Project number: 5583
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Benefits of agronomic plant diversity in forage mixtures

Key external stakeholders:

Policymakers
Participants in agri-environment schemes
Extensive farmers
Environmental NGOs

Practical implications for stakeholders:

Modest increases in sward diversity to four-species mixtures can increase yield and reduce weed invasion, compared to monocultures. These results are applicable to nitrogen fertiliser applications of about 200 kg ha^{-1} $yr^{-1}$of nitrogen per annum.

Main results:

Four-species grassland mixtures generally provided greater yield than monocultures. Mixtures consisted of perennial ryegrass, timothy, red clover and white clover. Beneficial effects of sward diversity occurred across nitrogen levels of 50 and 200 kg ha^{-1} yr^{-1}. On average, the beneficial effect on yield due to increased sward diversity at 50 kg ha^{-1} yr^{-1} was comparable in magnitude to the addition of 150 kg ha^{-1} yr^{-1}. Compared to monocultures, mixtures greatly reduced the biomass of weeds in the sward.

Opportunity / Benefit:

The use of simple agronomic mixtures with legumes offers potential further investigation of their contribution to ecosystem services from agricultural ecosystems, 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.

Collaborating Institutions:

UCD

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Mr Alan Cuddihy
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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 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 agri-environmental legislation are causing a re-evaluation of the use of fertiliser nitrogen on farms and a search for lower-cost and environmentally compliant alternatives. 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:

A field experiment was used to investigate the objectives. Main plots (n=56) were laid out (8.1 m × 4 m) and sown in mid-September 2006 with communities of four commonly used agronomic grassland species (*Lolium perenne* cultivar cv. Lacerta; *Phleum pratense* cv. Motim; *Trifolium pratense* cv. Merviot; *Trifolium repens* cv. Milo). Sowing proportions of these four species were systematically varied according to a simplex design giving 25 distinct communities: four monocultures, six binary mixtures (50:50) and 15 four-species mixture communities. The four-species mixtures consisted of four communities dominated in turn by one species (88:4:4:4), 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) All communities were sown at two levels of initial overall community biomass based on seed weight. Main plots were divided into four equally sized sub-plots. Split-plot treatments consisted of two levels of nitrogen (approximately 50 and 200 kg ha^{-1} $yr^{-1}$of nitrogen) and two levels of cutting severity at harvest (7 cm and 2 cm) in factorial combination.
Plots were harvested by mowing. Wet conditions over all three years limited harvesting to three occasions in 2007 and 2009 (spring, summer and autumn) and two in 2008 (late spring and late summer)

4. Main results:

Aboveground biomass was 16.5% higher in mixtures than in monocultures while weed biomass was reduced in mixtures by up to 99%. The effect of increased plant diversity (including legumes) was at least as big as the effect of adding 150 kg ha^{-1} yr^{-1} of nitrogen. The nitrogen content of biomass yield depended on the type of species and was increased by species richness. An increase in community evenness was associated with a decrease in the variation of biomass; thus, sward evenness conferred greater stability of biomass yield. Overall, effects of species interactions were positive and equivalent, leading to an evenness-driven effect of diversity on aboveground yield. Application of nitrogen fertiliser affected species differentially, and increased grass biomass but not legume biomass. Diversity effects remained stable until the third year, when community composition became dominated by *Phleum pratense*. Cutting had an overall negative effect on biomass but did not influence diversity effects. Mixtures had significantly lower weed biomass than monocultures.

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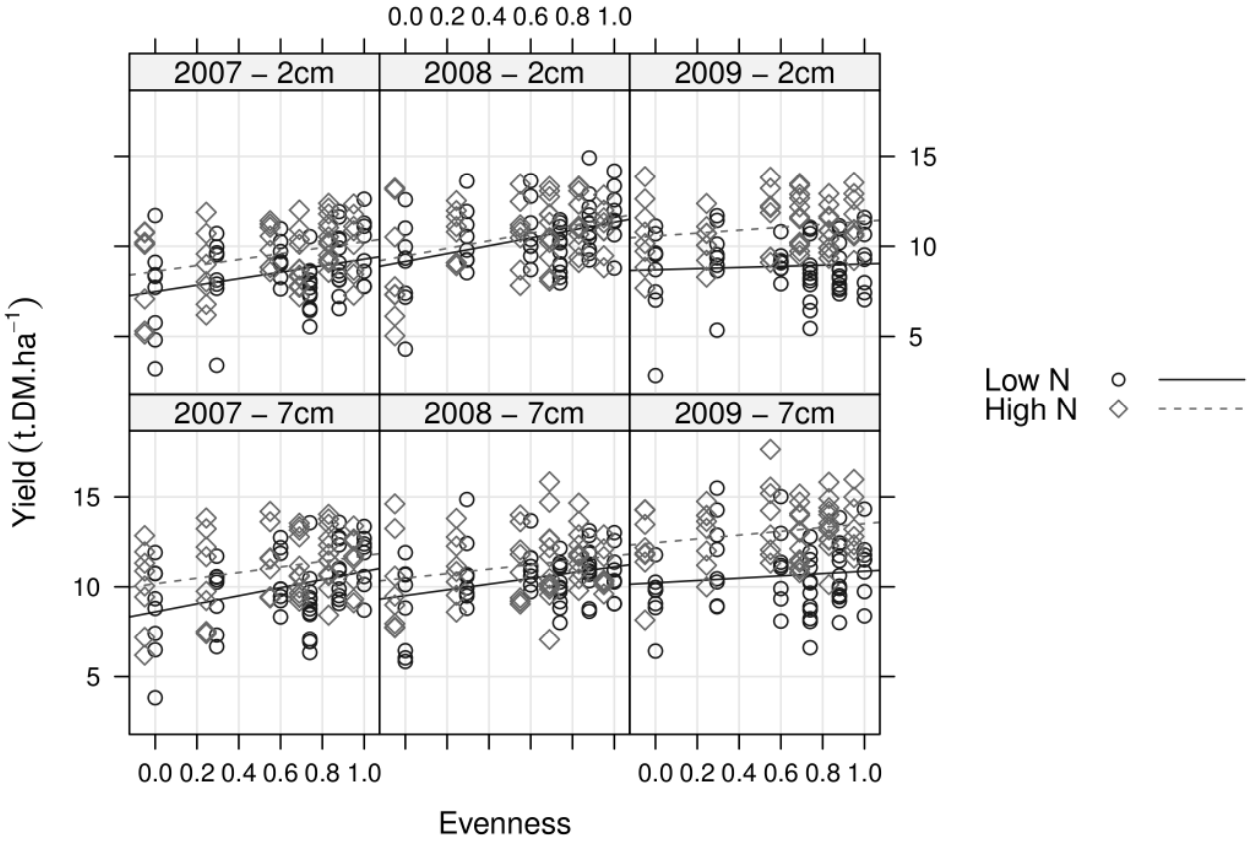

Figure 1 Effect of nitrogen level and evenness on aboveground biomass (tonnes per hectare of dry matter) across each year and cutting treatment (cutting to 2 cm height in top panels, and cutting to 7 cm height in bottom panels). Regression lines show the relationship between sward evenness and yield. Highest evenness value =1 corresponds to the equal mixture of all four species; evenness value = 0 corresponds to the average of the four monoculture species.

5. Opportunity/Benefit:

These results signal the merit of further investigation of the contribution of simple agronomic mixtures to soil carbon sequestration, and mitigation of greenhouse gas emissions through the ability of legumes to fix atmospheric nitrogen.

6. Dissemination:

This work was presented at a number of Open Days and visits by national and international groups of farmers to Johnstown Castle. It was also presented at several national and international conferences, as follows: Irish Plant Scientists' Association Meeting in 2008; Agricultural Research Forum in 2008 and 2009; Irish Environmental Researchers Colloquium in 2007, 2008 and 2009; Joint Meeting of the 21st International Grassland Congress and the 8th International Range-land Congress in 2008; the British Ecological Society Annual Meeting in 2007 and 2008.

Main publications:

Finn J.A., Carnus T., Kirwan L., Cuddihy A. and Connolly J. (2009) 'Four-Species Mixtures Enhanced Yield at Low and High Levels of Nitrogen Addition Over Two Years' *Irish Journal of Agricultural and Food Research* 48: 272.

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

Popular publications:

Carnus, T., Finn, J.A., Kirwan, L., Cuddihy, A. and Connolly, J. 2009. Benefits of Sward Diversity in

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Productive Grassland Systems. In: *Ireland's Rural Environment: Research Highlights from Johnstown Castle*. Teagasc, pp 98 – 99, ISSN 1841705438.

Carnus, T., Finn, J.A., Kirwan, L. and Connolly, J. (2007). Does Plant Diversity Stabilise Ecosystem Function? In: *Ireland's Rural Environment: Research Highlights from Johnstown Castle*. Teagasc, p. 85, ISSN 18 4170 4776

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