Plant species composition and plant species richness under long-term Brignant grassland experiment in Wales

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Abstract

To explore how long it takes for upland improved permanent pasture to revert to semi-natural grassland vegetation the Brignant grassland experiment was established in 1994 in Wales. It has seven treatments with three replications: sheep grazing with (GL+) and without (GL−) lime application; hay cutting with (HL+) and without (HL−) lime application; hay cutting followed by aftermath sheep grazing with (HGL+) and without (HGL−) lime application; control (CO) with previous grazed and fertilized plots. Percentage cover of individual plant species within randomly placed quadrats was estimated by visual observation in each plot during the growing season 2022. The mean total numbers of vascular plant species, vascular plant species with cover ≥1% and the Shannon diversity H index were significantly higher under treatments that included a cutting regime (HL+, HL−, HGL+, HGL−) than those with grazing management only (GL+, GL−, CO). Four groups of treatments were identified on the ordination diagram: CO treatment as the first group; GL+, GL− treatments as the second group; HGL+ and HGL− treatments as the third group; and HL+ and HL− treatments as the fourth group. There are still ongoing changes in the plant species composition almost after 30 years since the beginning of the experiment.

Keywords: defoliation, liming, managements, sheep grazing

Introduction

The restoration of species-rich grassland on previously agriculturally improved pasture (ploughed and reseeded, regular inputs of NPK fertilizers and lime) has several specific biotic and abiotic constraints. The potential for re-establishment of species from the seed bank, and, in the longer-term, the presence of the lost species in the locally surrounding vegetation are important for successful restoration of degraded plant communities (Van Diggelen and Marrs, 2003). Moreover, the type of applied management is also a key driver influencing floristic diversity of improved grasslands. This study addressed the related research question: What impact does type of defoliation with and without liming on plant species composition and species richness of formerly improved semi-natural grassland in the long-term?

Materials and methods

The 29-year-old Brignant grassland experiment was established in 1994. The experiment is located at 310 m a.s.l. on free-draining brown podzolic soils. The area of the experiment has a mean annual rainfall of approximately 1,850 mm and has an average annual minimum and maximum air temperatures of 5.2 and 11.9 °C, respectively. The plots are arranged in three replicated blocks, each containing seven plots of different treatments. The treatments are: sheep grazing, with (GL+) and without (GL−) lime application; hay cutting only, with (HL+) and without (HL−) lime application; and hay cutting followed by aftermath sheep grazing, with (HGL+) and without (HGL−) lime application. These six treatments are without additional fertilizer applications. Control (CO) plots continue the previous site management. These are limed and annually fertilized at a rate of 60 kg ha^{-1} N and 30 kg P ha^{-1}, with K also applied as required to maintain an index of 2+ (ADAS, 1983). The randomized block design experiment consists of

21 plots in total. The area of hay cut only plots is 0.08 ha and all grazed plots and plots with cutting and aftermath sheep grazing is 0.15 ha. The plots are stocked with sheep with numbers adjusted to maintain a sward surface height of approximately 4 to 6 cm. The HL+, HL−, HGL+, HGL− plots have a single hay harvest taken annually after 21 July, when weather conditions allow. Botanical data were collected during the growing season 2022 by one person only. Visual percentage cover of vascular plant species was estimated in five randomly located quadrats (0.4×0.4 m) in each plot. The mean of five quadrats of botanical composition was used for statistical evaluation. The scientific names of the plant species follow Kaplan *et al.* (2019). The Shannon diversity (H) index was calculated using cover data of vascular plant species from each sampling plot. A linear mixed-effects model (LMM) with fixed effects of treatment and random effect of replication and then Tukey's HSD tests were used for the univariate data. Redundancy analysis (RDA) in the CANOCO 5.0 program (Ter Braak and Šmilauer, 2012) was used to evaluate multivariate vegetation data (cover of vascular plant species).

Results and discussion

The mean total numbers of vascular plant species (P<0.001), vascular plant species with cover ≥1% (P<0.001) and the Shannon species diversity H index (P<0.001) were significantly higher under treatments that included a cutting (HL+, HL−, HGL+, and HGL−) than under those with grazing management only (GL+, GL−, CO) (Table 1). Based on the RDA analysis, four groups of treatments with similar plant species composition were identified on the ordination diagram: CO treatment as the first group; GL+, GL− treatments as the second group; HGL+ and HGL− treatments as the third group; and HL+ and HL− treatments as the fourth group (Figure 1). The results from this study were similar as the results obtained from the Brignant experiment after 19 years of management (Pavlů *et al.*, 2021). In contrast to previous research, we revealed significant effect of liming on the total number of vascular plant species and changes in plant species composition after application of fertilizers in the control treatment. It seems that level of dose and interval between the liming play important roles, as well as long-term application of fertilizers supporting plant species with higher nutrient demands in the control plots (CO) with long-term continuous sheep grazing (Pavlů *et al.*, 2021). Further, climate changes could also affect nutrient cycles in the soil and botanical composition under long-term lime and mineral fertilizer application.

Conclusions

The long-term impact of the different defoliation regimes or fertilizer applications resulted in different plant species composition within treatments. The treatments with grazing management in comparison to cutting has been shown to promote dominance of grasses such as *Agrostis capillaris* and *Lolium perenne* at the expense of forbs. In contrast, hay cutting and hay cutting followed by aftermath grazing was linked to increased forbs cover. Species diversity increased for all treatments which included a cutting management. Liming increased total number of species in all treatments. There are still ongoing changes in the plant species composition and species richness after almost 30 years since the beginning of the experiment.

Table 1. Numbers represent average of three replicates ± standard error of the mean (SE).[1,2]

	CO	GL+	GL−	HL+	HL−	HGL+	HGL−
Total number of vascular plant species	6.2±0.6a	8.9±0.6b	7.3±0.5ab	13.1±0.5cd	12.8±0.4c	15.0±0.6d	14.2±0.4cd
Number of vascular plant species ≥1%	5.3±0.5a	6.6±0.5ab	5.7±0.4a	8.1±0.5bc	8.6±0.4cd	10.1±0.4d	9.5±0.4cd
Shannon (H) diversity index	1.4±0.1a	1.6±0.1ab	1.4±0.1a	1.7±0.1bc	1.8±0.1bc	2.0±0.1c	1.8±0.0bc

[1] The result of post hoc comparison Tukey's HSD tests (P=0.05) are indicated by different lower-case letters.

[2] CO = control; G = sheep grazing; H = hay cutting; L+ = lime treatment; L− = no lime treatment.

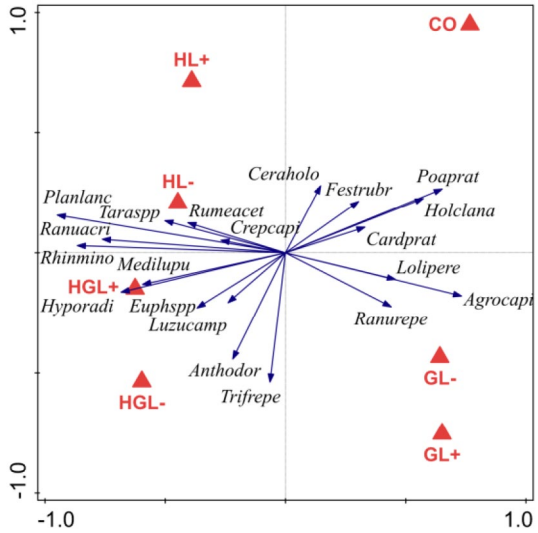

Figure 1. Ordination diagram representing the results of redundancy analysis (RDA) showing changes in plant species composition, treatments were used as predictors. Treatment abbreviations are explained in Materials and methods. Species abbreviations are based on the first four-letter of genera and the four-letter of species name: *Agrocapi* = *Agrostis capillaris*, *Anthodor* = *Anthoxanthum odoratum*, *Cardprat* = *Cardamine pratensis*, *Ceraholo* = *Cerastium holosteoides*, *Crepcapi* = *Crepis capillaris*, *Euphspp* = *Euphrasia* spp., *Festrubr* = *Festuca rubra* agg., *Holclana* = *Holcus lanathus*, *Hyporadi* = *Hypochaeris radicata*, *Lolipere* = *Lolium perenne*, *Luzucamp* = *Luzula campestris*, *Medilupu* = *Medicago lupulina*, *Planlanc* = *Plantago lanceolata*, *Poaprat* = *Poa pratensis*, *Ranuacri* = *Ranunculus acris*, *Ranurepe* = *Ranunculus repens*, *Rhinmino* = *Rhinanthus minor*, *Rumeacet* = *Rumex acetosa*, *Taraspp* = *Taraxacum* spp., *Trifrepe* = *Trifolium repens*.

Acknowledgements

This study was supported by a Stapledon Memorial Trust Travelling Fellowship awarded to J.T. Thanks to Iolo Davies for the professional comments and for the technical assistance.

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