Potential use of new generation annual pasture legumes in crop-pasture rotations in central and southern NSW

Belinda Hackney[1,2], Craig Rodham[2,3] and John Piltz[2,3]

[1] NSW Department of Primary Industries, Research Station Drive, Bathurst, NSW 2795 Email belinda.hackney@dpi.nsw.gov.au
[2] EH Graham Centre for Agricultural Innovation, Wagga Wagga, NSW 2650
[3] NSW Department of Primary Industries, PMB, Wagga Wagga, NSW 2650
Add in EH Graham Centre

Abstract
Biserrula (*Biserrula pelecinus*), French serradella (*Ornithopus sativus*), bladder clover (*Trifolium spumosum*) and subterranean clover (*T. subterraneum*) were evaluated under different methods of pasture establishment for subsequent use in self-sustaining crop-pasture rotations. Cover cropping, the most common method of pasture establishment used in NSW resulted in significant reduction in seed yield of biserrula, French serradella and bladder clover compared to stand-alone sowing. Subterranean clover seed yield was significantly lower than biserrula and bladder clover in the stand alone sowing treatment, and well below the level required for reliable regeneration. Cover cropping significantly reduced seed size of all legumes except French serradella compared to seed size in the stand alone treatments. Herbage production from legumes regenerating from the cover crop treatments was significantly lower than that achieved from the twin sowing treatments. Compared to sowing at normal time (late autumn), regeneration of legumes from cover cropping and twin sowing produced significantly more herbage over the autumn-winter period for all species except subterranean clover. Biserrula, French serradella and bladder clover were successful in surviving summer germination in the regenerating year. Seedling loss in traditional pasture legumes such as subterranean clover can be very high due to its shallow root system. The ability of recently developed annual legumes to survive what would traditionally be considered false breaks offer the potential to increase rotation flexibility compared to traditional phase farming systems. These legumes can also provide higher levels of herbage production over autumn and winter, a common time of feed shortage in animal production systems of southern Australia.

Keywords: biserrula, French serradella, bladder clover, twin sowing, cover cropping, crop-pasture rotations

Introduction

Pastures have traditionally been used as a four to six year phase in a cropping rotation in NSW (Dear et al. 2010). Such pastures have typically been based on subterranean clover with addition of perennial grasses. Lucerne has also been used in this role either alone or in combination with subterranean clover and/or perennial grasses (Dear et al 2010). The incorporation of a pasture phase in the cropping rotation should, in theory, allow a build up in soil nitrogen for the following crop phase via nitrogen fixation by legumes while providing high quality feed for grazing livestock. Under low and erratic rainfall conditions such as those experienced in the past decade, this type of crop-pasture rotation system, particularly those based on subterranean clover have performed poorly (Hackney et al. 2009). Subterranean clover is a shallow rooted species and as such can fail to persist in crop-pasture rotations of this type due to moisture stress adversely affecting seed production and thus ability to regenerate (Hackney et al. 2009). It is also susceptible to seed bank depletion via false breaks in late summer and autumn (Nichols et al. 2007). Cover cropping – the practice of sowing pasture under a light rate of cereal in the final year of the cropping phase has been used as a mechanism to recoup some of the costs associated with pasture sowing. Scott and Keys (2007) estimated cost of sowing a perennial grass-annual legume pasture at $230/ha with 12 years required to recoup the cost. Should liming be required, which it often is in the acidic soils of southern NSW (Scott et al. 2000), then an additional $180/ha could be added to the cost with an additional five years required to recoup the cost. A survey by Hackney et al. (2009) of 208 farmers found that 80% used cover cropping as a means to establish pastures with only 30% considering it to be highly successful. Stress imposed by the cover crop for light, but perhaps more importantly moisture, can severely affect productivity and persistence of pasture sown with a cover crop (Cregan 1987). Thus the combination of a relatively inflexible rotation system, species used in the rotation and establishment method have the capacity to severely reduce pasture production, animal production from pastures, nitrogen fixation and performance of following crops.

In the past two decades a wide range of new annual legume pasture species have been developed for use in Australian agriculture (Nichols et al. 2007). While these legumes have agronomic characteristics such as deeper root systems and/or higher levels of hard seed and have performed well in small scale field trials, they

have not been used widely in farming systems of southern Australia. Hackney et al. (2008) surveyed 300 farmers in central and southern NSW and attributed lack of use of new legumes to lack of readily available information on the growth and management of these new species. Despite lack of use, Hackney et al. (2008) found that farmers were keen to incorporate new annual legumes into their farming systems either as part of self-sustaining crop-pasture rotation system or for fodder conservation purposes. Given the hard seed attributes of some of the recently developed annual pasture legumes, alternative establishment techniques such as twin sowing (Loi et al. 2008) can be used to establish pasture. Loi et al. (2008) has described the process of twin sowing. Briefly, twin sowing is the practice of sowing unscarified or in-pod legume seed in combination with a crop. Unlike cover cropping, there is minimal germination of the legume seed in the sowing year due to very high hard seed content and the sowing year is essentially a seed softening year for the legume. This effectively removes competition experienced in cover cropping, and thus there is no requirement to reduce the crop sowing rate. Effectively, twin sowing still provides a means to reduce pasture establishment costs while still providing a one-pass crop-pasture sowing technique.
Further, once a seed bank of legume species with higher levels of hard seed is established, crop-pasture rotation systems can be implemented which allow crops to utilise nitrogen fixed by the legumes and have legumes regenerate following the cropping phase without the need for resowing (Loi et al. 2008). This paper reports the results of an experiment evaluating:

1. The effect of stand alone and cover cropping methods of pasture establishment on seed yield and seed size and
2. The herbage production achieved from cover cropped and twin-sown pasture establishment methods in the regenerating year compared to fresh sown stand alone sowings

Methods

The experiment was located at Greenethorpe, NSW (34^{o}02'S, 148^{o}23'E) on a red chromosol soil with a pH_{CaCl2} of 5.0. Prior to the commencement of the experiment, the site had been cropped with wheat for the previous two years. Three annual legumes, bladder clover cv. Bartolo, biserrula cv. Casbah and French serradella cv. Margurita were sown, either alone as scarified seed at, 6, 7 and 10 kg/ha respectively either alone (stand-alone) or under a wheat cover crop (wheat sown at 15 kg/ha). These legumes were also sown in unscarified form (bladder and biserrula) or in-pod (serradella) at 15, 15 and 30 kg/ha respectively for bladder clover, biserrula and French serradella in combination with wheat sown at 60 kg/ha (twin sowing treatments). Subterranean clover cv. Seaton Park was used as a control, sown either alone or in cover crop treatment at 10 kg/ha. Subterranean clover was not included in the twin sowing treatment as subterranean clover seed undergoes considerable scarification in the harvest process and therefore a truly 'unscarified' treatment would not be commercially possible. Individual plots measured 4 m wide by 6 m long and were replicated three times. All treatments were sown with starter fertiliser (6.7% N, 13.9 % P, 8.6 % S) at 140 kg/ha on 18 May 2009. Seed was harvested from two 50 x 50 cm quadrats on 15 December 2009. Both seed yield and individual seed weight were determined following harvest. Annual legume herbage production from the cover crop and twin sowing 2009 treatments was assessed in early spring (8 September 2010) by cutting two 50 x 50 cm quadrats in each plot to a height of 1 cm and drying at 80^{o}C for 48 hours. All plots reported here were part of a larger crop-pasture rotation experiment which examined different methods of establishing crop-pasture rotations with rotations commencing in both 2009 and 2010. Plots sown to stand-alone annual legumes were cropped in 2010 as were half of the cover crop plots. The herbage production of 2009 regenerating cover crop and twin sowing plots was compared to fresh sown 2010 stand alone annual legume plots (sowing date 28 May 2010) which formed a component of the 2010 rotation commencement plots.
Data was analysed using REML (Genstat Version 14) with sowing method as a fixed effect and species as a random effect

Results

Seed yield of all species was significantly lower under cover cropping than where scarified seed was sown as a stand alone pasture except for subterranean clover (Figure 1a). Subterranean clover seed production was significantly lower than biserrula and bladder clover when sown as a stand alone pasture (Figure 1a). Seed yield was insignificant on all twin sowing treatments as would be expected as hard seed levels of unscarified or in-pod seed was very high and the initial year of sowing is used to break down hard seed for germination in the following year.
The size of individual seed was significantly reduced in cover crop treatments compared to stand alone treatments for all species except French serradella (Figure 1b).

In the year following sowing, herbage production in twin sown biserrula and French serradella treatments was significantly higher than from the treatments sown using a cover crop in the establishment year (Figure 1c). Herbage production of subterranean clover regenerating following establishment using a cover crop was significantly lower than for all other species established either using twin sowing or cover cropping (Figure 1c). In all cases except for subterranean clover, herbage production from regenerating stands established using twin sowing or cover cropping was higher than herbage production from stands established as stand alone in the autumn of 2010.

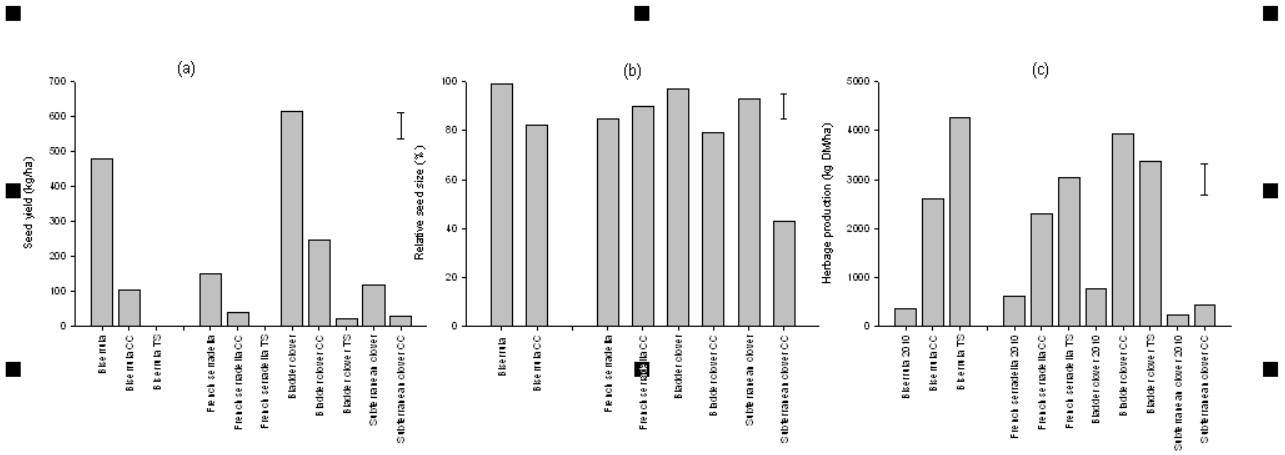

Figure 1. (a) Seed yield (kg/ha), (b) relative seed size of regenerating and freshly sown annual legumes, , and (c) herbage production (kg DM/ha) of regenerating and freshly sown biserrula, French serradella, bladder clover and subterranaean clover when sown alone, under a cereal cover crop (CC) or as a twin sowing (TS).

Discussion

Previous authors (e.g. Dear 1989) have reported decreases in subterranean clover seed yield under cover crops. At the cereal rate used in this experiment (15 kg/ha) Dear (1989) reported clover seed yields of 325 and 450 kg/ha at legume sowing rate of 3 and 7.5 kg/ha respectively, while when sown without a cover crop the seed yield was in excess of 500 kg/ha at both legume sowing rates. The seed yields achieved in this current experiment are considerably less than those reported by Dear (1989) for all legumes sown under a cover crop and for subterranean clover and serradella when sown as a stand alone pasture. Dear et al. (2008) suggested for strongly regenerating subterranean clover based pastures, a legume seedbank of 150 kg/ha should be targeted. Given this benchmark, cover cropping reduced seed production of all legumes except bladder clover below this suggested threshold. Attaining adequate plant density in pastures regenerating following cover crop establishment is likely to be compromised due to lack of seed reserves. The low and erratic spring rainfall in 2009 (92 mm) experienced at this site may have reduced seed yield compared to those achieved by Dear (1989).

The effect of low seed production on early season herbage production in the following year where cover cropping was the method of establishment is clearly shown in subterranean clover. In the regenerating year, subterranean clover established using cover cropping produced significantly less herbage than all other cover crop and twin sown treatments. Interestingly, while seed yield of biserrula, French serradella and bladder clover was reduced significantly by cover cropping, all these legumes produced in excess of 2t DM/ha over the autumn winter period in the regenerating year. All of these legumes are considerably smaller seeded (that is, more seeds per kilogram) than subterranean clover (Lattimore et al. 2010) so higher seed number may have compensated for some loss of yield in these treatments.

Regeneration from twin sowing resulted in significantly higher herbage production compared to cover cropping for both biserrula and French serradella. It is possible in the case of biserrula, that the significant reduction in seed size experienced under cover cropping may have negatively impacted on seed viability and plant vigour. Black (1957) showed in subterranean clover that seed size was directly related to early vegetative growth and it is not unreasonable to expect that this would apply to other species. The decrease in individual seed size of all species except French serradella is probably due to high competition for moisture between the cover crop and pasture legume. Andrews et al. (1977) demonstrated seed yield losses of up to

80% in subterranean clover when moisture stress was imposed over flowering and significant decreases in seed size. The lack of difference in seed size of French serradella may be due to an overall low level of seed production in both the stand-alone and cover crop treatments.

All alternative legume species showed significant yield increases as regenerating stands either from cover crop or twin sowing establishment compared to freshly sown plots (and compared to regenerating subterranean clover). At this site in 2010, rainfall resulting in germination of annual legumes occurred in January 2010. Both biserrula and French serradella have significantly deeper root systems which develop rapidly compared to subterranean clover which can enable them to survive out of season rainfall which may result significant mortality of shallower rooted species such as subterranean clover (Nichols et al. 2007). The autumn-winter period is commonly a period of feed deficit in southern Australia (Allen and Bell 2006) The ability of biserrula, French serradella and bladder clover to capitalise on out of season rainfall and produce significant amounts of herbage at this time make them potentially very valuable to animal productivity in this period and worthy of inclusion in farming systems. These results indicate that there is potential to shift sowing time of new legumes to earlier than the traditional sowing time of late autumn as they have the capacity to survive after emerging on late summer-early autumn rainfall. Similarly, new technologies such as twin sowing which still allows for one pass crop-pasture sowing operation offers potential to establish a legume based pasture with less compromise in both crop performance and legume seed set as compared to traditional cover cropping systems. Certainly these results question the validity of cover cropping as a means of pasture establishment due to its effect on seed yield and seed size in the establishment year. However, the more recently developed annual legumes still managed to produce useful amounts of herbage in the autumn-winter period of the regenerating year after being established under cover-cropping, though there was a significant yield penalty for biserrula and French serradella compared to twin sowing.

The superior seed production and/or ability to regenerate and survive on summer-early autumn rainfall combined with their potential to increase crop-pasture rotation flexibility, indicate new annual legumes evaluated in this paper have significant potential in crop-pasture rotation systems of southern Australia

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