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A biodiversity-friendly rotational grazing system enhancing flower-visiting insect assemblages while maintaining animal and grassland productivity

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ABSTRACT

Grazing management is an important tool to preserve insect biodiversity. Although literature has discussed the importance of grazing pressure adjustment to support grassland insect communities for the ecosystem services they provide, little has been published on the economic sustainability of such management adjustments to date. This study compared continuous grazing (CG) to an innovative rotational grazing system (the biodiversity-friendly rotation – BR), where a subplot was excluded from grazing for two months during the main flowering period. The effects of grazing two different species (cattle and sheep) within both systems were also evaluated. The aims were to assess the effects on butterfly, bumblebee, and ground beetle assemblages, along with the impact on herbage mass and animal performance. The BR enhanced both the abundance and species richness of flower-visiting insect assemblages and it was observed that cattle provided better results than sheep grazing. A multivariate redundancy analysis highlighted that most of the flower-visiting species (including almost all the endangered and locally rare species) were favoured by BR-cattle treatment, mainly due to the high percentage of flower cover and sward heterogeneity involved in this treatment. However, grazing system and grazer species did not affect ground beetle species richness or abundance. Moreover, herbage mass and animal performance (live weight and body condition score) were comparable between CG and BR throughout the grazing season. The BR could be a useful management system to enhance grassland flower-visiting insect assemblages whilst meeting farm production objectives, especially in protected environments where insect conservation is a major target.

1. Introduction

The sustainability of animal production systems has become a major issue over the last few years (Altieri, 2002; Brym and Reeve, 2016; Craheix et al., 2016; Tilman et al., 2002), emphasizing the need to optimize land-use, mitigate and adapt to climate change and to reduce biodiversity loss (Phalan et al., 2011; Seppelt and Voinov, 2002). Agro-pastoral systems play a pivotal role in this context (Soussana et al., 2014) as they must maximize the benefits provided to human society and the biosphere, such as food production and ecosystem functioning (Rey et al., 2015).

After several millennia of land management, agro-pastoral systems have contributed to create a wide variety of semi-natural habitats, often characterised by high biodiversity levels (Orlandi et al., 2016). Mountain grasslands, which have been mainly created and maintained by extensive cattle and sheep grazing and/or mowing, are among the most biodiverse habitats in Europe (Dengler et al., 2014) and the sustainability of the traditional management of these ecosystems is currently under constant threat due to socio-economic and market changes (Bernués et al., 2011; Dong et al., 2011). Indeed, the increase in production costs and reduction in product sale incomes have often led to an intensification of grassland management within the most productive sites, along with grassland abandonment when management has become unprofitable (Agnoletti, 2014; Caballero, 2015). In both cases, changes in management led to changes in grassland

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productivity and in an overall decrease in plant and animal diversity (Báldi et al., 2013; Orlandi et al., 2016; Sjödin et al., 2008; Söderström et al., 2001). Moreover, the highest biodiversity in these semi-natural ecosystems is generally associated to intermediate levels of management intensity, in agreement with the intermediate disturbance hypothesis (Cingolani et al., 2005; Grime, 1973; Yan et al., 2015). Within permanent mountain pastures, optimal livestock pressure for biodiversity conservation can be achieved by using specific pastoral practices (Pittarello et al., 2016a, 2016b) and/or by adjusting the number of grazing animals, the area available for grazing, the grazing schedule and system (e.g. rotational or continuous grazing; Farruggia et al., 2014; Probo et al., 2014). Nowadays, a major challenge is that of applying innovative management systems able not only to preserve plant and animal diversity but also to maintain levels of animal and grassland productivity.

Several studies focused on grassland insect communities so as to monitor the effects of different grazing regimes produced on grassland biodiversity as they can be considered key groups due to the fact that their assemblages are immediately and severely affected by habitat changes (Tocco et al., 2013). Moreover, grassland insect communities include a wide variety of species threatened by habitat loss and modification (Ewers and Didham, 2006), including several protected by local, national or EU legislation, such as the Habitat Directive (92/43/EEC). Livestock pressures on grassland habitats may have varying effects on insect communities in different ways, as reported by van Klink et al. (2015), including: i) modification of the abiotic conditions (modification of vegetation patches, a decrease in vegetation height, an alteration in structural complexity, and changes in soil conditions), ii) varying the feeding resource availability (flower and herbage mass reduction, the rate of dung depositions, and live tissue accessibility), and iii) ingestion or trampling by the grazing animals. Each of these actions depends on livestock species and management, due to grazer/browser feeding preferences, live weight and social behaviour (Iussig et al., 2015; van Klink et al., 2015). Amongst the most common grazer species, the higher selectivity of sheep for legumes and forbs and flowering plant parts can lead to grass-dominated plant communities with a lower diversity of nectar-dependent insect taxa than cattle-grazed grasslands (Dumont et al., 2011; Öckinger et al., 2006).

Furthermore, Sjödin et al. (2008) highlighted that it is essential to consider different insect taxa simultaneously in a systemic research as the effects of livestock pressure on insect diversity and abundance may differ when more than a single insect group is taken into consideration. Nevertheless, while multi-taxon approaches have been largely applied to compare variations in diversity and abundance for various insect groups at variable grazing pressures (Scohier and Dumont, 2012; Sjödin et al., 2008; Wallis De Vries et al., 2007), the simultaneous effects of different grazing systems and grazer species on a given plant community have, to date, been only scantily evaluated. Scohier et al. (2012) focused only on sheep grazing and observed that a particular rotational grazing system, with sheep exclusion from pasture during the main flowering period as proposed by Farruggia et al. (2012), was more beneficial for bumblebees than it was for butterflies. Zhu et al. (2015) focused on rationed grazing system with cattle, sheep and goats and recorded different responses of six insect groups (grasshoppers, homopterans, beetles, dipterans, hemipterans and butterflies) according to the grazer species, without considering grassland or animal performance during the grazing season. Contrasting results were reported in other studies that focused only on grassland and animal performance under continuous and rotational grazing systems, without considering their effect on insect diversity (e.g., Savian et al., 2014).

The present study aimed at assessing the effects produced by two grazer species (cattle and sheep) managed at the same stocking density under two grazing systems, i.e. continuous grazing (CG) and an innovative rotational grazing system to enhance biodiversity (the biodiversity-friendly rotational grazing system – BR), on three insect taxa (butterflies, bumblebees and ground beetles), as well as on herbage mass and animal performance. Butterflies and bumblebees were chosen for their role in pollination as flower-visiting insect taxa, whilst ground beetles were chosen as they represent a large insect taxon related to grassland structure, with different feeding behaviours (often carnivorous; van Klink et al., 2015) and as indicators of invertebrate abundance and Coleoptera richness (Cameron and Leather, 2012). The following hypotheses were tested: i) insect abundance and diversity would be enhanced by the BR, ii) sheep grazing would be detrimental for flower cover and, consequently, for insect assemblages, iii) benefits would differ among insect taxa, and iv) BR would not differ from CG in terms of herbage mass or animal performance.

2. Materials and methods

2.1. Study area

The grazing experiment was established in semi-natural mountain pastures managed by INRA (Institut National de Recherche Agronomique) in the upland area of central France, within the Volcans d'Auvergne Natural Park (Massif Central, 45°15′N, 2°51′E). The study area was located at 1100 m a.s.l. and it was characterised by volcanic soils and sub-Atlantic climate (Köppen's classification: Cfb, Climate-Data.org, 2016) with average annual temperature of 7.0 °C and precipitation of 1169 mm (average values for the period 1965–2010 according to the Marcenat weather station). Pastures without mineral fertilization had been extensively grazed by cattle since 1992 (Dumont et al., 2009). The dominant plant community belonged to the *Cynosurion cristati* alliance, *sensu* Braun-Blanquet et al. (1932).

2.2. Experimental design

In the years 2011, 2012 and 2013, continuous grazing (CG) was compared to an innovative rotational grazing system (hereafter referred to as 'biodiversity-friendly rotation', BR), i.e. a system in which enclosures (plots) were divided into four subplots (A–D), each one grazed for 35 days per year, with subplot D excluded from grazing for 63 days during the main flowering period, i.e. from early-June to early-August (see Annex A in Supplementary material). Two grazer species in the experimental design were compared (cattle and sheep) and each grazing system × grazer species treatment was replicated three times in a complete randomized design, so that 12 plots were set up (see Annex B in Supplementary material). A total of six 3.6 ha plots were grazed by seven Charolais heifers (corresponding to 6.30 livestock units) each and six 0.6 ha plots were grazed by seven Limousine ewes (corresponding to 1.05 livestock units) each, providing a comparable stocking density (1.75 livestock units ha^{-1}), which is in line with the local stocking density commonly applied in the region.

The plots were chosen with similar elevation, exposure, roughness and slope and each one had a randomly positioned water source to meet animal requirements. Moreover, grassland botanical composition was evaluated before setting the experiment up according to the characterisation made by a botanist (see Acknowledgements), to ensure that both plots and subplots were set-up on a similar plant community.