Overyielding in multi-species swards under simulated grazing management

Patterson J.D.[1,2], Herron E.R.[2], Mocarska M.[2], Gordon A.W.[3] and Young G.K.[2]
[1]Agri-Food and Biosciences Institute (AFBI), Hillsborough, Co Down, BT26 6DR, N. Ireland, United Kingdom; [2]AFBI, Loughgall, Co Armagh, BT61 8JB, N. Ireland, UK; [3]AFBI, Belfast, Co Antrim, BT9 5PX, N. Ireland, United Kingdom

Abstract

Species from different functional groups when grown together can produce higher biomass yield compared to the respective monoculture yields of component species, a phenomenon known as overyielding. This paper reports on yield effects from a multi-species sward (MSS) plot study in Northern Ireland and reviews likely explanations of overyielding. Two contrasting seed mixtures were sown in replicated plot trials in 2019, along with their component species as monocultures. *NoGrass* contained chicory, plantain, white clover and red clover. *GrassMix* contained tall fescue, cocksfoot, timothy, late heading perennial ryegrass and white clover. *NoGrass* produced a higher dry matter yield ($P<0.05$) in 2021 than all of its components, with the exception of the red clover component (12.2 t dry matter (DM) ha^{-1}; red clover 11.2 t DM ha^{-1}). *GrassMix* also exhibited overyielding for dry matter production compared with its component varieties. Further research is needed to explain this overyielding phenomenon in MSS.

Keywords: multi-species, yield, overyielding, seed mixtures

Introduction

Multi-species swards (MSS) could make an important contribution to sustainable livestock farming systems. Various studies have shown that mixtures of species with differing characteristics can produce greater yield than either the weighted average of the respective monocultures of the component species (Finn *et al.*, 2013; Sanderson *et al.*, 2004) or the best-performing monoculture. Explanation of such overyielding could be partly due to the respective use of resources, above and below ground characteristics of the component species as well as the effects of symbiotic nitrogen fixation (Suter *et al.*, 2015) in mixtures of functional groups of species such as grasses, legumes and herbs. The aim of this study was to investigate overyielding in MSS plot trials in Northern Ireland.

Materials and methods

The study, which lasted for 28 weeks in each of 2 consecutive years at AFBI Loughgall (54°27′N, 6°04′W), was composed of 3 replicates of 16 treatments comprising 8 treatments of clover and herb monocultures and 1 clover/herb mixture (*NoGrass*= chicory, plantain, white and red clover) and 8 treatments of grass monocultures and 1 multiple grass species mixture (*GrassMix*= tall fescue, cocksfoot, timothy, late heading perennial ryegrass and white clover). Two fertilizer regimes were applied: *NoGrass* and clover and herb monocultures received an early March application only (83 kg ha^{-1} N; 88 kg ha^{-1} P_2O_5; 71 kg ha^{-1} K_2O); *GrassMix* and grass monocultures received the equivalent March application and a June application (total of 155 kg ha^{-1} N; 88 kg ha^{-1} P_2O_5; 110 kg ha^{-1} K_2O) to reflect typical industry practice for grass-based swards. P_2O_5 and K_2O fertilizer was applied to maintain soil P and K at target Index 2, as per RB209 soil nutrient index values (AHDB, 2021). Plots were managed under a simulated grazing regime, with 8 sampling dates for herbage yield during the growing season, taken from early April to late October each year with harvest dates determined by sward height (target of 15 cm above ground level). Herbage was defoliated to 75 mm stubble height using a plot harvester (Haldrup, F55) and regrowth intervals ranged from 18 to 32 days. Fresh weight yields were recorded in 2020 and 2021 (not presented), with dry matter yields calculated in 2021 only. Analysis of Variance was applied to assess

the effects of variety and mixture on yield using Genstat (VSNi, 2017). Means were separated by Fisher's least significant difference (LSD) test at $P<0.05$.

Results and discussion

Grange *et al.* (2021) has described the effect by which mixtures can produce higher yield than any of their constituent components as transgressive overyielding. In 2021, *NoGrass* produced higher dry matter (DM) yield ($P<0.05$) than all of its components (Figure 1), with the exception of red clover variety A (*NoGrass* 12.2 t DM ha^{-1}; red clover A 11.2 t DM ha^{-1}); Chicory had the lowest yield in 2021 (6.2 t DM ha^{-1}). *GrassMix* also exhibited overyielding for DM yield in 2021 (Figure 2), yielding 11.0 t DM ha^{-1} compared to an average of 8.7 t DM ha^{-1} for the component varieties which is in keeping with the study of Vojtech *et al.* (2008), which showed that mixtures of grass species with differing foliar architecture can improve overall light interception and biomass production compared with monocultures. Overall, these results demonstrate that transgressive overyielding can occur when contrasting species are grown together in herb/legume and in grass/legume combinations. That *NoGrass* was the highest yielding treatment with only two functional groups present could suggest that combining species with contrasting traits may be more important than the number of functional groups present. Asynchrony in shoot growth of component species has been considered to be more important for yield than mixing species with contrasting foliar architecture (Husse, 2016). By contrast, Lorenz *et al.* (2020) found that increasing species diversity did not increase yield, as some species were replaced by others with similar functional traits. It is also noteworthy that *NoGrass* out-yielded *GrassMix* and all of the grass monocultures despite the slightly higher fertilizer N applied (83 and 155 kg ha^{-1} N respectively), which is in keeping with Grange *et al.* (2021), for whom higher fertilizer N perennial ryegrass monocultures (300 kg ha^{-1} N) yielded less than the most species-diverse mixture.

Conclusions

In general, legume-herb and grass-legume species combinations yielded more than their components grown as monocultures. It would appear that functional group composition could be more important than the number of species present for overyielding to occur. The factors controlling overyielding are not fully understood but asynchrony of growth patterns may be more important than contrasting foliar architecture, which will require further research to establish. Further research is also required to verify the productivity of diverse mixtures particularly under both conservation and grazing conditions, and at varying fertilizer rates, to more fully understand their yielding characteristics, along with yield stability and herbage quality in order to capture the full potential of MSS for sustainable livestock farming systems.

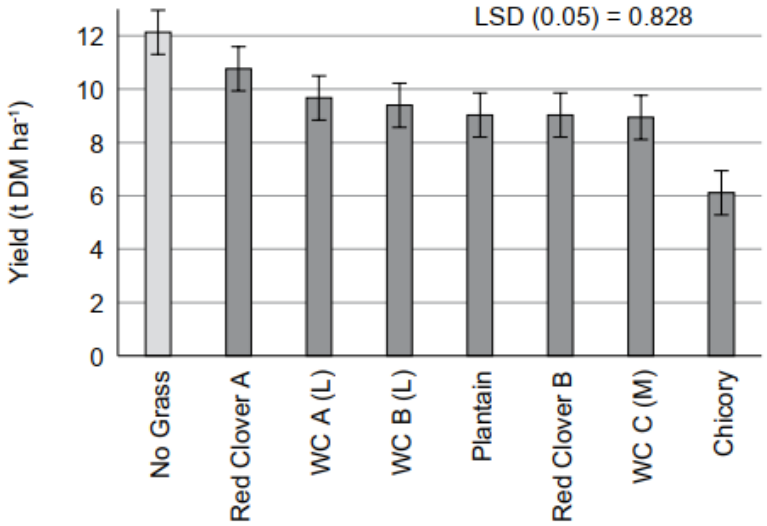

Figure 1. Dry matter yield (t DM ha^{-1}) of *NoGrass* and component varieties. WC = white clover; L = large leaved; M = medium leaved; PRG = perennial ryegrass; Int = intermediate maturity; Late = late maturity; LSD = least significant difference.

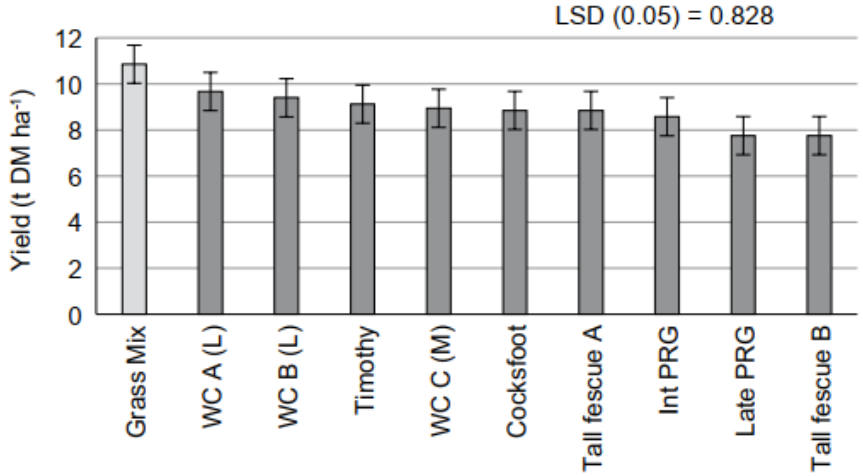

Figure 2. Dry matter yield (t DM ha^{-1}) of *GrassMix* and component varieties. WC = white clover; L = large leaved; M = medium leaved; PRG = perennial ryegrass; Int = intermediate maturity; Late = late maturity; LSD = least significant difference.

Acknowledgements

The authors wish to thank the contribution made by AFBI staff at Loughgall. This work was completed with support from SUPER-G (EU Horizon2020), Ecosward (DAERA Department of Agriculture, Environment and Rural Affairs 19/4/01) projects and AgriSearch.

References

AHDB (Agriculture and Horticulture Development Board) (2021) Nutrient Management Guide (RB209) Section 3 grass and forage crops. Available at: https://ahdb.org.uk/knowledge-library/rb209-section-3-grass-and-forage-crops

Finn J.A., Kirwan L. ... and Connolly J. (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.

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(9), 1864-1875.

Husse S. (2016) Larger yields of mixtures than monocultures of cultivated grassland species match with asynchrony in shoot growth among species but not with increased light interception. *Field Crops Research* 194, 1872-6852.

Lorenz H., Reinsch T., Kluβ C., Taube F. and Loges R. (2020) Does the admixture of forage herbs affect the yield performance, yield stability and forage quality of a grass clover ley? *Sustainability* 12(14), 5842. https://doi.org/10.3390/su12145842

Sanderson M.A., Skinner R.H., Barker D.J., Edwards G.R., Tracy B.F. and Wedin D.A. (2004) Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Science* 44, 1132-1144.

Suter M., Connolly J., Finn J.A., Loges R., Kirwan L., Sebastià M.T. and Lüscher A. (2015) Nitrogen yield advantage from grass–legume mixtures is robust over a wide range of legume proportions and environmental conditions. *Global Change Biology* 21, 2424-2438.

Vojtech E., Loreau M., Yachi S., Spehn E.M. and Hector A. (2008) Light partitioning in experimental grass communities. *Oikos* 117, 1351-1361.

VSN International (2017) Genstat for Windows 19th Edition. VSN International, Hemel Hempstead, UK.