Project number: 6023
Funding source: Science Foundation Ireland
Date: Feb 2016
Project dates: Sep 2009 -Dec 2013

Benefits of multispecies mixtures in grassland systems

Key external stakeholders:

Policymakers
Participants in agri-environment schemes
Extensive farmers
Environmental NGOs

Practical implications for stakeholders:

Over a three-year period, four-species mixtures (two grass and two legume species) increased yield and reduced weed invasion, compared to monocultures.

Main results:

In an international experiment across 31 sites, four-species grassland mixtures generally provided greater yield than monocultures, and regularly exceeded the yield of the best performing monoculture. Compared to monocultures, mixtures greatly reduced the biomass of weeds in the sward.

Opportunity / Benefit:

The use of four-species grass-legume mixtures can enhance nutrient use efficiency under intensive management. Grass-legume mixtures merit further investigation of their contribution to ecosystem services such as soil carbon sequestration, and mitigation of greenhouse gas emissions through the ability of legumes to fix atmospheric nitrogen. These may be options for future Greening measures. These experiments were conducted under mowing to simulate grazing; there is a need to investigate multispecies mixtures under grazing.

Collaborating Institutions:

Waterford Institute of Technology
Maynooth University
University College Dublin

Teagasc project team: Dr John Finn
External collaborators: Dr Laura Kirwan (PI), Dr Caroline Brophy, Prof. John Connolly

1. Project background:

Recent ecological research provides evidence that an increased number of plant species in semi-natural grasslands is strongly associated with increased biomass productivity, and provides a wide range of other ecosystem benefits. This suggests that increases in species diversity in agricultural ecosystems may similarly lead to increased benefits.

Traditionally, agronomic science suggests that, compared to more species-rich mixtures, species-poor mixtures or even monocultures of high-yielding species will maximise yield under productive and highly

Contact John Finn Email: john.finn@teagasc.ie.

fertilised conditions. Although the maximisation of yield is often the dominant reason for use of monocultures, other advantages of agricultural monoculture systems include the synchronisation of farm management and the simplified harvesting associated with a single crop type. Both the increasing cost of nitrogen fertiliser and greenhouse gas emissions are causing a re-evaluation of the use of fertiliser nitrogen on. Forage legumes offer the potential to lower fertiliser costs on farms and may offer a more sustainable option for pasture-based production, not just economically but also in terms of other environmental impacts. Whether increased crop diversity in species-poor agronomic systems could improve the provision of ecosystem services remains largely untested due to the rarity of multi-species agronomic experiments that use more than two species.

2. Questions addressed by the project:

The main objectives were:

- Do mixtures provide more yield than monocultures?
- If so, can mixtures maintain the yield benefit across different levels of nitrogen?

3. The experimental studies:

As part of a European project (COST Action 852), this international collaboration investigated the relationship between plant diversity and ecosystem function at 31 sites across Europe, and Canada. At each field site, a field experiment was established. Thirty plots were established with communities of four commonly used agronomic grassland species that were appropriate to each site, but always with two grasses and two legumes. The most commonly used species were *Lolium perenne, Dactylis glomerata, Trifolium pratense* and *Trifolium repens*. Sowing proportions of these four species were systematically varied according to a simplex design giving 15 distinct communities: four monocultures and elven four-species mixtures. The four-species mixtures consisted of four communities dominated in turn by one species (70:10:10:10), six communities co-dominated in turn by two species where (40:40:10:10) and one community where all four species were equally represented (25:25:25:25). Plots were harvested by mowing. Further details in Kirwan et al. (2007) and Finn et al. (2013).

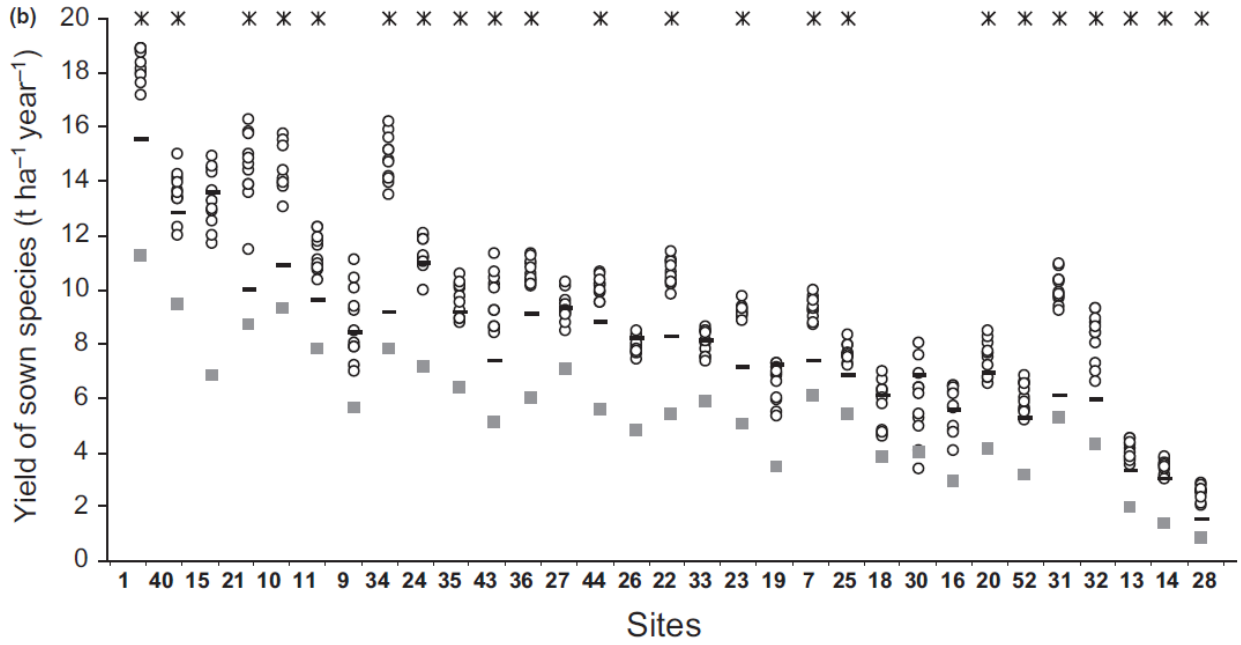

Figure 1 Average annual yield (dry matter) over the whole experimental duration of yield of sown agronomic species only (excludes weeds) at 31 sites. Data averaged across seed density and across years per site. Sites are arranged in order of decreasing total yield of the best-performing monoculture. Open circles represent each of the 11 mixture communities that differed in their relative abundance at sowing; horizontal bars represent the yield of the best-performing monoculture; squares represent the mean monoculture performance. Significant transgressive overyielding is indicated by the symbol over a site at the top of each panel. Note that not all of these sites had 3 years of yield data. From Finn et al. (2013).

4. Main results:

Contact John Finn Email: john.finn@teagasc.ie.

The results indicate strong benefits of sward diversity in intensive grassland systems across Europe. Mixtures provided more forage yield than would be expected on the basis of the species' performances in monoculture. Across multiple years, the total yield (including weed biomass) of the mixtures exceeded that of the average monoculture in >97% of comparisons. It also exceeded that of the best monoculture (transgressive overyielding) in about 60% of sites, with a mean yield ratio of mixture to best-performing monoculture of 1.07 across all sites. Analyses based on yield of sown species only (excluding weed biomass) demonstrated considerably greater transgressive overyielding (significant at about 70% of sites, ratio of mixture to best-performing monoculture = 1.18) (Fig. 1).

Mixtures maintained a resistance to weed invasion over at least 3 years. In mixtures, median values indicate <4% of weed biomass in total yield, whereas the median percentage of weeds in monocultures increased from 15% in year 1 to 32% in year 3 (Fig. 2).

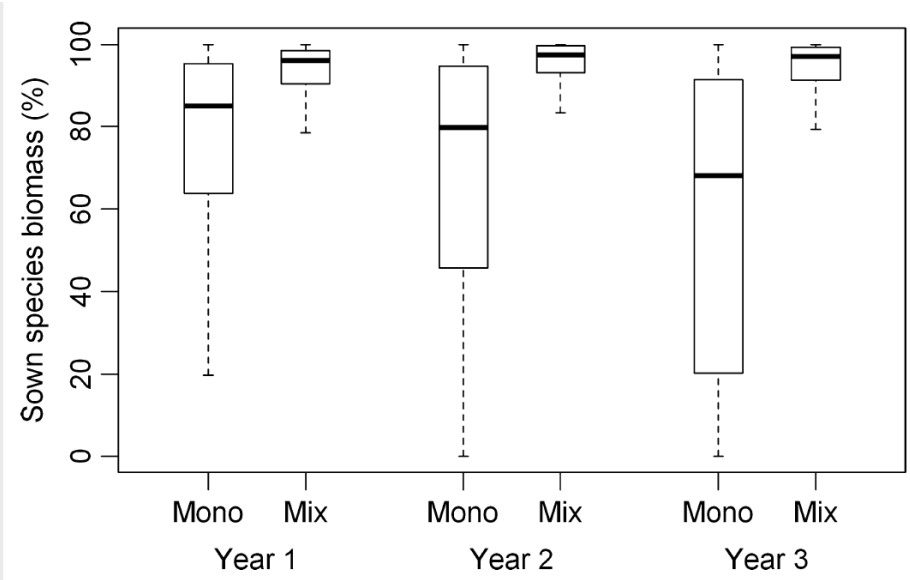

Figure 2 Box plots of the percentage of total yield (yield of sown species + weed yield) that was composed of the sown species, presented for monocultures (mono) and mixtures (mix) in each year. Data are averaged across all 31 sites. At each site, there were four monoculture communities (n = 8 plots in total) and 11 mixture communities (n = 22 plots in total).

5. Opportunity/Benefit:

The use of four-species grass-legume mixtures can enhance nutrient use efficiency under intensive management. Grass-legume mixtures merit further investigation of their contribution to ecosystem services such as soil carbon sequestration, and mitigation of greenhouse gas emissions through the ability of legumes to fix atmospheric nitrogen. These may be options for future Greening measures. These experiments were conducted under mowing to simulate grazing; there is a need to investigate multispecies mixtures under grazing.

6. Dissemination:

This work was presented at a number of Open Days and visits by national and international groups of farmers and researchers to Johnstown Castle. It was also presented at multiple international and national conferences.

Main publications:

Connolly et al. (2018) 'Weed suppression greatly increased by plant diversity in intensively managed grasslands: A continental-scale experiment' *Journal of Applied Ecology* 55: 852-862. Open Access.
Finn et al. (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.
Kirwan et al. (2009) 'Diversity–interaction modeling: estimating contributions of species identities and interactions to ecosystem function' *Ecology* 90: 2032-2038.
Kirwan et al. (2014) 'The Agrodiversity Experiment: three years of data from a multisite study in intensively

Contact John Finn Email: john.finn@teagasc.ie.

managed grasslands' *Ecology* 95: 2680. Open Access dataset.

Popular publications:

Connolly J., Bell T., Brophy C., Carnus T., Finn J., Kirwan L., Lüscher A., Sebastia M.T. and Weigelt A. (2010) Multi-Species Mixtures - New Perspectives on Models and Mechanisms. *Proceedings of 23rd General Meeting of the European Grassland Federation*, Kiel, Germany, 782-784

7. Compiled by: Dr John Finn

Contact John Finn Email: john.finn@teagasc.ie.