHELD & OYARZÁBAL 2004, MLÁDEK et al. 2013). Although the direct effect of grazing on the number of flowering shoots and flowering species is negative (KIMBALL & SCHIFFMAN 2003), a distinction must be drawn between this direct effect (consumption of first grass) and even the short-term effects (e.g. flowering of regrown plants or flowering in next year; PLACHTER & HAMPICKE 2010). ANDERSON & FRANK (2003) reported that in regularly grazed areas, which have not yet been grazed in the given year, the number of flowering shoots is twice as high as in abandoned areas. A likely explanation of this phenomenon is that in grazed grasslands light penetration is usually higher than in non-grazed ones

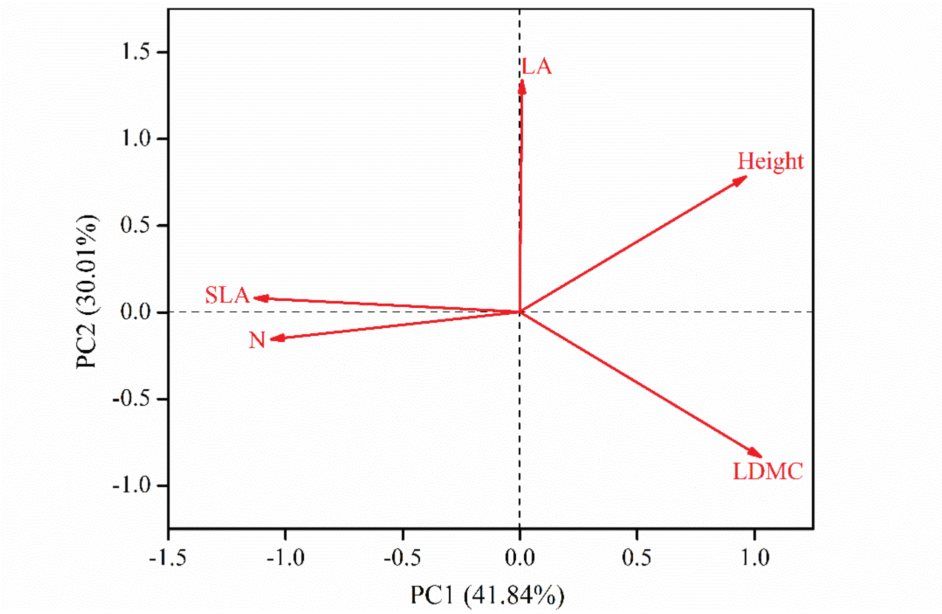

Fig. 5. PCA ordination to present the covariance amongst the studied functional traits of the vegetation. Eigenvalues for 1st and 2nd axis: 2.09 and 1.50, respectively; explained variation: 41.8 % and 30.0 %, respectively. LDMC = leaf dry matter content, LA = leaf area, SLA = specific leaf area, N = shoot nitrogen content, Height = shoot height.

Abb. 5. PCA-Ordination zur Darstellung der Kovarianz zwischen den untersuchten funktionellen Merkmalen der Vegetation. Eigenwert und erklärte Varianz der 1. Achse: 2,09 bzw. 41,8 %, und der 2. Achse: 1,50 bzw. 30,0 %. LDMC – Blatttrockenmasse, LA – Blattfläche, SLA – spezifische Blattfläche, N – Spross-Stickstoffgehalt; Height – Sprosshöhe.

(Bakker et al. 2003), which is favourable for flowering. Therefore, the biomass allocated to the reproductive parts of plants relative to their vegetative parts is higher in grazed habitats (Niu et al. 2009). Based on the above results, we emphasize that, in order to ensure the reproduction of most species in the long term, it is unfavourable to graze an area every year in the same period. Instead, it is recommended to use a grazing regime which is mosaic in space and time (Allan et al. 2014, Vadász et al. 2016).

5. Conclusions

For the implementation of the mosaic management, we have to consider the dietary strategies of cattle. The differences in cattle's preference can cause an uneven reduction in the biomass of different species, which can lead to a shift in the competitive interactions among species (Grant et al. 1996, Johnson & Sandercock 2010). Different functional traits of species affect the vegetation composition via these community-level mechanisms. Grazers prefer highly digestible species with high nutritional value (Moretto & Distel 1997, Mládek et al. 2013). These hard traits can be analysed via some soft traits as they positively correlate with SLA and nitrogen concentration (Bullock et al. 2001, Mládek et al. 2013). Our results justified this assumption as cattle preferred plants with high SLA and nitrogen concentration. These two traits were the only significant indicators of dietary preference.

The livestock carrying capacity of an area and the long-term management of grasslands can be carefully planned based on biomass measurements and the nutritional value of plants, which is well indicated by some easily measurable plant properties such as specific leaf area and nitrogen concentration. Moreover, it would be necessary to measure the amount of biomass in studies focusing on grazing effects, because using this method proper grazing intensities could be effectively determined for any given grassland.

Erweiterte deutsche Zusammenfassung

Einleitung – Zum Erhalt oder zur Verbesserung des ökologischen Wertes von Graslandflächen bedarf es einer geeigneten Bewirtschaftungsform (TÄLLE et al. 2016). In großen Teilens Eurasiens ist extensive Rinderbeweidung eine solche. Die Aufrechterhaltung einer geeigneten Bewirtschaftungsform ist dabei sowohl aus naturschutzfachlicher als auch aus finanzieller Sicht viel effizienter als die Wiederherstellung degradierter Bestände (TÖRÖK et al. 2011). Beweidung durch Rinder beeinflusst die Vegetation auf verschiedene Weise. Rinder breiten zahlreiche Pflanzenarten endo- und epizoochor aus und ermöglichen durch Schaffung von Störstellen deren Etablierung (KISS et al. 2021). Entlaubung und Biomasseentzug stellen wichtige Merkmale von Beweidung dar; sie verhindern Streuansammlung und Verbuschung, während die pflanzliche Biomasse in ausreichender Menge und Qualität wiederum für die Tierhaltung eine wichtige Ökosystemdienstleistung der Weide bildet (MOLNÁR et al. 2020). Um eine Weidefunktion dauerhaft zu gewährleisten, muss das Weideregime auf den Biomasse- und Nährstoffbedarf der Weidetiere abgestimmt werden; insbesondere muss die Kapazität einer dauerhaft artenreichen Weide bekannt sein. Hierzu fehlen jedoch oftmals Kenntnisse. Um diese Wissenslücke zu schließen, müssen der Biomasseverbrauch und die Ernährungspräferenzen der Weidetiere in ihrem Lebensraum untersucht werden. Wir taten dies und stellen dabei folgende Fragen: (1) Welche direkten Auswirkungen hat die Beweidung durch Rinder auf die Biomassefraktionen der Streu, Moose, Kräuter und Graminoiden sowie auf den Blüherfolg der Blütenpflanzen? (2) In welchen Merkmalen unterscheiden sich die von den Rindern stark bevorzugten, weniger stark bevorzugten und gar nicht bevorzugten Blütenpflanzen?

Methoden – Die beiden untersuchten Wiesensteppen liegen im Nationalpark Kiskunság in der großen ungarischen Tiefebene. In dieser Region gibt es uralte, mehrere tausend Hektar große, zusammenhängende Wiesensteppen. Sie gehören zur Assoziation *Succiso-Molinietum* (Verband *Molinion caeruleae*, Klasse *Molinio-Arrhenatheretea*) teilweise im Übergang zu pannonischen Sandsteppenrasen des *Astragalo-Festucetum rupicolae* (*Festuco-Brometea*). Der Anteil der Wiesensteppen hat in den letzten Jahrhunderten durch Grabenentwässerung auf Kosten der ehemaligen *Molinia*-Wiesen zugenommen; dieser Prozess dauert noch immer an. Heute stellen die Wiesensteppen den Graslandtyp mit der größten Ausdehnung im Untersuchungsgebiet dar. Sie besitzen einen eigenen Artenpool und eine hohe Diversität an u. a. seltenen und geschützten Pflanzenarten. Die beiden Untersuchungsflächen werden schon seit Jahrzehnten von April bis November extensiv (etwa 0,4 Großvieheinheiten pro Hektar) von Rindern beweidet. Die beiden Untersuchungsflächen wurden jeweils in zwei Teilflächen unterteilt, welche im Untersuchungsjahr unterschiedlich bewirtschaftet wurden. Je eine Teilfläche wurde vor der Probenahme drei Monate lang beweidet, während die andere als Kontrolle unbeweidet blieb. Innerhalb jeder der insgesamt vier Flächeneinheiten wurden auf 35 Kleinflächen der Größe 20 cm × 20 cm die oberirdische Biomasse geerntet und in die Fraktionen der Streu, Moose und lebenden Biomasse der Gefäßpflanzen getrennt; die Gefäßpflanzen wurden zusätzlich nach Arten getrennt und deren Blühtriebe wurden gezählt. Der Einfluss der Beweidung auf die Artendichte, Streumenge, Moosbiomasse, Lebendmasse der Gefäßpflanzen, Lebendmasse der Graminoiden und Lebendmasse der Kräuter, Artenzahl der blühenden Graminoiden und Artenzahl der blühenden Kräuter, Gesamtzahl der Blühtriebe, Blühsprosszahl der Graminoiden und Blühtriebzahl der Kräuter wurde mit Linearen *Mixed-Effect*-Modellen untersucht. Um den Biomasseverlust durch Beweidung auf Artenebene zuverlässig abschätzen zu können, wurden nur diejenigen Arten berücksichtigt, die in jeder der vier Einheiten in mehr als 10 % der Flächen auftraten. Dieses Kriterium erfüllten insgesamt 29 Arten, die 92,5% der Gesamtlebendmasse der Gefäßpflanzen ausmachten. Für den Vergleich der Biomasse dieser Arten zwischen den beweideten und unbeweideten Flächen, verwendeten wir paarweise Tests. Die 29 Arten wurden nach dem Grad ihres Biomasseverlusts durch Beweidung und nach den Ergebnissen der paarweisen Tests in drei Präferenzkategorien eingeteilt: i) nicht bevorzugt, ii) mäßig bevorzugt, iii) stark bevorzugt. Zur Untersuchung der Blatteigenschaften sammelten wir pro Art drei Individuen und maßen die folgenden Merkmale: Anteil der Blatttrockenmasse (LDMC – *leaf dry matter content*), Blattfläche (LA – *leaf area*) und spezifische Blattfläche (SLA – *specific leaf area*). Weiterhin wurde die N-Konzentration der Sprosse bestimmt und die Sprossbehaarung und Triebhöhe klassifiziert. Unterschiede dieser Merkmale zwischen den drei Fraßpräferenz-Kategorien wurden mit einfacher ANOVA mit Fisher-LSD-Post-hoc-Test untersucht. Hauptkomponentenanalyse (PCA) diente zur Einschätzung von Interkorrelation.

Ergebnisse – Artenreichtum, Streumasse und Moosbiomasse unterschieden sich nicht signifikant zwischen beweideten und unbeweideten Flächen (Tab. 1). Die Lebendmasse der Gefäßpflanzen der beweideten Flächen war gegenüber der der unbeweideten Flächen um 65,2 % reduziert. Graminoiden und Kräuter waren ähnlich stark reduziert (Abb. 2). Beweidung verringerte die Anzahl der blühenden Graminoiden und Kräuter signifikant. Die Zahl der Blühtriebe war in den beweideten Flächen um 85,5 % reduziert (Abb. 3). Die Arten der verschiedenen Fraßpräferenz-Kategorien unterschieden sich signifikant in ihrer spezifischen Blattfläche (SLA) und ihrer N-Konzentration. Konkret bevorzugten die Rinder Pflanzenarten mit großer spezifischer Blattfläche und hoher N-Konzentration (Abb. 4). Die spezifische Blattfläche (SLA) und die N-Konzentration waren positiv und das SLA und die Blatttrockenmasse (LDMC) negativ interkorreliert. Zudem waren Blatttrockenmasse und Blattfläche (LA) negativ interkorreliert (Abb. 5).

Diskussion – Der wichtigste direkte Effekt von Beweidung ist der Verzehr der Pflanzen. Ein mittelfristiger Effekt wären dagegen veränderte Vegetationseigenschaften im Folgejahr. Ein langfristiger Effekt schließlich wären eine veränderte Gesamtartenzusammensetzung. In dieser Arbeit untersuchten wir die direkten Auswirkungen von Beweidung um die Ernährungsstrategien der Weidetiere – in unserem Fall Rinder – besser zu verstehen. Da die langfristige Nutzung der von uns untersuchten beweideten und unbeweideten Graslandflächen seit Jahrzehnten identisch war, unterschied sich ihr Artenreichtum nicht voneinander. Wir fanden heraus, dass Streu und Moos kaum von den Rindern gefressen aber die Lebendmasse der Graminoiden und Kräuter um 60–70 % reduziert wird. Diese Ergebnisse stimmen mit früheren Studien gut überein (HOFSTEDE et al. 1995, AMIAUD et al. 2008). Weiterhin zeigt unsere Studie, dass Beweidung den Blüherfolg der Pflanzen überproportional reduzieren kann. Denn obwohl Rinder die blühenden Pflanzen (insbesondere die blühenden Graminoiden) eher meiden, weiden sie wiederholt den Großteil der schmackhaften Pflanzen ab – bevor diese zur Blüte kommen. Dadurch wird dann die Reproduktion und in Folge auch die generative Ausbreitung der Pflanzen reduziert. Wir sehen es daher als ungünstig an, wenn eine Fläche immer zur gleichen Jahreszeit beweidet wird. Um die generative Fortpflanzung und Ausbreitung möglichst vieler Pflanzenarten zu gewährleisten, empfehlen wir vielmehr ein mosaikartiges Weideregime mit abwechselnd frühen und späten Beweidungsterminen, das einer größeren Anzahl an Arten das Wachstum und die Reproduktion erlaubt (VADÁSZ et al. 2016). Weidetiere bevorzugen grundsätzlich gut verdauliche Pflanzenarten mit hohem Nährwert. Diese beiden relativ schwer messbaren Merkmale von Pflanzenarten, können jedoch über denen spezifische Blattfläche und Spross-N-Konzentration zuverlässig eingeschätzt werden, da diese Merkmale mit der Verdaulichkeit und dem Nährwert positiv korreliert sind (MLÁDEK et al. 2013). Diese Behauptung wird durch unsere Ergebnisse bestätigt, dass Rinder Pflanzen mit hoher spezifischer Blattfläche und hoher N-Konzentration präferierten. So können anhand der Biomasse und dem Nährwert der Pflanzen die Nutztiertragfähigkeit einer Fläche und deren optimale Bewirtschaftungsform vorhergesagt und geplant werden. Insgesamt ermöglichen Kenntnisse der Produktivität eines Graslands und der Ernährungspräferenzen der Nutztiere die Planung einer nachhaltigen Graslandwirtschaft und Nutztierhaltung (MOLNÁR et al. 2020).

Acknowledgements

The authors are grateful to Martin Magnes and one anonymous reviewer for valuable suggestions on the manuscript and the handling editor for handling work and for translating the expanded German summary. We appreciated the helpful comments from Péter Török. We thank colleagues of the Kiskunság National Park Directorate for their support. The authors were supported by MTA's Post Doctoral Research Program (AK), Hungarian Scientific Research Fund (OV: NKFI FK 124404, BD: NKFI KH 130338, NKFI FK 135329; BT: OTKA K 116639, NKFI KH 126477, KT: NKFI PD 128302, ET: NKFI KH 130320) and the Bolyai János Fellowship of the Hungarian Academy of Sciences (AK, OV, BD).

Author contributions

AK, OV, DB, CV planned the study and designed the methods. AK, OV, ZM, CV designated the study sites. NB, AK, OV, DB, TM collected the field data. NB, KT, ET, RK, JS, KA, JTB performed the laboratory work (biomass sorting, trait measurements). NB arranged and AK analyzed the data. AK and NB led the writing and all co-authors contributed to the writing process, developed the concept of this paper and reviewed the manuscript.

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