Benefits of small-seeded annual pasture legumes in pasture mixtures for variable environments

Richard Hayes, Brian Dear, Bev Orchard and Phil Eberbach

E. H. Graham Centre for Agricultural Innovation (an alliance between NSW Department of Primary Industries and Charles Sturt University) Pine Gully Rd, Wagga Wagga, NSW 2650, Australia. Email: richard.hayes@dpi.nsw.gov.au

Abstract

Balansa clover (*Trifolium michelianum*) and gland clover (*Trifolium glanduliferum*) are both small-seeded annual pasture legumes adapted to environments where periodic waterlogging limits production. The objective of this study was to evaluate their performance when grown on an acid soil in the absence of waterlogging and in mixtures with subterranean clover (*Trifolium subterraneum*), a species considered generally well adapted to acid soils. Their performance was also assessed when established in mixtures with one of 3 perennial pasture species, and with and without the application of lime. The major finding from this study was that under drier than average seasonal conditions, the small-seeded species, particularly balansa clover, were able to set more seed in the establishment year than subterranean clover. Although seed yields of both balansa clover and gland clover were more responsive than subterranean clover to the application of lime, both the small-seeded species were more prolific than subterranean clover in terms of seed production in both the limed and unlimed treatments. Implications of this finding in terms of revised recommendations for pasture mixtures are discussed.

Key Words

Diversity, soil pH, seed size, chicory, lucerne, phalaris

Introduction

The impacts of increased species diversity on pasture swards are varied. Highly diverse pastures have been shown to be beneficial in the context of production agriculture through reducing weed invasion and increasing biomass stability (Tilman 1996; Tracey *et al.* 2004). However, increased diversity does not always translate into production increases (Sanderson *et al.* 2004) and often involves more complex management regimes. Despite the intricacies of population dynamics theory, in practice complex pasture mixtures, whilst widely advocated in Australian agriculture, have been shown to be largely ineffective in increasing the long-term robustness of pasture swards. It is common for commercial swards to diminish to only 1-3 sown species within a very short period and to incur a high level of weed invasion (Bowcher 2002; Virgona and Hildebrand 2007).

Subterranean clover and annual medics (*Medicago* spp.) have traditionally been the most widely used annual legume species in pasture swards across southern Australia, but during the past two decades research has emphasised the need to identify and develop alternative annual legume species (Nichols *et al.* 2007). This research was driven in part by the desire to increase the diversity of species with a view to more stable biomass production, but there were also other important objectives: improved availability of annual legumes suitable to problematic soils, increased levels of 'hard' seed for better adaptation to drier environments, reduced reliance on vacuum seed harvesting in seed production systems, reduced annual legume seed production costs, and increased diversity in seasonal growth patterns of annual legumes.

Whilst the newer annual legume species and cultivars offer exciting opportunities to extend and develop conventional farming systems (Nichols *et al.* 2007), it is highly improbable that they can fully replace the more traditional species which are supremely adapted to local environments and management practices. It is likely that they will instead complement the traditional species to maximise production and increase the versatility of conventional systems. This will mean they will either be used as specialty forages on a small portion of farms, or they will be used in mixtures with traditional species to maximise the productivity and resilience of pasture swards. The objective of the current study was to evaluate the performance of two alternative annual legume species, balansa clover and gland clover, when grown in mixtures with subterranean clover and several perennial pasture species on an acidic soil.

Methods

Experimental design

A field experiment was sown in May 2002 on an acid soil (pH 4.3; 1:5 soil/0.01M $CaCl_2$, 15% Al at 0 – 10 cm) near Gerogery, in southern NSW. The experiment was a randomised split-plot design with 4 replicates. Mainplot treatments were 4 pasture sward treatments, consisting of 3 perennial species/annual legume mixes and an annual legume only mix. Subplot treatments (plots) were nil or 2.9 t/ha of incorporated lime. A mixture of the following annual legume species was sown to every plot: 2.5 kg/ha each of subterranean clover cvv. Goulburn and Riverina, 0.5 kg/ha balansa clover cv. Paradana, 0.5 kg/ha gland clover cv. Prima and 1.5 kg/ha burr medic (*Medicago polymorpha* L) cv. Santiago. Perennial species were either 5 kg/ha lucerne (*Medicago sativa* L.) cv. Aurora, 4 kg/ha chicory (*Cichorium intybus* L.) cv. Grouse, or 4 kg/ha phalaris (*Phalaris aquatica* L.) cvv. Holdfast and Landmaster. Seed of each legume species was inoculated with rhizobia using the appropriate commercial inoculant and lime pelleted before being included in the various seed mixes for sowing. Plot size was 6 x 4 m.

Management and seed harvest

Lime was applied to half of each mainplot and incorporated to approximately 8 cm one month prior to sowing. Plots were sown on 16 May 2002 using a cone seeder, at which time 150 kg/ha starter fertiliser (15% N, 13% P, 10% S) was applied to all treatments. All treatments were sprayed with 100 ml/ha bifenthrin (100g a.i./L) immediately following sowing as a preventative measure against insect damage, which was followed up with a second application of insecticide one month later, of 200 ml/ha methidathion (400g a.i./L). The selective grass herbicide clethodim (240g a.i./L), was applied to all treatments except phalaris at 400 ml/ha on 20 June to control emerging grass weeds such as annual ryegrass (*Lolium rigidum* Gaudin) and pyridate (450 g a.i./L) was applied at 1L/ha to all except the chicory plots on 2 July to control emerging broadleaf weeds, especially capeweed (*Arctotheca calendula* L.). Plots were not grazed in the establishment year.

The experiment was mown on 14 November 2002 after annual legume species had senesced, ensuring material was not removed from plots. Annual legume seed reserves on each plot were measured on 3 December 2002 by excavating 2 strips, each 2 m long x 0.1 m wide x 0.02 m deep. Seed and burr were separated from soil by washing samples in a fine sieve. The samples were threshed and seed of each species separated by sieving. The seeds of balansa and gland clovers and of Riverina (white seed) and black-seeded subterranean clover were separated by hand on the basis of seed colour. The low levels of background subterranean clover, predominantly cv. Junee, could not be distinguished from the sown cv. Goulburn on the basis of seed colour, therefore black-seeded subterranean clover is referred to as ‘other’ subterranean clover.

Seasonal conditions

Seasonal conditions during the establishment year were considerably drier than average, particularly during the typically reliable months of winter and spring (Fig. 1). Total rainfall received at a nearby weather station during 2002 was 347 mm, 45% below the long term average of 630 mm for that site (Bureau of Meteorology pers. comms).

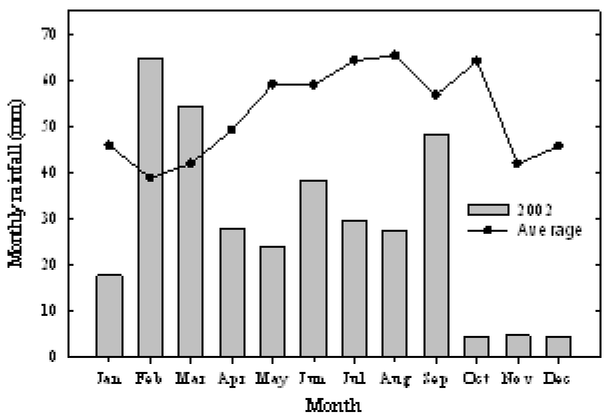

Figure 1. Monthly rainfall (mm) received at Gerogery during the establishment year compared to the long-term average monthly rainfall.

Results

Balansa clover comprised the highest proportion of the annual legume seed bank in the establishment year, both in terms of seed weight and number of seeds set (Fig. 2). However, in contrast to subterranean clover, the percentage of balansa clover was lower in the phalaris plots relative to other swards. The proportion of gland clover in the annual legume seed bank increased with lime whereas the proportion of balansa and subterranean clovers were stable or declined. The highest proportion of subterranean clover in the annual legume seed reserves was in lucerne swards in the absence of lime. The proportion of burr medic was less than 5% in all swards (data not presented).

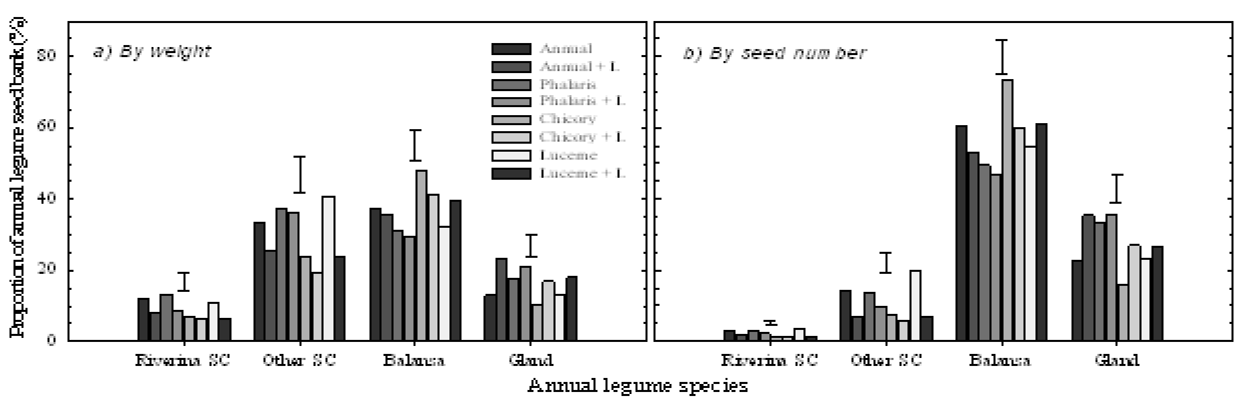

Figure 2. The proportion of balansa clover, gland clover, Riverina subterranean clover (SC) and 'other' subterranean clover (cv. Goulburn plus background) in the annual legume seed bank at the end of the establishment year of annual-, phalaris-, chicory- and lucerne-based pasture swards grown with and without the addition of lime (L) on an acid soil.

Balansa clover was the most prolific of the annual legume species, with increases in seed reserves of more than 100-fold in the establishment year where lime had been applied, compared to the quantity originally sown (Table 1). By contrast subterranean clover only increased by about 5-fold. Seed yields of balansa clover and gland clover were both increased where lime was applied whereas subterranean clover was unresponsive. Annual legume seed size, in terms of seed mass, was not affected by the addition of lime.

Table 1. Initial sowing rate, seed mass, seed harvest at the end of the establishment year and ratio of seed at sowing compared to seed at harvest of 3 annual legume species grown in mixtures with and without lime (L).

Within columns, values followed by the same letter are not significantly different at *P* = 0.05.

Legume	Seed by weight (kg/ha)			Seed by number (/ha)[1]		
	Quantity sown (kg/ha)	Seed at end of year 1 (kg/ha)	Seed mass (mg)	Quantity sown (x 10^3)	Seed at end of year 1 (x 10^3)	Ratio (sowing : harvest)
Riverina SC	2.5	11.3 a	4.81 b	52	2 349	1:5
Riverina SC + L	2.5	11.2 a		52	2 328	1: 5
Balansa	0.5	40.2 b	0.67 a	746	60 000	1:80
Balansa + L	0.5	58.3 c		746	87 015	1:117
Gland	0.5	13.9 a	0.65 a	769	21 385	1:28
Gland + L	0.5	31.0 b		769	47 692	1:62

Discussion

The results of this study reflect the performance of the various pasture species under considerably drier than average seasonal conditions. However, under Australian farming systems where drought is common and rates of pasture establishment are relatively low, it is important that pastures can be successfully established even in dry years. For annual pastures, it is critically important that they be able to set a large quantity of seed in the establishment year as this will largely determine the productivity of the annual legume component in subsequent years of the pasture phase, which typically would last 3 years or longer.

The key finding of this study is the increased capacity of the small-seeded annual legume species, balansa clover and gland clover, to set seed under moisture stress compared with subterranean clover. Despite the fact that the small-seeded species were more sensitive to acid soil than subterranean clover, their seed production was more prolific even in the absence of lime. This study has demonstrated that these small-seeded species not only have a role in maximising pasture production in the niches to which they are adapted, such as waterlogged soils or (in the case of gland clover) where insect burdens are high (Dear *et al.* 2003; Nichols *et al.* 2007), but also in maximising sward productivity under drought conditions. There are implications of the differences observed in initial seed yields in this study for annual legume performance in subsequent years. Based on the seed yields observed in the establishment year, it is estimated that the biomass production of balansa clover 1-2 months after emergence in the first year of regeneration could be up to 20 fold greater than that of Riverina subterranean clover, based on estimated seedling populations and differences in the relative growth rates of the large and small-seeded species (Dear *et al.* 2006). Of course, this ignores relative differences in the levels of hard seed between the cultivars Paradana and Riverina (Dear *et al.* 1996; Craig *et al.* 1998); a characteristic that will vary with the individual cultivars used.

This study has also demonstrated that small-seeded annual legume species such as balansa clover and gland clover can be grown successfully in mixtures with other common pasture species such as subterranean clover. Their inclusion in pasture mixtures is likely to add only a minor expense to the sowing operation due to their small seed size and the requirement to sow only a very small quantity. To achieve an equivalent legume seedling biomass, it is estimated that the quantity of balansa clover seed required would be around one quarter that of a subterranean clover cultivar such as Goulburn (Dear *et al.* 2006). That is, a sowing rate of 4 kg/ha of Goulburn subterranean clover would produce equivalent amounts of annual legume biomass soon after emergence as 1 kg/ha of balansa clover. In a mixture with other annual legume species, even less seed of a small-seeded species would be required. The inclusion of several hundred grams of small-seeded annual legume seed per hectare adds almost a trivial amount of cost to pasture establishment and can therefore be seen as a very effective way for farmers to reduce the risk of failure at establishment due to drought, and is a technology that is already widely available for immediate adoption.

Complex pasture mixtures have been enthusiastically advocated in Australia for many years but until now the weight of evidence suggests that this enthusiasm is barely justified due to the low densities of many of the components of complex mixes present in paddocks several years after establishment (Bowcher 2002; Virgona and Hildebrand 2007). The persistence of alternative annual legume species in mixtures has been shown to be less than that of subterranean clover, perhaps due to management (Dear *et al.* 2002). The current study demonstrates that the inclusion of small-seeded species with the capacity to set large quantities of seed can increase the resilience of pasture swards to stresses such as drought provided they are managed appropriately. More work is required to understand the agronomy of these species, to better enable Australian production systems to exploit the benefits offered by more diverse pasture mixtures.

References

Bowcher AJ (2002) Competition between temperate perennial pasture species and annual weeds: the effect of pasture management on population dynamics and resource use. PhD thesis, School of Agriculture, Charles Sturt University, Wagga Wagga.

Craig AD, Sandral GA, Latta RA, Evans PM, Dear BS, Hill NL (1998) Early flowering balansa clovers for the cereal livestock zone. In 'Proceedings of the 9th Australian Agronomy Conference 1998 '. (The Australian Society of Agronomy: Wagga Wagga).

Dear BS, Hodge A, Lemerle D, Pratley JE, Orchard BA, Kaiser AG (2006) Influence of forage legume species, seeding rate and seed size on competitiveness with annual ryegrass (*Lolium rigidum*) seedlings. *Australian Journal of Experimental Agriculture* **46**, 627-636.

Dear BS, Nichols PGH, Clark SG, de Koning CT, Orr RJ (1996) Register of Australian Herbage Plant Cultivars B. Legumes 1. Clover (*d*) *Trifolium subterraneum* L. var. *yanninicum* (Katz et Morley) Zohary and Heller (subterranean clover) cv. Riverina. *Australian Journal of Experimental Agriculture* **36**, 519-520.

Dear BS, Sandral GA, Peoples MB, Wilson BCD, Taylor JN, Rodham CA (2003) Growth, seed set and nitrogen fixation of 28 annual legume species on 3 Vertosol soils in southern New South Wales. *Australian Journal of Experimental Agriculture* **43**, 1101-1115.

Dear BS, Wilson BCD, Rodham CA, McCaskie P, Sandral GA (2002) Productivity and persistence of *Trifolium hirtum*, *T. michelianum*, *T. glanduliferum* and *Ornithopus sativus* sown as monocultures or in mixtures with *T. subterraneum* in the south-eastern Australian wheat belt. *Australian Journal of Experimental Agriculture* **42**, 549-556.

Nichols PGH, Loi A, Nutt BJ*, et al.* (2007) New annual and short-lived perennial pasture legumes for Australian agriculture - 15 years of revolution. *Field Crops Research* **104**, 10-23.

Sanderson MA, Skinner RH, Barker DJ, Edwards GR, Tracey BF, Wedin DA (2004) Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Science* **44**, 1132-1144.

Tilman D (1996) Biodiversity: Population versus ecosystem stability. *Ecology* **77**, 350-363.

Tracey BF, Renne IJ, Gerrish J, Sanderson MA (2004) Effects of plant diversity on invasion of weed species in experimental pasture communities. *Basic and Applied Ecology* **5**, 543-550.

Virgona J, Hildebrand S (2007) Biodiversity and sown pastures: what you sow is not what you get. In '"From the Ground Up", Proceedings of the 48th Annual Conference of the Grassland Society of Southern Australia'. Murray Bridge, South Australia pp. 33-39.

[1] **Calculated from weight of seed harvested and average seed mass of each annual species**