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Connolly, J.; Sebastià, M. T.; Kirwan, L.; Finn, J. A.; Llurba, R. ; Suter, M.; Collins, Rosemary; Porqueddu, Claudio; Helgadóttir, Á.; Baadshaug, O. H.; Bélanger, G.; Black, A.; Brophy, C.; Čop, J.; Dalmannsdóttir, S.; Delgado, I.; Elgersma, A.; Fothergill, M.; Frankow-Lindberg, B. E.; Ghesquiere, A.

Published in:
Proceedings of the 27th General Meeting of the European Grassland Federation

Publication date:
2018

Citation for published version (APA):
Connolly, J., Sebastià, M. T., Kirwan, L., Finn, J. A., Llurba, R., Suter, M., Collins, R., Porqueddu, C., Helgadóttir, Á., Baadshaug, O. H., Bélanger, G., Black, A., Brophy, C., Čop, J., Dalmannsdóttir, S., Delgado, I., Elgersma, A., Fothergill, M., Frankow-Lindberg, B. E., ... Lüscher, A. (2018). Plant diversity greatly enhances weed suppression in intensively managed grasslands. In B. Horan, D. Hennessy, M. O'Donovan, E. Kennedy, B. McCarthy, J. A. Finn, & B. O'Brien (Eds.), *Proceedings of the 27th General Meeting of the European Grassland Federation: Sustainable meat and milk production from grasslands* (pp. 142-143). European Grassland Federation.

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Connolly J.[1], Sebastià M.T.[2,3], Kirwan L.[4,1], Finn J.A.[5], Llurba R.[2,3], Suter M.[29], Collins R.P.[6], Porqueddu C.[7], Helgadóttir A.[8], Baadshaug O.H.[9], Bélanger G.[10], Black A.[11], Brophy C.[12], Čop J.[13], Dalmannsdóttir S.[8,14], Delgado I.[15], Elgersma A.[16], Fothergill M.[6], Frankow-Lindberg B.E.[17], Ghesquiere A.[18], Goliński P.[19], Grieu P.[20], Gustavsson A.M.[21], Höglind M.[22], Huguenin-Elie O.[29], Jørgensen M.[14], Kadziuliene Z.[23], Lunnan T.[24], Nykanen-Kurki P.[25], Ribas A.[2,26], Taube F.[27], Thumm U.[28], De Vliegher A.[18] and Lüscher A.[29]

[1]School of Mathematics and Statistics, University College Dublin, Dublin 4, Ireland; [2]Laboratory ECOFUN, Forest Sciences Centre of Catalonia (CTFC), 25280 Solsona, Spain; [3]Group GAMES and Dept HBJ, ETSEA, University of Lleida, 25198 Lleida, Spain; [4]Waterford Institute of Technology, Cork Road, Waterford, Ireland; [5]Teagasc, Environment Research Centre, Johnstown Castle, Co. Wexford, Ireland; [6]IBERS, Plas Gogerddan, Aberystwyth University, SY23 3EE, Wales, UK; [7]CNR-ISPAAM, Via Traversa la Crucca 3, 07100 Sassari, Italy; [8]Agricultural University of Iceland, Keldnaholti, 112 Reykjavík, Iceland; [9]Faculty of Biosciences, P.O. Box 5003, 1432 Ås, Norway; [10]Agriculture and Agri-Food Canada, 2560, Hochelaga Blvd, Québec, Quebec G1V 2J3, Canada; [11]Teagasc, Beef Research Centre, Grange, Dunsany, Co. Meath, Ireland; [12]Department of Mathematics and Statistics, Maynooth University, Maynooth, County Kildare, Ireland; [13]Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia; [14]NIBIO – Norwegian Institute of Bioeconomy Research, Holt, 9269 Tromsø, Norway; [15]CITA-DGA, Av. Montañana 930, 50059 Zaragoza, Spain; [16]Plant Sciences Group, Wageningen University, P.O. Box 16, 6700 AA Wageningen, the Netherlands; [17]Department of Crop Production Ecology, Box 7043, 750 07 Uppsala, Sweden; [18]Institute for Agricultural and Fisheries Research (ILVO), Caritasstraat 39, 9090 Melle, Belgium; [19]Department of Grassland and Natural Landscape Sciences, Poznan University of Life Sciences, Dojazd 11, 60-632 Poznan, Poland; [20]UMR ARCHE INRA-ENSAT, 31326 Castanet Tolosan, France; [21]Department of Agricultural Research for Northern Sweden, Section of Crop Science, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden; [22]NIBIO – Norwegian Institute of Bioeconomy Research, Saerheim, 4353 Klepp st., Norway; [23]Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Akademija, 58344, Kedainiai, Lithuania; [24] NIBIO – Norwegian Institute of Bioeconomy Research, Løken, 2940 Heggenes, Norway; [25]MTT Agrifood Research Finland, Ecological Production, Karilantie 2A, 50600 Mikkeli, Finland; [26]CREAF, Cerdanyola del Valles 08193, Catalonia, Spain; [27] Institute of Crop Science and Plant Breeding, University of Kiel, Hermann-Rodewald-Str. 9, 24118 Kiel, Germany; [28]University of Hohenheim, Institute of Crop Sciences, Germany; [29]Agroscope, Forage Production and Grassland Systems, Reckenholzstrasse, 191 Zurich, Switzerland

Abstract

Weed suppression was investigated in a field experiment across 31 international sites. The study included 15 plant communities at each site, based on two grasses and two legumes, each sown in monoculture and 11 four-species mixtures varying in the relative proportions of the four species. At each site, one grass and one legume species was selected as fast establishing and the other two species were selected for persistence. Average weed biomass in mixtures over the whole experiment was 52% less (95% confidence interval, 30 to 75%) than in the most suppressive monoculture (transgressive suppression). Transgressive suppression of weed biomass persisted over each year for each mixture. Weed biomass was consistently low and relatively similar across all mixtures and years. Average sown species biomass was greater in all mixtures than in any monoculture. The suppressive effect of sown forage species on weeds in mixtures was achieved without any herbicide use. At each site, weed biomass for almost every mixture was lower than the average across the four monocultures. The average proportion of weed biomass in mixtures was less than in the most suppressive monoculture in two thirds of sites. Mixtures outyielded monocultures, and mixture yield comprised far lower weed biomass.

Keywords: legume-grass mixtures, diversity, weed suppression, evenness, GDI model (Generalised-Diversity_interactions model)

Introduction

A major challenge to agroecosystems is to increase agricultural production to meet an increased demand for food production (Lüscher *et al.,* 2014) while sustaining the environment and flexibly adapting to climate change. The use of multi-species mixtures (plant diversity) in intensively managed systems has been proposed as one strategy to improve agricultural sustainability. Plant diversity potentially provides a substitute for many costly agricultural inputs (Isbell *et al.,* 2017). Here we focus on the use of plant diversity to suppress weed biomass in intensively managed grasslands. Uncontrolled weed growth can represent a major source of inefficiency, diverting nutrients, water, light and labour to an undesirable form of biomass, while herbicide use incurs significant environmental and economic costs. In pastures, weeds can impair forage quantity and quality resulting in reduced animal production, and increase the need for reseeding with its consequent costs. If diversity helps in maintaining a low level of weeds in pastures (and increases yield) it can increase the sustainable production of higher quality forage compared to systems relying on monocultures.

Using data from the 31-site Agrodiversity field experiment (Kirwan *et al.,* 2014) which used four-species mixtures (two grasses and two legumes), we addressed the following questions:

1. Do monocultures of grassland species differ in their suppression of weeds?
2. Are weeds transgressively suppressed by mixtures of grassland species? (Weed biomass in mixture being less than weed biomass in the most suppressive monoculture.)
3. Is weed suppression by mixtures affected by differences in species' relative abundance?
4. Is variation in weed biomass less in mixtures than in monocultures?

Materials and methods

We conducted a co-ordinated continental-scale field experiment across 31sites to investigate these questions. At each site the study included 11 four-species mixtures, varying in the relative proportions of two grass and two legume species. The four species were also sown in monoculture. The four species used were not the same at all sites, at each site species were selected that suited local conditions, the two grasses being selected from non-fixing grasses *Dactylis glomerata* L., *Festuca arundinaca*, *Lolium perenne* L., *Lolium rigidum* L., *Phleum pratense* L., *Poa pratensis* L. and the two legumes from N_2-fixing species, *Trifolium repens* L., *Trifolium pratense* L., *Trifolium ambiguum* L., *Medicago sativa* L., *Medicago polymorpha* L. At each site, one grass and one legume species was selected as fast establishing (G_F and L_F) and the other two species were selected for persistence (G_P and L_P). Mixtures were designed to reduce reliance on fertiliser nitrogen. We first summarised information on the suppression of weed biomass across the 15 communities for each of the three years and across years. We tested at each site for transgressive suppression of weeds. To address questions 1 to 4 we used a version of diversity interactions modelling (Connolly *et al*., 2013). This uses a mixed model to relate weed biomass per plot to sown proportions of each of the four species and also includes a diversity effect to estimate the effect of various mixtures on weed yield.

Results and discussion

Previously, we showed strong effects of plant diversity in enhancing total biomass, biomass of sown species and N capture across the 11 four-species grass-legume mixtures (Finn *et al*., 2013; Suter *et al*., 2015). Here, we summarise results from Connolly *et al*. (2017) showing similar strong effects of mixtures on weed suppression in the same experiment.

Averaged across all sites, weed biomass in mixtures over the whole experiment was 52% less (95% confidence interval 30 to 75%) than in the most suppressive monoculture (transgressive suppression). Transgressive