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Functional response of leaf- and planthoppers to modern fertilisation and irrigation of hay meadows

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Abstract

In the drier regions of the European Alps, traditional land-use of montane and subalpine meadows, i.e. extensively managed with solid manure application and irrigation via water channels, is currently shifting towards application of slurry and aerial irrigation. The impact of these new practices upon biodiversity remains poorly understood and calls for quantitative assessments of their effects. Relying on a full block design, we tested the effects of six management treatments corresponding to an increasing gradient of farming intensification (fertilisation with slurry and/or irrigation with sprinklers) on Auchenorrhyncha (Hemiptera) communities occurring in the inner Swiss Alps. The experimental set up consisted of: control plots (no fertiliser, no irrigation; C-plots); plots that received only fertiliser (F-plots); plots that were only irrigated (I-plots); and plots that received low-, medium- and high-input of fertiliser and water (F + I 1/3-plots; F + I 2/3, F + I 3/3-plots; 3/3 corresponds here to the input level necessary for achieving maximum theoretical hay yield locally). After two years of experimental treatment (2012), plots that were only fertilised or only irrigated showed no change in the population sizes of Auchenorrhyncha, while plots that received low-, medium- and high-input of fertiliser and water harboured significantly higher abundances (1.9, 1.5 and 1.4 times higher, respectively), biomass (1.8, 1.6 and 1.8 times higher, respectively), as well as species richness (+27–30%, on average) than control plots. Abundances and species richness were also higher in plots with low-input of fertiliser and water compared to fertilised only plots. Monophagous and oligophagous species were most abundant in plots with low-input of fertiliser and water. Medium- and high-input treatments (F + I 2/3 and 3/3) increased the number of generalist (eurytopic) species, while only low-input treatment (F + I 1/3) boosted the more specialised (stenotopic) species. This provides support to the hump-shaped diversity-disturbance relationship and guidance for sustainable management of biodiversity-rich mountain hay meadows.

Zusammenfassung

In den trockeneren Gebieten des europäischen Alpenraums findet zurzeit eine Veränderung in der landwirtschaftlichen Nutzung von Wiesen der montanen und subalpinen Höhenstufen statt: Extensive Bewirtschaftungsformen wie das Einbringen von Feststoffdünger und eine Bewässerung mit Hilfe von Wasserkanälen werden dabei zunehmend durch den Einsatz von Gülle und Sprinkleranlagen ersetzt. Wie sich diese Bewirtschaftungsmaßnahmen auf die Biodiversität auswirken ist jedoch noch weitgehend unbekannt und quantitative Erhebungen dazu fehlen noch weitgehend. In einem Freilandversuch mit je 6

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unterschiedlich intensiv bewirtschafteten Probeflächen im Block-Design wurden die Auswirkungen von Flüssigdünger- und Sprinklereinsatz auf die Artengemeinschaften von Zikaden (Auchenorrhyncha, Hemiptera) im inneralpinen Gebiet der Schweiz untersucht. Das experimentelle Grundschema bestand jeweils aus einer Kontrollfläche (ohne Dünger und Bewässerung: C-Fläche), einer nur gedüngten Fläche (F-Fläche), einer nur bewässerten Fläche (I-Fläche) und weiteren 3 Flächen, die jeweils eine niedrige, mittlere oder hohe Dosis an Dünger und zusätzlichem Wasser (F + I 1/3, F + I 2/3, F + I 3/3) erhielten. Der Intensivierungsgrad F + I 3/3 entspricht dabei dem Wasser- und Düngemitteleintrag, der für einen maximalen, theoretisch an einem Standort erzielbaren Heuertrag benötigt würde. Nach zweijähriger Projektlaufzeit konnten auf Flächen, welche entweder nur gedüngt oder nur bewässert wurden, keine Veränderungen bei den Populationsgrössen der Zikaden festgestellt werden. Der Einsatz einer Kombination von Dünger und Bewässerung (niedriger, mittlerer und hoher Intensivierungsgrad) führten hingegen zu signifikant höherer Abundanz (1.9-, 1.5-, 1.4-fach), Biomasse (1.8-, 1.6-, 1.8-fach) und einem grösseren Artenreichtum (im Durchschnitt +27–30%) der Auchenorrhyncha. In Probeflächen mit niedriger Wasser und Düngemittelzugabe waren Abundanz und Artenreichtum höher als in nur gedüngten Flächen. Auch waren monophage und oligophage in diesen Flächen am häufigsten. Mittlere und hohe Intensivierungsgrade (F + I 2/3 und F + I 3/3) führten zudem zu einer Förderung der (eurytopen) Generalisten, während sich niedrige Dosen an Dünger und Wasser (F + I 1/3) positiv auf spezialisierte (stenotope) Arten auswirkten. Dieser Befund bestätigt die Theorie einer glockenförmig verlaufenden Beziehungskurve zwischen biologischer Diversität und Bewirtschaftungsintensität und eröffnet Möglichkeiten für eine nachhaltige Bewirtschaftung von artenreichen Heuwiesen im Berggebiet.

Keywords: Auchenorrhyncha; Agriculture intensification; Invertebrates; Mountain grasslands; Slurry; Sprinkler

Introduction

In the past 50 years, management of montane and subalpine meadows of Western and Central Europe has shifted from traditional practices with no or low input of solid animal manure to more mechanised practices with higher input of fertilisers, essentially in the form of liquid manure (Strijker, 2005). In addition, in the drier inner and southern valleys of mountain massifs such as the European Alps, hay meadows are also irrigated. For centuries, gravitational, terrestrial irrigation systems conducting water from the main tributaries to the cultivated slopes have been used. Yet, this traditional system has been progressively abandoned and replaced by underground water pipe networks conducting water to aerial sprinklers, which require far less maintenance (Crook & Jones, 1999). These marked changes of farming practices have negatively impacted the biodiversity of plants, arthropods and vertebrates found in traditionally managed mountain meadows (e.g. Britschgi, Spaar, & Arlettaz, 2006; Riedener, Rusterholz, & Baur, 2013).

Farming intensification in mountain grasslands results from increasing fertiliser and/or water inputs, which enhances phytomass production but induces a reduction of plant species richness (Dietschi, Holderegger, Schmidt, & Linder, 2007; Homburger & Hofer, 2012; Humbert, Dwyer, Andrey, & Arlettaz, 2016). The resulting alteration of vegetation structure (Andrey, Humbert, Pernollet, & Arlettaz, 2014) and microclimate can in turn positively or negatively affect arthropod abundance, biomass and species richness, with the direction of response depending on the taxon (e.g. Delley, 2014; Grandchamp et al., 2005). In line with the hump-shaped hypothesis (Mittelbach et al., 2001), several studies have suggested that an intermediate level of grassland management intensity, notably a low or moderate input of fertiliser and/or water, may indeed benefit productivity and fodder nutritional quality, as well as plant species richness (Bowman, Gartner, Holland, & Wiedermann, 2006; Jeangros & Bertola, 2000; Peter, Gigon, Edwards, & Lüscher, 2009). Although this might in turn boost resources for herbivorous arthropods (Andrey et al. 2014; Grandchamp et al., 2005; Haddad, Haarstad, & Tilman, 2000), a recent meta-analysis by Humbert et al. (2016) pointed out a lack of experimental studies on the effects of intensification upon grassland arthropod communities.

To fill this knowledge gap, we launched a series of controlled experiments with the objective to quantitatively define whether an optimal trade-off exists in terms of degree of grassland management intensity, looking in particular at hay production versus maintenance of biodiversity and related ecosystem functions. The research was conducted at 12 replicated sites in the SW Swiss Alps, among traditionally managed montane and subalpine hay meadows (no or low input of solid manure, and occasional terrestrial irrigation). Six different experimental treatments were applied to the study plots from 2010 onwards, generating a full factorial design and a gradual level of fertilisation and irrigation. The study plots were sufficiently large (20 m diameter; 314 m^2) to allow investigating the responses of plant and arthropod populations to experimental manipulation of management type and intensity. As study models, we selected Auchenorrhyncha (Hemiptera: Fulgoromorpha and Cicadomorpha), also known as plant-, frog- and leafhoppers. This taxon is highly diverse and fairly abundant in grasslands, and is considered an excellent bioindicator, notably of