The impact of mountain hay meadow management on litter decomposition and root colonization by arbuscular mycorrhizal fungi

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Abstract

Soil life and particularly arbuscular mycorrhizal fungi (AMF) play a fundamental role in ecosystem functioning and are crucial drivers of vegetation dynamics and efficient nutrient use. This study investigated the effect of liquid manure application and aerial irrigation on litter decomposition and AMF colonization in mountain meadowlands. Six intensity levels of irrigation and fertilization were experimentally tested in eleven meadows located in the Swiss Alps. For litter decomposition, a novel tea-bag approach was followed. AMF root colonization was assessed from field samples and a trap culture experiment. Decomposition measured with tea bag burials was higher under maximal management intensity levels. AMF colonization was 22% lower in high-input compared to low-input plots in the field while in the trap cultures colonization levels depended on the functional plant species group. Our findings shed light on the impact of management intensification in mountain hay meadows on belowground functioning. Ultimately, the findings of this study will help to develop pragmatic management recommendations to farmers that would allow acceptable yields while preserving functional diversity.

Keywords: subalpine meadows, arbuscular mycorrhiza, decomposition, fertilization, irrigation

Introduction

During recent decades, grassland management in montane and subalpine regions has been highly intensified (Tasser *et al.*, 2007). The application of slurry (i.e. liquid manure) instead of solid manure and the progressive replacement of traditional ground irrigation with water channels by aerial irrigation with sprinklers (Crook and Jones, 1999) are two examples of novel and common practices that were introduced to increase hay production. Their impact on plant and invertebrate communities in mountain grasslands has already been investigated (Andrey *et al.*, 2014). However, we still aim for a better understanding of belowground responses to human-induced land use changes (Wardle *et al.,* 2004). The objective of this study was therefore to gain knowledge about the influence of intensified irrigation and fertilization practices on litter decomposition and root colonization by arbuscular mycorrhizal fungi (AMF).

Materials and methods

Using a randomized block design, six management treatments were experimentally tested in mountain hay meadows (replicated at 11 study sites in SW Switzerland), namely: (1) management without either irrigation or fertilization, as control; (2) aerial irrigation only, by the means of sprinklers; (3) fertilization only, with slurry; (4-6) aerial irrigation combined with fertilization at, respectively, low, medium, and high input levels. For more information on the study design, see Andrey *et al.* (2014). Litter decomposition was measured by the relative residual mass (remaining after a given period of time) of buried green and rooibos tea bags and with two indices: the decomposition rate (k) that describes the speed of decomposition, and the litter stabilization factor (S) that indicates inhibiting environmental effects on the decomposition of labile material (Keuskamp *et al.*, 2013). Root colonization by AMF was analysed from field samples as well as from trap cultures where AMF were amplified in pots by growing them on *Plantago lanceolata*, *Trifolium pratense* and *Lolium perenne*.

Results and discussion

After four months, the relative residual mass of tea bags was lower in high-input than in control plots (41% and 44%, respectively, for green tea; 69% and 74%, respectively, for rooibos), which yielded higher k and lower S values (Figure 1). Furthermore, S was lower under irrigation alone. These results suggest accelerated litter decomposition under intensified meadow management. Intensification negatively affected root colonization by AMF in the field samples, which was 22% lower, on average, in high-input compared to low-input plots. In the trap cultures, lower AMF colonization was measured under medium and high management intensity for *Trifolium pratense* (minus 45% and 47%, respectively, compared to control plots). When irrigation and fertilization were applied alone, they did not affect root colonization by AMF (Figure 2).

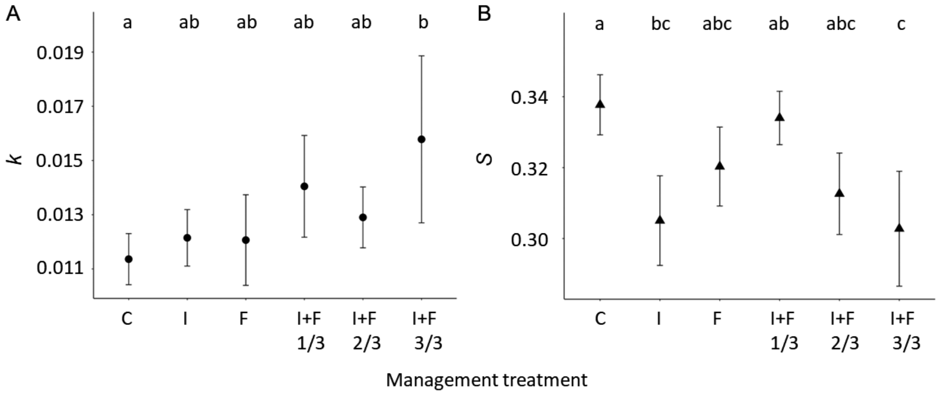

Figure 1. Decomposition rates k (a) and stabilization factors S (b) after four months of burial in response to the different management treatments. Management treatment abbreviations are: C = control; I = irrigated; F = fertilized; and I+F 1/3, I+F 2/3 and I+F 3/3 state for treatments fertilized and irrigated at respectively 1/3 (low), 2/3 (medium) and 3/3 (high) of the dose that would be necessary to achieve the maximum theoretical local hay yield. Different letters indicate significant differences among treatments at an alpha rejection value set to 0.05. Mean values ± standard errors (SE) are presented.

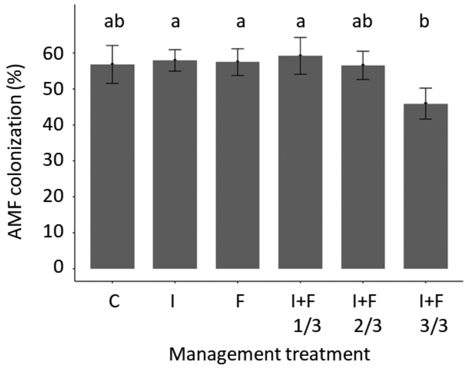

Figure 2. AMF root colonization in the field samples. For the management treatment abbreviations see Figure 1. Different letters indicate significant differences among treatments at an alpha rejection value set to 0.05. Mean values ± standard errors (SE) are presented.

Conclusion

Our findings indicate that the intensification of hay meadow management practices affects soil litter decomposition and root colonization by AMF. Possible consequences from faster decomposition are altered nutrient cycles with a lower carbon sequestration potential, while decreased root colonization by AMF may lead to restricted nutrient transfer, reducing plant growth and health. In line with former studies of the response norms of aboveground organisms to hay meadow management intensification, the present results suggest that moderate intensification may represent a good compromise in terms of biodiversity preservation, ecosystem functions and forage production.

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References

Andrey A., Humbert J.-Y., Pernollet C. and Arlettaz R. (2014) Experimental evidence for the immediate impact of fertilization and irrigation upon the plant and invertebrate communities of mountain grasslands. *Ecology and Evolution* 4, 2610-2623.

Crook D.S. and Jones A.M. (1999) Design principles from traditional mountain irrigation systems (bisses) in the Valais, Switzerland. *Mountain Research and Development* 19, 79-99.

Keuskamp J.A., Dingemans B.J.J., Lehtinen T., Sarneel J.M. and Hefting M.M. (2013) Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. *Methods in Ecology and Evolution* 4, 1070-1075.

Tasser E., Walde J., Tappeiner U., Teutsch A. and Noggler W. (2007) Land-use changes and natural reforestation in the Eastern Central Alps. *Agriculture Ecosytsems and Environment* 118, 115-129.

Wardle D.A., Bardgett R.D., Klironomos J.N., Setala H., Van der Putten W.H. and Wall D.H. (2004) Ecological linkages between aboveground and belowground biota. *Science* 304, 1629-1633.

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