"On-demand" hardseeded pasture legumes – a paradigm shift in crop-pasture rotations for southern Australian mixed farming systems

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Abstract
This paper presents a synopsis on the past 10 years of hardseeded annual legume research and adoption. Failure of traditional legume species such as subterranean clover (*Trifolium subterraneum*) and annual medics (*Medicago* spp.) in the medium and low rainfall zones of NSW and WA necessitated the development of crop-pasture rotation systems underpinned by more resilient legume species. Such species had been developed and included biserrula (*Biserrula pelecinus*), bladder clover (*Trifolium spumosum*), gland clover (*T. glanduliferum*) and French serradella (*Ornithopus sativus* cvv. Margurita and Erica). However, their use in farming systems was limited by lack of information on how to manage them and perceived high cost of establishment. The ability to harvest seed on farm using conventional headers and the unique hard seed characteristics of the new legumes resulted in development of the low-cost, one-time establishment options of twin and summer sowing. Robust rhizobia delivery technology was developed concurrently. Following establishment of the seedbank, new legumes can be used as an on-demand break option in the crop-pasture rotation as they, unlike traditional pasture legumes, do not need to be resown following each cropping phase. Additionally, legume species/varieties have significant potential for sustaining high levels of livestock production. Biserrula also has considerable potential in offering alternative control methods for the problematic cropping weed, annual ryegrass (Lolium rigidum).

Key words
Crop-pasture rotation, hardseeded legumes

Introduction

Southern Australian crop-pasture rotation systems have traditionally relied upon the annual legumes subterranean clover, annual medics, and where soil conditions allow, the perennial legume lucerne (*Medicago sativa*). Such pasture species have and are being used in ley and phase farming systems and require resowing at costs in excess of $200/ha. Unreliable climatic conditions, particularly false breaks and dry spring conditions, have resulted in decline in seedbank populations of annual legumes in regenerating pastures and often failure of newly sown species (Hackney et al. 2008). Lack of reliability in performance of traditional pasture species has reduced break options in cropping rotations. At the same time cropping input costs, particularly nitrogen fertiliser, have increased. Further, increased herbicide resistance in common cropping weeds are challenges facing Australian cropping systems (Powles and Yu 2010).

Howieson et al. (2000) reported on the development of a range of new species/varieties of hardseeded legumes including biserrula, bladder clover, gland clover and hardseeded species of French serradella. In small plot studies, these species/varieties had exhibited increased drought tolerance and widespread adaptation to southern Australian farming systems. In contrast to subterranean clover and annual medics, new species/varieties have the capacity for seed to be harvested relatively cheaply using conventional cereal headers. However, widespread consultation with industry in NSW (n=300) by Hackney et al. (2008) revealed little uptake of new species/varieties by farmers (<5%). Lack of reliable extension material on how to incorporate and manage them in farming systems cited by 79% of farmers as restricting uptake of new species/variety. While cautious on utilising new species/varieties in rotations, only 35% of farmers considered subterranean clover and lucerne to be highly successful in meeting their overall production goals. Farmers identified main areas of importance in future research be associated with development of new crop-

pasture rotation systems (particularly for the purpose of reducing fertiliser N reliance) and use of legumes for strategic on-off uses such as fodder conservation (36% and 42% respectively). Similar results were found by the authors in consultation with Western Australian farming groups, where in a 2004 survey, 24-47% of farmers cited establishment costs as a disincentive for sowing pastures in general. With respect to consultant, the same survey reported 53% required development of extension packages prior to recommending the use of new legume species and 26% requested educational courses specifically for consultants to develop skills in use of new annual legume species in farming systems (Hogg and Davis 2009).

As a result of this industry consultation, the authors commenced research, development and extension activities (RD&E) to deliver new low cost establishment systems for the introduction of new legumes into crop-pasture rotation systems. A key component of this program was the involvement of farmers in the initiation and development of new system technology. The remainder of this paper will discuss briefly the processes in development of new rotation crop-pasture rotation systems where pastures regenerate without the need for resowing following the cropping phase. Their potential implications for crop production, livestock production and weed management are also discussed.

Materials and Methods

Initial industry consultation in NSW and WA (Hackney et al. 2008, Hogg and Davis 2009) identified 'champion' farmers who were keenly interested in working collaboratively with the research team. This involved 3-4 farmers per region. In NSW, target research regions were the central-west and south-west slopes-Riverina and in WA the central wheatbelt and south coast. At each farm site, replicated small plot studies were established. Participating farmers were supplied with seed of one or more species to sow in 5-10 ha larger scale areas. Farmers and associated farmer groups were encouraged to undertake 'experiments' within these sown areas to test the suitability of new species/varieties in a commercial industry setting.

One of the first studies implemented in WA and NSW evaluated "twin sowing". This practice involves a late-autumn sowing with the last year of the crop rotation of unscarified or in-pod hard seed of the legumes together with the use of a rhizobial inoculant capable of colonising the soil in the absence of the host. The legume hard seed breaks down (the seed coat becomes permeable) over 12 months and emerges with the first rains in the following autumn. The legume doesn't germinate under the crop therefore a reduction in the sowing rate of the final crop is not required. This system removes competition between the crop and the pasture, which is in contrast to cover cropping that requires significant reduction in the sowing rate of the crop, sometimes by more than 50% and associated opportunity cost of reduced yield. In NSW, twin sowing and conventional sowing were compared to cover cropping – the most common method of pasture establishment used by 80% of farmers in NSW (Hackney et al. 2012). The second stage of experiments involved investigation of the use of "summer sowing" compared to conventional autumn sowing of scarified seed. As for twin sowing, summer sowing utilises unscarified (or in-pod) seed sown in February and relies on the ensuing high summer temperatures to break down this hard seed allowing for emergence on the opening autumn rain. Summer sowing requires a long-life rhizobial inoculant with the capacity to withstand soil temperatures of above 50°C at the time of sowing.

In both of the first and second stage experiments and at many of the producer-sown sites, the yield and quality of crops following the legumes were assessed and compared to the 'control' (traditional) system. Hard seed breakdown was also studied as it is critical in determining how many crops can be sown over the legumes once a seedbank had been established, without the need for re-sowing. Results in initial experiments to evaluate new species/varieties and anecdotal reports had shown considerable differences in regeneration capacity in second year stands in NSW compared to WA (Hackney et al. 2012).

The scientist-farmer teams moved on from the early focus on establishment via twin and summer sowing and associated legume agronomy and rhizobiology to assessing the livestock production potential from new legume species. In the case of biserrula, associated investigations were undertaken into the causative agents involved in a primary photosensitisation which can be experienced with this species. Additionally, the capacity to utilise biserrula's lower palatability in grazing systems through winter and spring to selectively remove the problematic but highly palatable cropping weed, annual ryegrass has been investigated.

Throughout the >10 year duration of the development of pasture-livestock-crop rotation systems with these new annual legumes, there has been considerable interaction with industry stimulated by field days, field walks, seminars, written and visual media releases.

Results and Discussion

The development and optimisation of practices for establishing and then managing pasture-crop systems based on these new hardseeded annual legumes are ongoing. The key findings so far have included:

i New "on-demand", self-sustaining crop-pasture rotation systems have been successfully developed from a one-time sowing event with adoption by industry through the target research zones.

ii Significant differences in regeneration between WA and NSW across years, particularly for biserrula. In WA, little regeneration occurs in the year following legume establishment. Therefore paddocks are usually cropped in the second year allowing hard seed break down for regeneration in year 3. In NSW, biserrula regenerates strongly in the year following sowing, allowing for paddocks to be either grazed or cropped in the second year. Results indicate that biserrula is a successful candidate for summer sowing in NSW, but not in WA due to lower hard seed breakdown in WA.

iii In WA and NSW twin sowing has been successful in establishing new legume pastures of French serradella and bladder clover in replicated experiments and on-farm broad scale sowings (Loi et al. 2008, Hackney et al. 2012, Butcher and Butcher 2015). In NSW, twin sowing has been successful in establishing biserrula but this technique has not been used for biserrula in WA (Hackney et al. 2012). Additionally, in NSW conventional cover cropping using scarified seed resulted in significant reduction (15-90%) in seed yield and seed size (up to 50%) of the sown legume and decreased production compared to twin sown treatments in the year following sowing (Hackney et al. 2012).

iv Summer sowing has been shown to be a highly effective method of legume pasture establishment across the wheatbelt of WA for French serradella and bladder clover (Loi et al. 2012). In NSW, similar success has been achieved with these species and also with biserrula where forage yield in the establishment year has been 2-16 times greater for summer sowing compared to conventional sowing (Hackney and Quinn 2015). Gland clover has also been successfully established using summer sowing (Hackney and Quinn 2015). However, some caution is required with its use for this purpose as it has a shallower root system and therefore if regional summer conditions are likely to induce rapid seed softening and early germination, greater seedling mortality may be experienced.

v A benefit of both twin and summer sowing is provision of opportunity for more rapid legume growth in early autumn, prior to onset of low temperature and frost. Both systems allow use of cheaply produced unscarified or in-pod seed, produced and harvested on-farm, enabling high sowing rates. Additionally, for species such as French serradella, utilising pod negates the requirement for the expensive process of dehulling to remove seed from the pod required for conventional sowing. Summer sowing also allows sowing of a pasture at a time of year when farmers are generally less busy. Both sowing techniques can be undertaken using conventional sowing machiney.

vi Nodulation studies have focussed upon biserrula as it has a specific inoculant that is not yet widespread in southern Australian soils. Thus, if the inoculants sown in summer or twin-sowing operations did not survive, then nodulation failure would have been evident. There has been no nodulation failure in biserrula when inoculants have been delivered either in February (summer sown) or in June, with hard seed that does not establish until the following autumn. Studies are on-going with bladder clover and serradella.

vii Crop yield and quality without N-fertiliser addition, recorded in replicated plots, has been equivalent to, or better than that achieved under a continual cropping system where N-fertiliser is provided (Hackney et al. 2012, Butcher and Butcher 2015). This has also been reported in commercial farming operations with an estimated reduction in crop production cost of $100/ha, which is attributed to reduced N-fertiliser use (Butcher and Butcher 2015).

viii Hard seed break down varies considerably between WA and NSW with rates faster in NSW (Hackney, pers. comm). There does not appear to be a linear relationship between measured breakdown rates and number of crops that can be grown over an established seedbank without affecting regeneration. For example, in WA bladder clover is usually used in one year crop-one year pasture rotation. In NSW, bladder clover has regenerated strongly following a one-year-in-four year regeneration. Biserrula has been observed to survive seven successive cropping years in northern WA wheatbelt but has not been tested beyond four years in NSW.

ix High livestock production from new legumes has been recorded in replicated plot and on-farm situations. Hackney and Quinn (2015) reported average weight gain of 350 g/head/day for suckling crossbred lambs grazing biserrula over an eight week period in an on-farm study. Similarly, in a small plot experiment, lactating merino ewes grazing biserrula over a six week period gained over 200 g/head/day, and their lambs over 250 g/head/day compared to their counterparts grazing typical volunteer pasture where ewes lost 75 g/

head/day and lambs grew at only half the rate of those on biserrula. Also in this experiment, sheep grazing Casbah biserrula pasture effectively removed ryegrass selectively over the grazing period and this has also been anecdotally reported in broadacre situations on-farm thus reducing reliance on herbicides in the following crop rotation

x Livestock production on dry legume residues over summer has also been monitored. In an on-farm study in NSW, replacement ewes weighing an average of 47 kg liveweight in December, were grazed on biserrula or bladder/gland clover residues over summer without supplementary feeding. Ewe liveweight at the end of summer was 45 kg (Mike O'Hare, pers. comm.). Initial small plot studies (Quinn, unpub.) comparing changes in liveweight of replacement ewes grazing biserrula (n=102) or wheat stubble (n=95) over a three week period in summer, reported reduced weight loss in animals grazing biserrula (-164 g/head/day) compared to wheat stubble (-248 g/head/day). Thus, requirement for supplementary feeding for livestock grazing hardseeded legume stubbles is lower than cereal stubbles and feeding costs for liveweight maintenance may be considerably reduced.

xi Primary photosensitisation can occur on biserrula dominant pastures but its incidence is greatly reduced by presence of other species, even at very low levels in the pasture sward. Photosensitisation is not observed once plants begin to senesce. If 'managed', photosensitisation appears to have no long-term impact on livestock performance (Hackney and Quinn 2015)

xii In both WA and NSW, the involvement of producers and particularly the 'champion' producers has resulted in enhanced uptake of hardseeded annual legumes into farming systems. The producer 'champions' who have been involved in the development of pasture-crop rotation systems have been instrumental in ensuring adoption as producers want 'proof' that new technology is robust outside of the confines of well-manicured replicated plots. Survey of 300 farmers in central and southern NSW five years after commencement of extension efforts showed adoption had increased from 2 to 15% over a five year period (Hackney, unpublished).

In the last ten years, a substantial breakthrough has been achieved in the uptake of new, robust, crop-pasture rotation options utilising hardseeded pasture legumes sown at unconventional times. Instrumental to the success of the RD&E presented here has been the combined efforts of a multidisciplinary team working in western and eastern regions of southern Australia. RD&E efforts have delivered sound component outcomes in the areas of agronomy, rhizobiology and livestock endeavours. More importantly however, the team has always had in mind the delivery of an overall systems outcome and the involvement of farmer champions from the outset has been instrumental in ensuring this is achieved. Commitment to systems R,D&E rather than isolated component research is required by research organisation and funding bodies to ensure robust farming systems with adequate diversity to cope with current and future biological, climatic and economic constraints can continue to be developed. Only then can we ensure the long-term viability of the Australian agricultural sector and the world population its food and fibre production support.

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