

Developing pasture-crop rotation systems with hard seeded self-regenerating legume species to fix more N for crops and feed livestock in medium and low rainfall zones

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Take home messages

- Hardseeded pasture legumes have produced significantly more herbage, supplied more nitrogen and have capacity to support increased livestock production compared to traditional legumes over the past decade across regions of NSW under variable growing conditions
- Summer sowing has proven to be significantly more effective as an establishment method for hardseeded legumes than conventional sowing
- Hardseeded legumes can provide more flexible pasture-crop rotation systems than afforded by traditional legumes.

Summary

Over the past decade, hardseeded annual legumes including arrowleaf clover, biserrula, bladder clover, gland clover and serradella (French and yellow) have proven to be more productive than traditional legumes with greater capacity to supply nitrogen for following crops and provide high quality feed for livestock. The capacity to harvest seed on farm and employ alternative establishment methods such as summer sowing has been a particularly effective strategy across regions of NSW under a range of growing conditions including extreme drought. Hardseeded pasture legumes offer capacity to develop very flexible crop-pasture rotation systems that exploit the hard seed characteristics of these legumes.

Introduction

Pastures used in rotation with crops in eastern Australia have traditionally relied on subterranean clover, annual medics and the perennial legume, lucerne. The traditional annual legumes rely on sowing after the danger of a false break has past due to their relatively shallow root system and poor capacity to control moisture loss through transpiration which can give rise to high seedling mortality. When used in the mixed farming zone, traditional annual legumes are frequently sown after the main winter cropping program has been completed. Consequently, sowing may occur in late autumn or even early winter. While pasture legumes are capable of germinating at lower temperatures of late autumn and early winter, the time for emergence is greatly increased in these circumstances.

Thus, poor herbage production can be a feature of late sown conventional annual legume-based pastures. Further, plants established on late sowing are frequently small coming into spring. Small plants with poorly developed root systems are more prone to spring moisture stress and the strongly determinate nature of subterranean clover and annual medics mean that such conditions can result in low levels of seed production that compromises future regeneration capacity. Poor growth also means reduced capacity to build soil nitrogen via biological nitrogen fixation. Lucerne, while more hardy in terms of establishment as a consequence of a vigorous root system, has adaptation limitations, particularly with respect to tolerance of soil acidity and the often associated aluminium and/or manganese toxicities which limits its production, persistence and capacity to build soil nitrogen. Growers also frequently report high levels of bare ground in lucerne stands and seek companion plants to fill these gaps. This can be difficult to achieve as lucerne is very effective in drying the soil and reducing opportunity for germination of companion annual species in established stands. In eastern Australia, regardless of whether pastures used are based on traditional annual legumes or lucerne, they tend to be grown in phase systems with crops, with the pastures sown after each cropping phase. These systems can be considered relatively inflexible in terms of achieving rapid change in crop to pasture ratios on farm. In turn, capacity to change the ratio of crop to livestock in the farming system is constrained. High returns from livestock systems is seeing increasing interest in including pastures in rotations, while there is also increasing appreciation amongst growers of the capacity of pasture legumes to contribute to building soil nitrogen for following crops. In recent decades, a range of annual legumes have been developed which have proven to be well adapted to the soil and climatic challenges frequently encountered in the medium and low rainfall cropping regions of eastern Australia. These legumes produce their seed aerially which means they can be harvested using cereal headers and enabling on-farm seed production. When harvested in this manner, a high hard seed content is retained. This opens the opportunity for alternative pasture establishment options. Summer sowing (Nutt et al. 2021) was developed to exploit the opportunity of being able to header harvest pasture legume seed easily on farm and then successfully establish pasture without needing to further process the seed. Over the last decade, this technique has proven to be highly successful in establishing pastures in eastern Australia across a range of soil and climatic conditions. Hardseeded legumes are contributing significantly higher quantities of nitrogen to future crops compared to traditional legumes. Additionally, replicated trial and grower experience is showing these legumes are regenerating strongly following cropping phases of variable length without the need for resowing. Feed quality of hardseeded legumes has been found to be equivalent to or higher than traditional legumes at the same stage of growth. But higher herbage biomass means livestock production per hectare is significantly higher, with capacity to utilise herbage directly or conserve as silage or hay. Hardseeded legumes including arrowleaf clover, biserrula, bladder clover, French serradella, gland clover and yellow serradella, provide rotation options to complement those provided by traditional legume species. The remainder of this paper will provide snapshots of research undertaken involving hardseeded legumes over the last decade in NSW.

Getting started with hardseeded legumes

Because seed of many of the hardseeded annual legumes can be harvested with a standard header, there does not need to be a large on-going investment after the initial purchase of seed. Purchase seed to grow a nursery paddock, harvest it and then utilise that seed to commence a summer sowing program. The seed you initially purchase for your nursery paddocks, if coming from a reseller, will have been scarified so that there is a high percentage (usually > 90%) that will germinate soon after sowing. For that reason, sow your nursery paddock as you would a traditional legume such as subterranean clover or annual medic; that is, from mid-autumn onwards. Seed sowing rates for hardseeded annual legumes in nursery paddocks range from 5-10 kg/ha depending on species, regional climatic conditions and machinery spacing.

From our work with growers over the last decade, the quantity of seed of annual legume species harvested with a header are shown below. The range in seed yield achieved reflects differences between regions (i.e. low vs medium rainfall) and seasonal conditions:

Arrowleaf clover – 300-800 kg/ha. Most growers windrow arrowleaf clover for harvesting as the cultivars are relatively long-season and this prevents green stalks blocking the header.

Biserrula – 100-350 kg/ha. Biserrula has a very papery pod. To achieve higher yields, biserrula is best harvested under hot, dry conditions. Raking into windrows generally results in higher yields. (Note: total seed available for harvest typically ranges from 500-1000 kg/ha but as the pod is papery, a lot will pass through the header and will contribute to regeneration in subsequent years.)

Bladder clover – 300-1200 kg/ha. Bladder clover is a prolific seeder and is relatively easy to harvest. It generally harvests well via direct heading.

Gland clover – 250-600 kg/ha. Gland clover has a very high harvest index. It harvests very well via direct heading.

French serradella – 300-1000 kg pod segments/ha. French serradella harvests well via direct heading.

Yellow serradella – 200-500 kg pod segment/ha. Yellow serradella cultivars can vary in ease of harvest. Some of the old cultivars have quite hooked pods that can become entangled in the box and therefore growers often recommend only partially filling the box (one-third to one-half) to prevent difficulty in augering out the pods.

While these seed yields may appear low compared to yields achieved by winter crops, it needs to be remembered in using this harvested seed in summer sowing, sowing rates will be 10-12 kg/ha for bare seed and 20-30 kg/ha for the in-pod serradella. Therefore, a small nursery paddock can yield sufficient seed for subsequent sowing of very large areas. The advantage of using nursery paddocks, is that a range of species can be evaluated for their suitability on your farm and you can then harvest those that you think are most suitable. Over the last decade, we have worked with many growers who typically start with nursery paddocks of 40-80 ha where they might evaluate 4-5 species/cultivars in 5-20 ha blocks.

(Important note: Some cultivars of hardseeded legumes are protected by Plant Breeders Rights. Growers are able to harvest seed of these cultivars for their own use, but it is illegal to sell them)

Summer sowing in a nutshell

Summer sowing relies on having a ready source of pasture legume seed that has been minimally processed and therefore retains a very high proportion of hard seed. Seed of these legumes is then sown in mid to late summer with a robust legume inoculant capable of supporting rhizobial survival until opening autumn rains are received. Seed then softens due to fluctuation in temperature and moisture. Pasture sowing is therefore completed prior to the commencement of the winter cropping program and the pasture can get up and away while temperatures are warm and conducive to supporting growth.

Over the last decade across environments receiving long term average rainfall of 350-650 mm, summer sowing has, across all 14 replicated field sites for all hardseeded legumes, resulted in significant increases in herbage production compared to when the same species is conventionally sown using scarified seed (Figure 1). Moreover, summer sowing of any of the hardseeded species has given significantly higher herbage production than conventional sowing of subterranean clover or annual medics.

If we divide the data for the 14 sites up for seasonal conditions, we see the same trends emerging for severe drought (2019) and average years (Figure 1). Only in the wet year (2016), did conventional sowing for some species equal or exceed that achieved by the summer sowing. Interestingly, in

2020, herbage yields for summer sowing was significantly higher than for conventional sowing (data not shown). In summary, summer sowing has proved to be a robust method for the establishment of pasture giving significantly higher herbage production than where legumes are conventionally sown in late autumn.

Not all cultivars of all hardseeded legumes are suitable for summer sowing. In Western Australia, where the summer sowing technique was pioneered, hardseeded French serradella (cv. Margurita^b and Frano) and bladder clover (cv. Bartolo) can be successfully used in summer sowing. In NSW however, in addition to these species and cultivars, arrowleaf clover (cv. Cefalu), biserrula (cv. Casbah), gland clover (cv. Prima) and yellow serradella (cv. Avila and acc. 87GEH72.1a) have been successfully used in summer sowing. Differences between WA and NSW in species and cultivar suitability for summer sowing appears to be a consequence of differences in summer moisture regimes (Howieson et al. 2021). Bottom line: it is important to consider which cultivars of certain species are suitable for summer sowing. Some just do not break down sufficiently for use in summer sowing.

Nitrogen fixation

Across sites, biological nitrogen fixation for all hardseeded and traditional legumes has ranged from 18-33 kg N/t shoot DM with an average of 23 kg N/ t DM. Average biomass production for most species when summer sown across 14 sites and six years is around 4 t DM/ha indicating close to 100 kg N/ha is being fixed on average (Figure 1). Interestingly, the summer sown hardseeded legumes, based on this average would have contributed similar quantities of nitrogen in drought and average years (Figure 1). In comparison, most conventionally sown legumes have contributed < 50 kg N/ha except in 2016. Summer sown arrowleaf clover has, from our results, tremendous capacity for nitrogen fixation exceeding 150 kg N/ha averaged across all 14 sites, under severe drought (2019) and in average years and >200 kg N/ha in 2016.

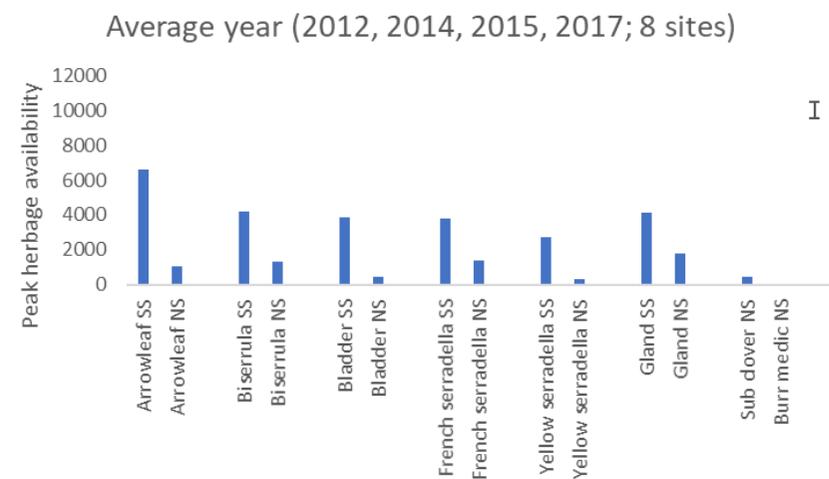
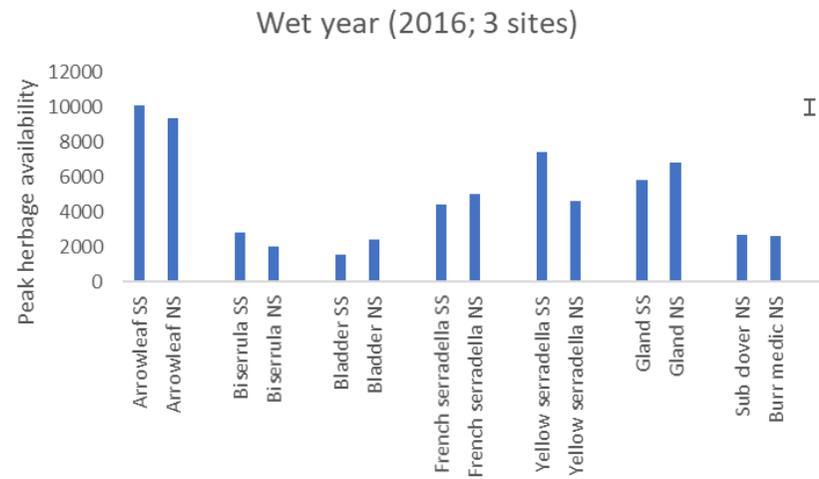
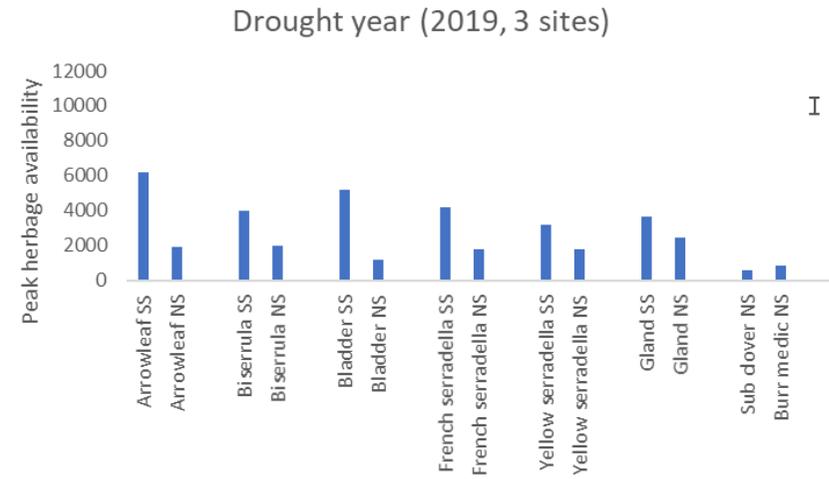
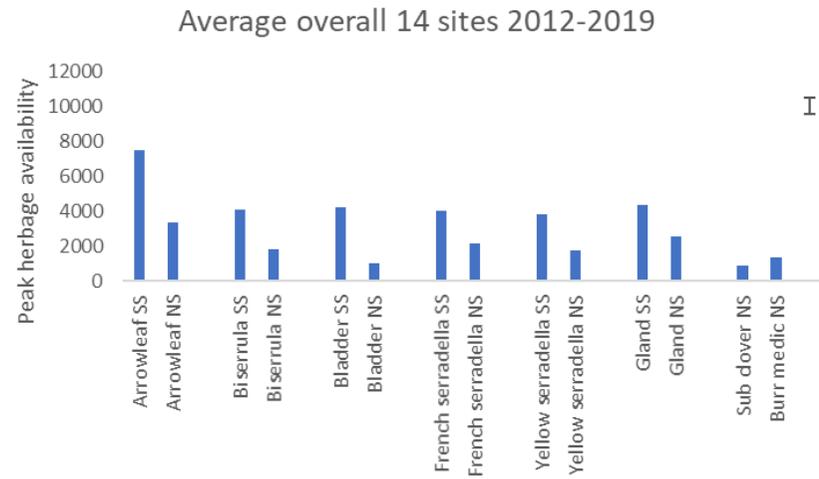


Figure 1. Peak biomass (herbage) production (kg DM/ha) for a range of annual legumes sown either as unscarified/in-pod seed in mid to late summer (SS) or as scarified seed in May (NS) averaged across 14 sites from 2012-2019. The data is then divided into peak biomass production in drought, wet and average rainfall years

Seed yield

As with herbage production, seed yields achieved from summer sowing of hardseeded legumes has been significantly higher than that achieved by conventional sowing. For traditional species such as subterranean clover and annual medics, the aim would be to achieve a minimum seed set of 150 kg seed/ha to have reasonable capacity for subsequent regeneration (Dear et al. 2008). Using that benchmark (Figure 2), it can be seen that summer sowing averaged across all sites and all years for each hardseeded legume achieved or exceeded this benchmark whereas conventional sowing of the same species was less consistent. Interestingly, subterranean clover and burr medic did not achieve this benchmark. Even under severe drought conditions, all hardseeded legumes that were summer sown achieved this benchmark with the exception of gland clover.

Herbage quality and livestock production potential

The results presented above indicate significant increases in capacity of hardseeded legumes to increase feed supply for livestock compared to conventional sowing. While feed supply is one component impacting potential livestock production, herbage quality (digestibility and crude protein) also needs to be considered.

During 2019, herbage quality assessments were undertaken throughout the growing season. These results were then used to predict liveweight gain in merino lambs (25 kg liveweight) using Grazfeed. Liveweight gain per head ranged from 340-430 g/hd/d for hardseeded legumes sown in summer (Figure 3). Some of the conventionally sown legumes were predicted to provide <100 g/hd/d gain, a consequence of low herbage availability. Given feed was very scarce in 2019 and if feed available had been utilised to support weaner lambs, then weight gains of 470-1440 kg/ha (average 870 kg/ha) were predicted from summer sowing, depending on legume species. This compared to 35-460 kg/ha (average 145 kg/ha) for conventionally sown legumes.

Weeds

While summer sowing can produce dense, vigorously growing stands that compete well with weeds, it does not compensate for a lack of site preparation prior to sowing of pastures. As with conventionally sown pastures, it is advisable to have a minimum of two and preferably three years of sound weed control prior to sowing of pastures. Unlike conventional sowing where there is opportunity for a final knockdown of weeds after opening autumn rains, this opportunity is foregone for summer sowing. Research is ongoing in terms of selective herbicide options for use in alternative legumes.

In terms of alternative weed control strategies, species such as biserrula give some opportunity for non-herbicide options. Biserrula is not a highly palatable legume and sheep will tend to graze other pasture components initially. In replicated field trials we have measured significant reductions in density of ryegrass (plants and inflorescences) following grazing by sheep (Howieson and Hackney 2018). Further, growers have reported success with control not only of annual ryegrass but also capeweed and other problem broadleaves using sheep. Again, this is a complementary strategy in weed control and is not a substitute for weed control prior to pasture establishment.

There is often concern expressed by growers and advisors that the legumes themselves may become weeds in following crops. Knockdown herbicides used prior to sowing crops control any summer germinating legumes. Crops compete very strongly against germinating legumes post-sowing and the hardseeded legumes are highly susceptible to many of the common selective broadleaf sprays used in-crop.

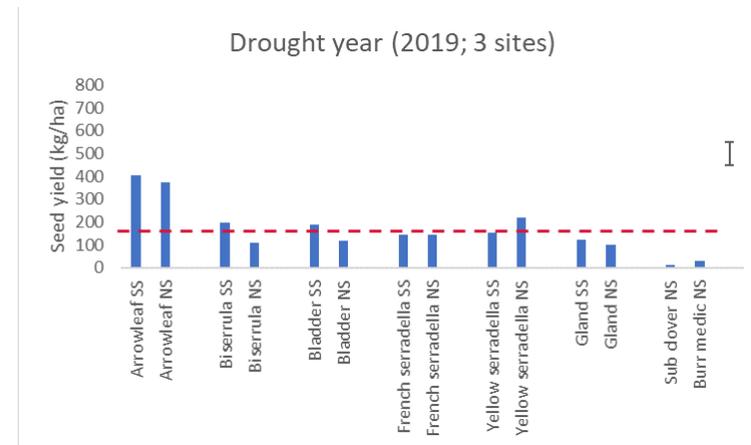
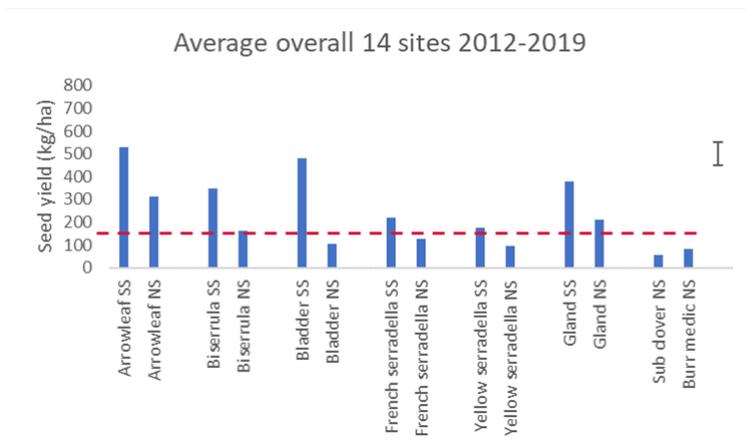


Figure 2. Seed yield (kg/ha) for a range of annual legumes sown either as unscarified/in-pod seed in mid to late summer (SS) or as scarified seed in May (NS) averaged across 14 sites from 2012-2019. The seed yield under severe drought (2019) conditions is also shown. Red dotted line = minimum seed set of subterranean clover and annual medics of 150 kg seed/ha

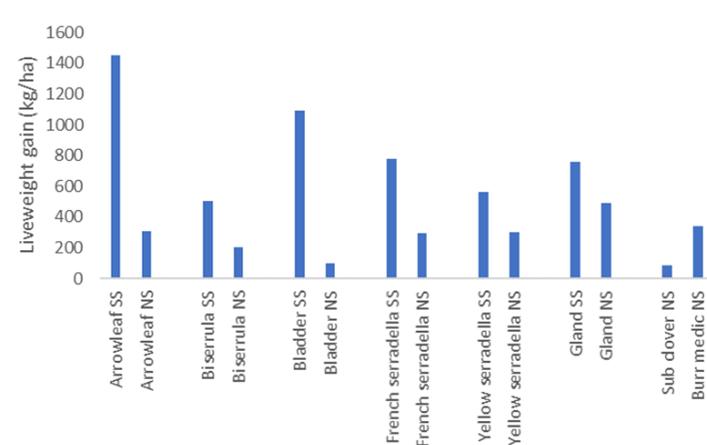
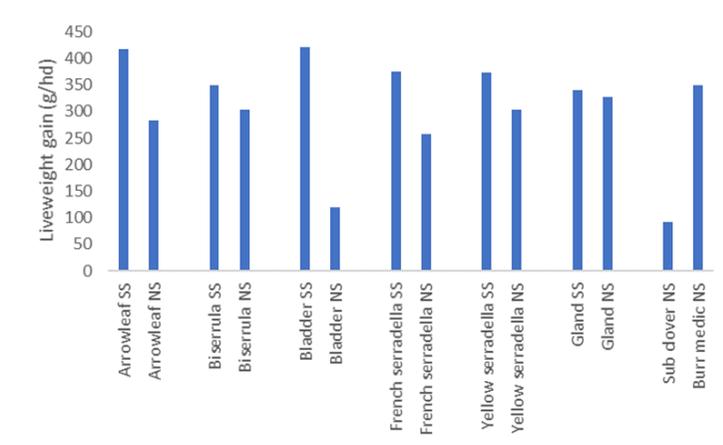


Figure 3. Predicted liveweight gain (g/hd/d) from Grazfeed for a range of pasture legumes established via summer sowing (SS) or conventional sowing in May (NS) based on feed quality (digestibility and crude protein), herbage biomass and the calculated weight gain (kg/ha) based on herbage biomass at the time of sampling for three sites in 2019.

Using hardseeded legumes in rotations

Once a seedbank of hardseeded legumes is established, they can be cropped and have the capacity to regenerate following the cropping phase without the need for resowing. The length of the cropping phase that can be employed without risking seedbank exhaustion varies with species and cultivar. For example, biserrula and some cultivars of yellow serradella have very high levels of hard seed (>90%) and can persist in the seedbank for many years. These species can survive longer cropping phases. Species such as arrowleaf clover, bladder clover and gland clover tend to have hard seed levels in the autumn following seed set of 50-60% depending on environmental conditions. As a result, shorter cropping phases are preferred to facilitate seed bank replenishment. Ultimately, the decision on cropping phase length will include consideration of utilisation of fixed nitrogen.

Growers using hardseeded legumes report running cropping phases of 2-4 years over areas with established legume seedbanks, and shorter phases (2 years) for hardseeded clovers, while legumes with higher hard seed content are used in both short and longer term rotations. We are currently evaluating the effect of rotation systems on regenerative capacity of these legumes.

Conclusions

Hardseeded annual legumes have been proven over many years and across regions to have significant potential to contribute to increased farm productivity through capacity to fix nitrogen for following crops and provide high quality feed for livestock. Such legumes provide flexibility and risk reduction options in terms of alternative methods for pasture establishment and development of more flexible crop-pasture rotation systems.

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Ⓟ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.