Species diversity enhances multifunctionality in sown grass-legume mixtures

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Introduction: Legume-based grassland systems provide several key functions for the provision of high quantity and quality forage at low to moderate nitrogen (N) fertilizer input (Lüscher *et al.* 2014). Despite their high agronomic and economic importance, there is no up-to-date evaluation of the diversity-multifunctionality relationship in these systems.

Materials and methods: A diversity experiment was set up with sown monocultures, 2- and 4-species mixtures comprising *Lolium perenne* L., *Dactylis glomerata* L., *Trifolium pratense* L., and *Trifolium repens* L., and was maintained for three years at 150 kg N fertilization ha^{-1} yr^{-1}. Nine functions were measured that represented (1) production: aboveground biomass yield, between-year temporal yield stability (mean yield/standard deviation), aboveground weed biomass; (2) N cycling: symbiotic N_2 fixation (N_{sym}), N efficiency (N yield/N applied), NO_3 in soil solution; and (3) forage quality: crude protein content (CP), organic matter digestibility (OMD), metabolizable energy content (ME). All functions were jointly regressed on sown species proportions using multivariate linear mixed-effects regression (all stands used).

Results: Across the three years, all functions regarding production and N cycling revealed significantly enhanced performance in the 4-species equi-proportional mixture (used as a reference) compared to averaged monocultures ('overyielding'). Thus, the reference mixture had 62% more biomass yield, a 73% increase in temporal stability, 80% less weed biomass, 99% and 50% higher N_{sym} and N efficiency, respectively, and 85% less NO_3 in the soil solution (Table 1). The reference mixture and averaged monocultures did not significantly differ in CP, OMD (g kg^{-1} yield), and ME (MJ kg^{-1} yield) (Table 1). This, however, resulted in significant overyielding between 49% and 68% in all three forage quality functions on a per-hectare basis (kg or MJ ha^{-1} $year^{-1}$) ($P<0.01$). Thus, the use of grass-legume mixtures enhanced the performance of all measured functions, without trade-off between them, indicating enhanced multifunctionality in mixtures.

Table 1. Percent overyielding of nine functions representing forage production, N cycling, and forage quality, measured over three experimental years.[1]

Service	Function	Unit *(Ratio)*	Targeted direction	Overyielding
Production	Aboveground biomass yield	Mg ha^{-1} $year^{-1}$	positive	62% ***
	Temporal stability of yield	μ / σ	positive	73% **
	Weed biomass	Mg ha^{-1} $year^{-1}$	negative	-80% ***
N cycling	Symbiotic N_2 fixation	kg ha^{-1} $year^{-1}$	positive	99% ***
	N efficiency	N yield/N applied	positive	50% ***
	NO_3 in soil solution	mg $liter^{-1}$	negative	-85% *
Forage quality	Crude protein content	g kg^{-1} yield	positive	-8% ns
	Organic matter digestibility	g kg^{-1} yield	positive	-2% ns
	Metabolizable energy	MJ kg^{-1} yield	positive	-3% ns

[1] μ: mean, σ: standard deviation; *** $P \leq 0.001$, ** $P \leq 0.01$, * $P \leq 0.05$, ns: $P > 0.05$.

Conclusions: Sown grass-legume mixtures at moderate N fertilization sustain high multifunctionality and, compared to monocultures, enhance levels of individual functions that jointly promote sustainable forage production.

Lüscher A., Mueller-Harvey I., Soussana J.F., Rees R.M. and Peyraud J.L. (2014) Potential of legume-based grassland-livestock systems in Europe: a review. *Grass and Forage Science* 69, 206-228.