Grassland at the heart of circular and sustainable food systems

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Overseeding and rehabilitation of degraded upland grasslands after *Arvicola terrestris* outbreaks

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Abstract

Outbreaks of grassland rodent (water vole: *Arvicola terrestris*) populations can cause dramatic grassland damage, impacting grassland structure and function, as well as the provision of ecosystem services. There is a pressing need to identify effective management techniques which promote grassland recovery after rodent disturbance, and clear guidelines on soil preparation and species mixtures are currently lacking. We have set up a field-scale experiment to examine the interactive effects of mechanical soil treatments and seed mixtures on an upland permanent grassland experiencing an *A. terrestris* outbreak. The ultimate objective is to determine which management practices satisfy two key criteria: (1) sufficient hay production to support a dairy herd during the winter; and (2) limited adverse effects on plant community recovery and longer-term grassland biodiversity. We test two types of soil preparation (with or without use of a disc cultivator) in combination with five overseeding treatments (no seed, annual species in monoculture, mixtures of annual species), and record biomass production, forage quantity and quality and soil properties over a two-year period. Aerial pictures and trapping are used to estimate rodent population density and dynamics. First results are presented and suggest effects of both seed mix and soil preparation treatments on hay quantity and quality.

Keywords: water vole, grassland recovery, management practices, seed mix, soil preparation

Introduction

Permanent grasslands are the main source of fodder for livestock in upland and mountain areas, both for grazing and/or hay production. Aside from climate-driven threats to grassland structure and function, such as drought-induced decreases in grassland productivity, European grasslands also face risks of recurrent rodent outbreaks, with implications for farming sustainability (Jacob *et al.,* 2020). For example, the fossorial water vole *Arvicola terrestris* lives in underground burrows in the grasslands of mountainous areas and is characterised by population outbreaks every 5-9 years (Berthier *et al.,* 2014). These dramatic increases in rodent abundance may have long-lasting effects on plant communities, grassland productivity and forage quality (Quéré *et al.,* 1999, Nicod *et al.,* 2020). A variety of chemical (rodenticides) and agrotechnical approaches can be used for rodent management, but once high-density populations of rodents are present, field control of rodents is forbidden in France (Arrêté du 14 mai 2014). In such situation, there is therefore a pressing need to identify management techniques that promote short-term forage production and longer-term plant community recovery. Overseeding techniques are one promising option for the renovation of degraded grasslands, offering the possibility to ensure sufficient hay production for winter feeding while limiting adverse effects on grassland biodiversity, but clear guidelines on soil preparation and seed mixtures are currently lacking. Here we aimed to examine the importance of soil disturbance and diversity of seed mix for the diversity and forage production in overseeded grasslands exposed to high levels of rodent damage.

Materials and methods

We implemented a field-scale experiment at the INRAE-Herbipole experimental farm (https://doi.org/10.15454/1.5572318050509348E12) in the Massif Central region of France (45.30°N, 2.84°E, 1080 m a.s.l.), following a rodent outbreak on an 18 ha area of permanent grassland in early 2021. Interactive effects of mechanical soil treatments and seed mixtures were assessed using two types of soil preparation (SP) (with or without disc cultivator [DC]), and five overseeding treatments (OT): no seed [Control]; *Avena strigosa* 50 kg ha^{-1} [A]; *Avena* + *Lolium multiflorum* 15 kg ha^{-1} [AL]; *Avena* + *Vicia sativa* 25 kg ha^{-1} [AV]; *Avena* + *L. multiflorum* 12.5 kg ha^{-1} + *Trifolium incarnatum* 6 kg ha^{-1} + *V. sativa* 4 kg ha^{-1} + *Trifolium squarrosum* 2.5 kg ha^{-1} [MIX]. Overseeding treatments represented a gradient of diversity, and all sown species were annuals known to be able to grow at the study site, with a limited risk of regrowth the following year. Each experimental treatment represented an area ranging from 1.1 to 1.4 ha. In the two weeks prior to seeding and after harvesting, rodent populations (RP_1 and RP_2) were estimated by trapping (TopCat ©, Andermatt, France) all rodents in a 400 m^2 area over a 5-h period in each treatment. Aerial pictures were taken in all treatments to estimate soil cover rate before seeding (SCR_1) and after harvesting (SCR_2), defined as the proportion of visible fresh soil. Seeding was carried out using a 3 m-large seed drill on 26 May. On 27 July aboveground biomass was determined in each treatment (eight 50×50 cm quadrats cut to a height of 5 cm, samples oven-dried for 48 h at 60 °C then weighed). Plots were mowed on 9 August and forage yields were estimated for ground-cured hay by weighing the amount of dry hay on the ground in three 20 m^2 squares per treatment. Hay samples were analysed using NIRS techniques, and the feed value was estimated using existing equations (INRA, 2018). Data on hay quantity and quality were statistically analysed using general linear models, with soil treatment and seed mix as fixed effects. Rodent numbers were regressed against levels of soil cover and levels of soil cover were also compared over time using linear models.

Results and discussion

Delattre and Giraudoux (2009) estimate that at over 200 rodents ha^{-1} the situation can be considered as critical for the plots. The presence of *A. terrestris* was high in all treatment plots (337±129 rodent ha^{-1}) and rodent numbers increased by 61% during the trial, suggesting that rodent populations were still in a growth phase. Average fresh soil cover prior to seeding was 37.4±16.8% across plots and SCR_2 was 51.4±10.8%. SCR_1 was marginally correlated with RP_1 (P=0.06) but SCR_2 showed no relationship with RP_1 or RP_2, suggesting that these are not good indicators of rodent population size and dynamics at the plot scale. Soil preparation had no effect on SCR_2, but SCR_2 was positively correlated to SCR_1 (P=0.002).

Effects of seed mix on yield varied depending on soil preparation treatment (SP×OT interaction) (Table 1). With the exception of AV, all seeding treatments showed decreased yields with the disc cultivator (-23% on average). Differences between biomasses and yields of the different seed mixes correspond to losses at harvesting (-16% on average). The most important losses were recorded for AV (-35%, P=0.03), probably due to the loss of *V. sativa* leaves during tedding; AL and MIX treatments did not show significant yield losses (P>0.1).

Forage mineral content, reflecting soil presence in the hay samples, was lower in DC treatments for all seed mixes except AV (Table 1). At the same time, the disc cultivator treatment generally increased forage nitrogen content and decreased cellulose content, resulting in higher NEL levels.

Table 1. Production and nutritive values of forage from the different experimental treatments.[1]

	Soil preparation		Overseeding treatment					*P*-value[2]		
	Control	Disc	Control	A	AL	AV	MIX	SP	OT	SP×OT
Biomass (t ha^{-1})	2.67	2.27	2.64	2.86	2.64	2.10	2.11	*	**	NS
Yield (t ha^{-1})	2.36	1.83	2.02	2.31	2.99	1.35	1.82	***	***	***
Minerals (g kg^{-1})	98	96	94	85	107	102	97	NS	***	*
CP[3] (g kg^{-1})	104	117	108	95	112	123	113	**	**	NS
Cellulose (g kg^{-1})	324	316	312	338	328	301	321	NS	***	NS
NEL[3] (Mcal kg^{-1})	1.36	1.43	1.37	1.36	1.36	1.44	1.41	*	NS	NS

[1] Results for GLMM are shown; soil preparation treatment is given by SP, overseeding treatment is given by OT [A = *Avena strigosa*; AL = A + *Lolium multiflorum*; AV = A + *Vicia sativa*; MIX = AL + *Trifolium incarnatum* + *V. sativa* + *Trifolium squarrosum*].

[2] *** $P<0.001$; ** $P<0.01$; * $P<0.05$; NS (not significant) $P\geq0.05$.

[3] CP = crude protein; NEL = net energy for lactation.

Conclusions

Preliminary results suggest that both soil preparation and seed mix composition have a significant effect on forage quantity and quality following overseeding. Decreases in yield induced by the disc cultivator were at least partly compensated for by higher quality hay. Acceptable fodder quantity and quality were obtained with simple mixes (A, AL) and were not significantly improved by seeding with a more diverse mixture. Subsequent measurements will examine whether effects of overseeding on hay production persist in time and will address impacts on plant community recovery. However, impacts of the treatments have to be balanced by the fact that *A. terrestris* population seemed to be in a growth phase and that seeding may extend the length of the outbreak. Economic analyses are also required to determine the cost-effectiveness of using a disc cultivator as part of the overseeding procedure.

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