Impact of tillage methods and sowing rates on yield and weed suppression in multi-species swards

Beaumont D.A.[1], Storkey J.[2], Eales G.[3], Jones H.E.[3], LeCocq K.[1], Saunders K.S.[1], Stagg B.[3] and Lee M.R.F.[1,4]

[1]Rothamsted Research, North Wyke, Okehampton, Devon EX20 2SB, United Kingdom; [2]Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, United Kingdom; [3]Duchy College, Stoke Climsland, Callington, Cornwall PL17 8PB, United Kingdom; [4]University of Bristol, Bristol Veterinary School, Langford, Somerset BS40 5DU, United Kingdom

Abstract

Recent experimental studies have demonstrated increased plant diversity in agricultural pastures can benefit a variety of ecosystem functions including increased biomass production and weed suppression. With rising global demand for more sustainable ruminant production systems, multi-species swards are growing in popularity as an alternative to high-input ryegrass monocultures. Minimum tillage reduces disturbance to soil structure compared with conventional ploughing, however, weed infestation can be potentially higher under non-inverted, shallow cultivation as seeds remain near the soil surface. A multi-factorial field experiment was established to assess the impact of three tillage methods and four seed mixes, with increasing diversity, sown at two different rates on sward productivity and weed ingress. We found tillage depth, increased plant diversity or sowing rate had limited beneficial effect on dry matter yield in the first growing year. However, increased species diversity and ploughing reduced weed pressure.

Keywords: seed mixes, cultivation, sown and unsown species, establishment, productivity

Introduction

Many studies have shown a positive relationship in grasslands between plants species richness and a variety of ecosystem functions. Increasing the complexity of forage seed mixes can improve weed suppression (Suter *et al.*, 2017) and enhance above ground biomass (Küchenmeister *et al.*, 2012) through positive species interactions and species niche complementarity in resource capture. Pasture weeds can lower forage yield by competing for water, sunlight and nutrients and can also reduce forage quality (DiTomaso, 2000). As the application of herbicides is not an option to control weeds in multi-species leys it is imperative to select tillage methods and sowing rates to minimize weed ingress, thus reducing a decline in sward productivity and consequently the frequency and associated economic and environmental costs of re-seeding. Cultivation techniques which minimise soil disturbance are recommended for reducing establishment costs, increasing soil nutrient stocks, improving soil structure and increasing beneficial soil fauna compared with conventional ploughing. However, there are some concerns regarding increased weed densities and shifts in weed species communities with minimal tillage practices (Derksen *et al.*, 2002). The objective of this research was to investigate the impact of three tillage practices and four seed mixes with increasing diversity sown at two different rates on above ground biomass and relative weed abundance in the first growing year.

Methods and materials

A randomised split-plot design field experiment with three replicates was established in autumn 2018 at Rothamsted Research North Wyke, Devon, UK on a permanent, species-poor grassland on clay soil. Prior to cultivation the field was sprayed with glyphosate (2.16 kg ha^{-1}). Experimental plots were cultivated using three contrasting tillage depths: shallow, intermediate and deep by (1) power harrow (PH) to a depth of 5-7 cm; (2) disc harrow (DH) to a depth of 10-15 cm; (3) conventional ploughing (P) to a depth of 20-25 cm. Plots of 24 m^2 (8×3 m) were sown with four seed mixes of increasing plant diversity, a binary

mix of *Lolium perenne* and *Trifolium repens* (PC) and mixes that comprised three functional groups (grass, legume and non-leguminous forbs), six species (A), twelve species (B), eighteen species (HD) each sown at a conventional rate of 34.59 kg ha^{-1} (CS) and a high rate of 51.89 kg ha^{-1} (HS). Plots were cut three times, early, mid and late during the 2019 growing season, at a 5 cm height with a Haldrup harvester. Application rates of inorganic fertiliser to each cultivation treatment were based on soil concentrations found in soil samples collected during autumn 2018. In 2019 all three cultivation types received 13 kg ha^{-1} of P and 48 kg ha^{-1} of S, however, potassium rates differed with 158, 100 and 174 kg ha^{-1} of K applied to the PH, DH and P plots respectively. Botanical percentage cover was assessed visually in two 0.25 m^2 quadrats per plot before each harvest. There were not resources available for destructive sampling and separation of species at each harvest, but this was done once on two 0.25×0.5 m quadrats per plot, cut to ground level immediately following the May cover assessments to assess the accuracy of the visual estimates. Above-ground dry matter yield (DMY) and sown and unsown plant abundance were analysed using general analysis of variance models with GenStat, release 19.1 (VSN International 2018).

Results and discussion

No significant treatment effects for average annual DMY were found; however, there were some temporal differences. At the first harvest in May (overall mean 2.60 Mg ha^{-1}) there were no significant differences between the treatments, but by July the ploughed plots had significantly more biomass than either DH or PH plots (P=0.039). The average values were 2.32, 1.81 and 1.68 Mg ha^{-1} for P, DH and PH, respectively. There were significant differences between seed mixes in July with the highest biomass recorded in seed mix A (P=0.006). Highest productivity was recorded on the ploughed plots sown at the higher rate with a 6-species mix (2.70 Mg ha^{-1}), however, sowing rate had no significant effect in July or at any other timepoint. After the second cut the ploughed plots lost the advantage yielding the least in October (average 2.74, 3.24 and 3.27 Mg ha^{-1} for P, DH and PH respectively) although cultivation treatment was not significant. Seed mix had no significant effect at the last harvest.

To assess the effect of the treatments on sward composition across the season, % cover data were analysed. Although not as accurate as relative dry weights, all visual assessments were done by a single expert to minimize observer error and a Pearson's correlation between the proportion of sown species in the destructive sample taken in May and the corresponding visual estimate was highly significant (r=0.58, P<0.001). While there were no significant differences in total biomass in May between the treatments, the seed mixes differed in the relative cover of sown (P=0.023) compared with unsown species (P=0.019) recorded prior to the first cut (Figure 1a). In May the binary mix (PC) had the lowest percentage cover of sown species and highest weed pressure; the best performing mix in terms of weed suppression was A (6 species). These seed-mix trends were similar for the PC mix prior to the second (sown species P<0.001, weed species P=0.003) and third (sown species P=0.003, weed species P<0.001) cuts although the HD

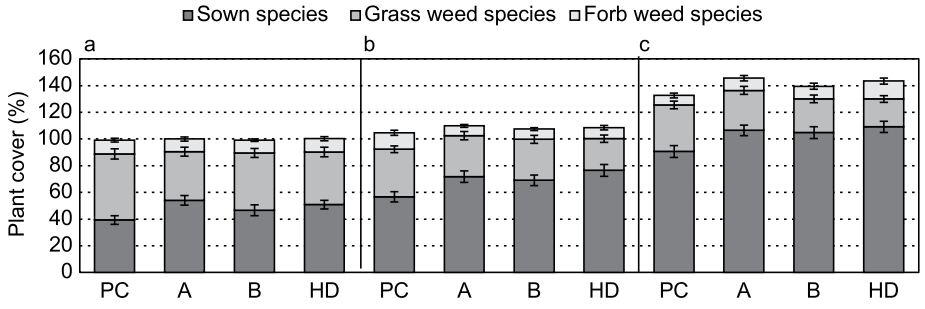

Figure 1. Average percentage cover of sown, weed grass and weed forb species in seed mixes, binary (PC), 6 species (A), 12 species (B) and 18 species (HD) at: (a) May, (b) July (c) October 2019.

(18 species) mix had the highest sown species and lowest weed cover and overall weed cover decreased with time (Figure 1). Cultivation was also a significant treatment in July (sown species P=0.015, weed species P=0.026) and almost significant in September for sown species (P=0.052) with the highest sown species establishment and lowest weed ingress recorded in the ploughed plots (July average weed species cover: P=23.6%, DH=53%, PH=43.2%, September average weed species cover: P=19.4%, DH=47.7%, PH=45.34%). The higher sowing rate had no significant impact on sown or unsown species relative abundance during the growing season. At all three sampling timepoints grass species dominated the weed community (Figure 1).

Conclusions

Tillage depth or increased plant diversity had no overall impact on annual yield in the first growing season. However, abundance of sown species was higher and weeds generally lower under ploughing, indicating that deeper cultivation is beneficial for establishment of desired species. Complex seed mixes reduced weed invasion compared with a binary mix which may have implications on forage quality and longevity of leys. Our results suggest there is no benefit of sowing at a higher rate in terms of yield or weed suppression.

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