Multispecies mixtures enhance yield and trampling resistance

Suter M.[1,2], Vishwakarma R.[3], Bendalam P.[1], Lüscher A.[1,2] and Huguenin-Elie O.[1]
[1] Agroscope, Forage Production and Grassland Systems, 8046 Zürich, Switzerland; [2] Swiss Grassland Society, 8046 Zürich, Switzerland; [3] School of Computer Science and Statistics, Trinity College Dublin, Dublin, Ireland

Abstract

Resistance and resilience of grasslands to disturbance is crucial in grassland-based production systems. Here, we investigated the effect of simulated trampling in a field experiment using six key forage species of temperate productive grasslands: two grasses, two legumes, and two herbs. Grassland communities were established by varying species richness and composition, and two trampling events were applied by a device simulating the pressure of adult cattle claws and treating on average 30% of the area. Total community yield was then harvested three times until the end of the growing season and compared to a non-trampling control. Six weeks after trampling, species-specific yield reductions were observed with grasses being least affected (−4%), followed by legumes (−27%) and herbs (−37%). Mixtures generally outperformed the monocultures' average, and the six-species mixture yielded more under trampling than the grass monocultures under control conditions. Nineteen weeks after trampling, at the end of the growing season, all communities recovered and no trampling effect was observed. We conclude that multispecies mixtures comprising grasses, legumes, and herbs enhance short-term yield resistance and are largely resilient to trampling events.

Keywords: multispecies mixtures, resilience, resistance, simulated trampling, yield loss

Introduction

Resistance and resilience of grasslands to disturbance is crucial in grassland-based ruminant production systems. Livestock can cause damage to grasslands through trampling and indeed, yield reductions from trampling in field trials are reported to range from 7 to 88% in productive grasslands (Drewry *et al.*, 2008). However, in livestock grazing trials, a consistent trampling effect across the experimental area can hardly be achieved, and the direct effects of trampling on plant growth can generally not be distinguished from the indirect effects caused by trampling-induced poorer soil properties (Greenwood and McKenzie, 2001). For a consistent assessment, a mechanical device should be used so that the trampling damage could be applied in a standardised manner.

In sown grasslands, the benefits of grass–legume leys are well documented (e.g., Nyfeler *et al.*, 2011; Finn *et al.*, 2013; Suter *et al.*, 2021). However, less is known about the benefits of including herbs into leys and the use of multispecies mixtures. So far, grass-legume-herb mixtures have revealed additional benefits in terms of yield (Cong *et al.*, 2018; Grange *et al.*, 2021) and improved animal health and performance (Grace *et al.*, 2019). However, the yield response of multispecies mixtures to trampling remains unknown.

To this aim, we set up a field experiment with multispecies, intensively managed grasslands using grasses, legumes, and herbs. A device was constructed with rollers on which metal blocks were mounted, allowing the application of a standardised ground pressure to the sward. We wished to know (1) whether trampling affected the single species' yields differently, (2) whether multispecies

mixtures reduced trampling losses observed in monocultures, and (3) whether trampling effects were still observed at the end of the growing season.

Materials and methods

The field experiment was located in Northern Switzerland near Zurich and included two species from each of three functional groups: *Lolium perenne* (L.) and *Phleum pratense* (L.) (grasses), *Trifolium repens* (L.) and *Trifolium pratense* (L.) (legumes), and *Cichorium intybus* (L.) and *Plantago lanceolata* (L.) (herbs). Communities were established in mainplots (63 m^2) by systematically varying species richness and composition following a simplex design, which resulted in 39 different communities with sown species richness ranging from 1 to 6. One randomly selected half of the mainplots was assigned to either the control or the trampling treatment, resulting in a split-plot design. Monocultures and the six-species mixture were set up in two replicates, with a third replicate for the non-trampling control. Trampling was simulated by a motorised device consisting of two front rollers on which metal blocks were mounted to simulate the pressure of adult cattle claws. Two trampling events were applied (8 and 30 May), treating on average 30% of the designated subplot area. After the second event, aboveground biomass of a central plot strip was harvested three times until the end of the growing season and dried to constant mass (hereafter 'yield').

Repeated measure linear mixed-effects regression with mainplot as a random factor was used to analyse the trampling effect on yield of all communities six weeks after treatment (resistance) and at the end of the growing season (recovery). Here, we present results on monocultures and the six-species equi-proportional mixture, reflecting the range of species richness and a typical outcome of trampling effects on communities in the experiment.

Results and discussion

Six weeks after the second trampling event, yield of monocultures was impaired on average by −23%; however, yield reductions were species specific with grasses being least affected (−4%), followed by legumes (−27%) and herbs (−37%) (Figure 1). *T. repens* (−41%) and *T. pratense* (−13%) differed in their trampling response, which might be explained by the species' differing morphological characteristics (Black *et al.*, 2009).

The six-species equi-proportional mixture revealed only a marginal trampling effect of −3% and yielded significantly more than the average of the monocultures under control ($P < 0.001$) and trampling ($P < 0.001$) conditions (Figure 1). More important, the six-species mixture had yields at least as high as the best performing monoculture, *T. pratense*, evident under control and trampling conditions (Figure 1; $P > 0.1$ for both conditions). However, a *T. pratense* monoculture would not typically be a sward to be compared with under grazing conditions. Therefore, we compared the six-species mixture with the most resistant grass monocultures and a 50:50 *L. perenne*-*T. repens* mixture set up in the experiment, both being more convenient sward types for grazing (Grace *et al.*, 2018). Here, the six-species mixture under trampling outperformed the two grass species ($P < 0.001$ each) and the *L. perenne*/*T. repens* mixture under control conditions ($P < 0.001$), indicating a clear mitigation effect of multispecies mixtures to trampling. The strong performance of the six-species mixture under trampling was explained by beneficial interactions between legumes and each of grasses and herbs, resulting in a smaller overall impact of trampling.

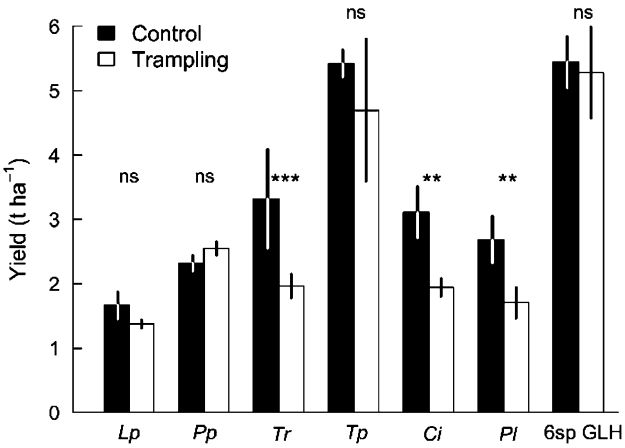

Figure 1. Yield of sown grassland communities under non-trampling control (n = 3) and trampling conditions (n = 2) six weeks after treatment application. Monocultures: *Lp*, *L. perenne*, *Pp*, *P. pratense*, *Tr*, *T. repens*, *Tp*, *T. pratense*, *Ci*, *C. intybus*, *Pl*, *P. lanceolata*, 6sp GHL, 6 species grass/legume/herb mixture sown in equal species proportions (for each species 1/6 of the seed weight needed to establish a monoculture). Displayed are means ± 1 SE. ***$P \leq 0.001$; **$P \leq 0.01$; ns, not significant.

Nineteen weeks after the trampling events, at the end of the growing season, all communities recovered and no trampling effects were observed ($P > 0.2$ for all, no figure shown). Yet, in that final cut, the six-species mixture still outperformed the average of monocultures and the 50:50 *L. perenne*/*T. repens* mixture ($P < 0.001$ each) and had yields as high as the best-performing monoculture (*T. pratense*).

Conclusion

We conclude that multispecies mixtures comprising grasses, legumes, and herbs enhance short-term yield resistance and are resilient to trampling events.

Acknowledgements

The project has received funding from the European Union's Horizon research and innovation program under grant agreements No. 101072579 (LegumeLegacy) and No. 101135494 (LEGENDARY).

References

Black A.D., Laidlaw A.S., Moot D.J. and O'Kiely P. (2009) Comparative growth and management of white and red clovers. *Irish Journal of Agricultural and Food Research* 48, 149–166.

Cong W.-F., Suter M., Lüscher A. and Eriksen J. (2018) Species interactions between forbs and grass–clover contribute to yield gains and weed suppression in forage grassland mixtures. *Agriculture Ecosystems and Environment* 268, 154–161.

Drewry J.J., Cameron K.C. and Buchan G.D. (2008) Pasture yield and soil physical property responses to soil compaction from treading and grazing – A review. *Australian Journal of Soil Research* 46, 237–256.

Finn J.A., Kirwan L., Connolly J., Sebastià M.T., Helgadottir A., Baadshaug O.H., … and Lüscher A. (2013) Ecosystem function enhanced by combining four functional types of plant species in intensively managed grassland mixtures: a 3–year continental–scale field experiment. *Journal of Applied Ecology* 50, 365–375.

Grace C., Boland T.M., Sheridan H., Lott S., Brennan E., Fritch R., … and Lynch M.B. (2018) The effect of increasing pasture species on herbage production, chemical composition and utilization under intensive sheep grazing. *Grass and Forage Science* 73, 852–864.

Grace C., Lynch M.B., Sheridan H., Lott S., Fritch R. and Boland T.M. (2019) Grazing multispecies swards improves ewe and lamb performance. *Animal* 13, 1721–1729.

Grange G., Finn J.A. and Brophy C. (2021) Plant diversity enhanced yield and mitigated drought impacts in intensively managed grassland communities. *Journal of Applied Ecology* 58, 1864–1875.

Greenwood K.L. and McKenzie B.M. (2001) Grazing effects on soil physical properties and the consequences for pastures: a review. *Australian Journal of Experimental Agriculture* 41, 1231–1250.

Nyfeler D., Huguenin–Elie O., Suter M., Frossard E. and Lüscher A. (2011) Grass–legume mixtures can yield more nitrogen than legume pure stands due to mutual stimulation of nitrogen uptake from symbiotic and non–symbiotic sources. *Agriculture Ecosystems and Environment* 140, 155–163.

Suter M., Huguenin–Elie O. and Lüscher A. (2021) Multispecies for multifunctions: combining four complementary species enhances multifunctionality of sown grassland. *Scientific Reports* 11, 3835, DOI: 10.1038/s41598-021-82162-y.