Plant species diversity and productivity in grazed permanent grasslands

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Abstract

Within the higher rainfall areas across southern Australia livestock producers are aiming to optimise the productivity of their enterprises and to satisfy the multiple goals of enhancing economic, environmental and social capital. Biodiversity has become a particular interest due to concern about minimising species loss, to maintain species rich grasslands, and also to optimise production. Within the Sustainable Grazing Systems Key Program (SGS) National Experiment a major theme addressed the impact of management on biodiversity *i.e*. on how the grassland ecosystems were functioning. This paper outlines the relationship between plant species biodiversity and grassland productivity. Across seven of the SGS sites more than 200 plant species were found, with about one-third being native. Individual small plot treatments had 10-40 species. Nearly half of the species found were non-leguminous broadleaves and about one third were grasses (approximately half annuals and half perennials). The more northerly sites had more species than those in Victoria or WA and there were more C4 grasses at northern sites *e.g*. Manilla and Carcoar in NSW. Within sites there was either no clear association between annual pasture production and species richness or a trend for the treatments with the most species to also be the less productive. The more productive treatments had more species present than are typically sown in mixtures. It is suggested that pasture mixtures could be redesigned to include more desirable broadleaf species, in part to minimise weed invasion.

Key words

grasslands, biodiversity, plant species, productivity, mixtures, pasture growth

Introduction

Grasslands are complex ecosystems upon which livestock production depends. Across southern Australia, the permanent grasslands, sown or naturalised, support over half of the total national meat and wool production (unpublished analysis of Australian Bureau of Statistics data). The history of many of these grasslands is complex, as they have been shaped by many influences over the last two hundred years. One common element, however, is that they comprise a wide range of species – often including both native and exotic plants. This also applies to recently sown pastures where volunteer species always occur and where after a few years, the species initially sown become a reduced fraction of the biomass. The impact of this diversity of species on productivity has received little study in Australian grasslands to date.

Ecological studies in grasslands elsewhere have suggested that productivity increases with species richness (*i.e*. the number of species), at least up to a certain point (2,7)(Grime, 1973; Nichols et al., 1993). This point would be well in excess of the number of species typically sown in a pasture. Mixtures may include a range of cultivars within a species, but in this context those cultivars only represent a fraction of the variation that would exist within a species occurring naturally and hence cannot cover the range in adaptation and resource use (niche width) that several species would.

The Sustainable Grazing Systems Key Program (SGS) National Experiment (5) provided an opportunity to evaluate the relationship between the total diversity of plant species and the productivity of a wide

range of grasslands under a range of management treatments across southern Australia. This paper reports on the general results from those studies and the implications for management.

Methods

Within the SGS program there were 12 sites within the National Experiment, each varying in complexity, aims and methodology. A standard protocol was used to record the total plant species present every autumn and spring (5). At 7 sites, regular estimates were made of the standing herbage mass and of net herbage growth rates using cages and these data are reported here.

Results

Species present

Across the SGS sites 210 plant species were identified, 73 of which were native (Table 1). Grazed grasslands present a particular taxonomic challenge since the livestock more-or-less continuously destroy plant structures that may be key diagnostic features. As a consequence it was necessary to treat some groups of species as a single taxon. A number of genera, including *Austrodanthonia*[1], *Austrostipa*, *Bothriochloa* and *Vulpia*, were therefore treated as single taxa where necessary for further analysis. For clarity, this paper will continue to refer to 'species' rather than the more strictly correct 'taxa.

Nearly half of the species found were broadleaf species, apart from legumes. These species include some well-recognised weeds *e.g*. thistles, and a range of minor species that collectively made a moderate contribution to the total biomass. The second most common group were perennial grasses, followed by annual grasses – temperate C3 species were especially important in both groups. While some sites had approximately 100 species, others had 20-50 species present. Species number often increased with the size of the treatment paddock sampled.

Table 1. The number of species identified within the major species groups found at the seven SGS sites where data was available on net herbage growth rates. Both sown and volunteer species are included. Total species across all sites applies to all 12 SGS sites. Key: An – annuals; Pr - perennial species; na – data not available for Yass where all non-legume broadleaf species were recorded as one species.

Species group	Origin	Barraba	Manilla	Carcoar	Yass	Wagga	Vasey	Albany	Total
An grass C3	native				1				1
	exotic	3	6	11	7	9	10	6	25
An grass C4	native	1	2	1	1	1			2
	exotic		2	2		1			4
Pr grass C3	native	3	6	6	5	5	2		17
	exotic			8	2	1	5		11

Pr grass C4	native	6	6	3		3			10
	exotic	1	2	1		4		1	6
An legume	native								0
	exotic	6	6	11	2	7	7	4	16
Pr legume	native			1					1
	exotic			1			2		3
An broadleaf	native	4	5	6		2			11
	exotic	16	14	25	na	7	9	5	49
Pr broadleaf	native	11	13	5			3		17
	exotic	6	8	12	na	5	3	3	19
Other monocots	native			5	3	1	1		13
	exotic	1	2	1		2	1	1	4
Total species	native	25	33	27	10	12	7	0	73
	exotic	33	40	70	11	37	37	20	137

Species diversity and productivity

Within each site there were variable relationships between species richness and mean net annual pasture growth (Figure 1). At some sites no relationship was evident. Where trends were evident within sites, the treatments with the most plant species were among the least productive. The reverse was not found. These trends were strongest at Albany and Carcoar. In the later case the more productive treatment was sown to chicory and this species dominated the growth of that treatment – if left out of the analysis then a more significant trend was found. At Vasey the trend was driven by one treatment and hence should be treated with caution. At Barraba and Manilla there was only one treatment available with growth data. In these cases productivity was overall, relatively low. The two points for Wagga compare a fertilised phalaris catchment with unfertilised naturalised grassland (more diverse). In general, the more diverse grasslands were unfertilised and were managed to maintain herbage mass > 2 tonnes of dry matter per hectare (t DM $ha^{-1)}$ throughout the study. There was some evidence that, on treatments with higher average levels of herbage mass (~3-4 t DM ha^{-1}), there was some loss of minor broadleaf species. This occurred at Carcoar and Albany (data not shown).

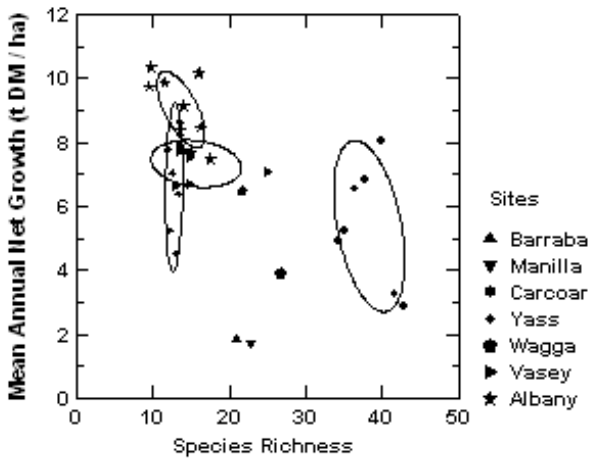

Figure 1: The relationship between species richness and mean annual net growth of grasslands for seven SGS experiments. Data are means for each treatment over 3-4 year periods. The 95% confidence ellipses are centred on the sample means of the x and y variables. The unbiased sample standard deviations of x and y determine its major axes and the correlation between x and y determine its orientation.

Discussion

The SGS sites have all demonstrated that permanent grasslands across southern Australia are more diverse than is often considered. At Albany, the kikuyu grasslands are often considered to be relatively simple in structure, yet they still contained > 10 species in every treatment and 20 species across that site. The naturalised grasslands of central NSW at Carcoar were structurally the most complex (~100 species). In general, the more northerly sites (Barraba, Manilla and Carcoar) were more diverse than those in Victoria and WA. The number of species found is probably a conservative estimate of what were actually present for the reasons discussed earlier and because additional species will be present in the seedbank that did not appear in above-ground samples (King *et al.* unpublished data). Moreover, the species recorded are from routine sampling only and species that occurred in the paddock, but by chance were not present in a sampled quadrat, will have been omitted. It is therefore, almost certain that the total number of species in permanent grasslands across southern Australia considerably exceeds the figures presented here.

All treatments studied had > 10 species. As the area surveyed increased species number also increased. The trend for less productive treatments at some sites to have more plant species has not previously been recorded in Australian pastures. The reverse condition was not evident at any site – with the possibly exception of chicory at Carcoar, which has some implications about functional groups as discussed below. The less productive treatments were often unfertilised. When fertiliser is applied to these grassland ecosystems, those species with a higher production potential then, arguably, become more competitive and this results in the loss of some species, typically minor exotic broadleaves (data not presented here).

Many of the small paddocks studied in SGS had > 20 plant species. This applied even in the sown paddocks – even though mixtures of only 2-3 species were originally sown. This suggests that there are niches available in sown paddocks that the sown species are unable to exploit. Often weed invasion occurs within sown pastures. This suggests the typical mixtures sown in grasslands are inadequate at exploiting all the available resources and maybe we should redesign the types of mixtures sown. In the 19th Century in the UK, ‘meadow’ mixtures typically contained a much wider range of species from more functional groups than the grasses and legumes sown today (3). This practice has declined however, as the emphasis shifted towards correcting nutrient deficiencies and the selection of more productive, persistent grasses and legumes. At present, chicory is the only non-legume broadleaf species commonly

recommended. It can be a very productive species (6) and is apparently able to exploit resources and obtain nutrients more successfully than many other species. At Carcoar the chicory plots were often more productive than adjacent paddocks, sown to phalaris and cocksfoot. The only two non-grass species common to all SGS sites were subterranean clover and cat's ear (*Hypochaeris radicata* – see also 1). We know little about the ecology and function of the latter species and what role it performs in pastures, though it is highly palatable to livestock. The deliberate inclusion of a wider mix of species in sown pastures may prevent, or at least reduce, the rate of invasion by weedy species.

The stability of a grassland (its composition and production through time) will depend upon maintaining a mixture of the most desirable species. The SGS experiment has shown that many management treatments did result in stable productive mixtures (see SGS Special Issue of Aust. J. Exp. Agric. in 2003). The treatments that maintained an annual average herbage mass greater than 2 t DM ha^{-1} (5) tended to retain a desirable mixture of species (including natives). This lower limit for grazing management should be considered in recommendations for producers. Further work is needed though, to refine this limit for a range of grassland and enterprise types.

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[1] *nomenclature follows (4) except for Austrostipa* and *Austrodanthonia* (8).