Improving weed management with biserrula in the pasture phase of WA cropping systems

Summary

This project was designed to provide information about the ability of biserrula (<i>Biserrula pelecinus</i>) pastures to contribute to grain production systems in the medium and low rainfall wheatbelt areas of Western Australia. A grazing experiment confirmed that preferential grazing can be exploited in biserrula dominant pastures to reduce weeds and increase grain production in a subsequent wheat crop. Pasture crop rotation trials demonstrated that biserrula and its rhizobia are capable of persistence through at least three consecutive cereal crops, allowing farmers to crop more frequently and still retain legume dominant pastures. Constraints to adoption included the risk of photosensitivity in sheep and poor aphid tolerance.

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Conclusions

The conclusions from this project can be drawn together in the framework of a farming system that will be applicable to large areas of the wheat-livestock zone in southern Australia. Biserrula offers an opportunity to lift the productivity of ley farming systems in medium rainfall environments (350-500 mm average annual rainfall), particularly where cropping makes up a high proportion of the farm business.

It is clear that biserrula has a range of characteristics that are distinct from other traditional annual pasture legumes and which create greater flexibility in paddock management. Preferential grazing in biserrula pastures can be successfully used to reduce weed burdens, but the impact is greatest when biserrula is the dominant component of the pasture. Biserrula dominance is best enhanced by exploiting its high level of hardseededness (once established) and using it in intensive crop rotations that may include up to three consecutive cereal crops. This will create lower weed burdens overall (especially for broadleaf weeds) and allow biserrula to dominate. It appears that both biserrula seed banks and its associated rhizobia are sufficiently resilient to persist through multiple crop cycles.

There is a trade-off between early germination in biserrula and false break tolerance. Early germination at high seedling density allows biserrula to respond quickly to favourable seasonal conditions, improving early pasture production and reducing weed burdens through competition and weight of numbers. Loss of legume density through false breaks of season is a risk but seedlings appear to have reasonable drought tolerance and there are subsequent waves of germination, though at much lower densities. Crop establishment with reduced tillage systems will enhance biserrula regeneration by minimising the depth of seed burial, which is critical for the establishment of biserrula seedlings.

There is also a trade-off between biserrula dominance in a pasture and the risk of photosensitivity. Biserrula dominant pastures (above 70-80%) will enhance the selective grazing effect on weed burdens (especially grass seed production) but elevate the risk of photosensitivity in sheep during late winter and spring. In these situations, grazing biserrula pastures may need to be deferred until after senescence - as it appears dry pastures do not induce photosensitivity, but are still of sufficient quality for liveweight gain. Photosensitivity in the green phase appears unlikely when biserrula makes up less than two-thirds of the pasture, which is likely to be the situation in higher rainfall areas and longer pasture phases. Livestock performance on biserrula pasture appears to be at least as good as on other annual pasture legumes. Under favourable conditions, biserrula can extend the length of the growing season and increase animal growth rates or grazing days.

Legume dominance in biserrula pastures is associated with enhanced crop performance, either through improved yields or increased grain protein. Responses are seasonally dependent and most pronounced in the first crop after pasture. Benefits decline with subsequent crop cycles, requiring either additional nitrogen fertiliser to maximise yields or the use of crops (e.g. barley) with lower nitrogen requirements in later years. There is little requirement for in-crop weed control of biserrula in subsequent crops, as most pasture regeneration is killed with knockdown herbicides. Little biserrula emerges under the crop.

Biserrula is unlikely to become a major agricultural or environmental weed and should behave similarly to other annual pasture legumes. While it has persistence characteristics, it is not particularly invasive without some form of disturbance. The species may encroach onto disturbed sites, such as roadsides, but it is unlikely to invade bushland or wetlands. It can be
controlled with in-crop and conventional knockdown herbicides.

Clearly, biserrula provides some valuable new opportunities for farmers in mixed crop-livestock systems to optimise land use and farm businesses. It provides a feasible alternative to annual medics and subterranean clover.

Recommendations

Two roles for biserrula can be envisaged for ley farming systems - one for crop dominant systems and one for livestock dominant systems.

Preferential grazing is likely to be of most value in cropping systems and the focus should be on managing pastures for legume dominance.

Important elements of the biserrula package for cropping systems include:

1. Paddock selection - target sand over clay duplex, sandy loam and loam soils with pH (CaCl2) above 4.5. Biserrula will be productive on acid soils if there is >10-12% clay in the topsoil.
2. Treat the pasture as a crop in the establishment year to maximise seed production - inoculation, shallow depth of sowing and insect control are crucial.
3. Biserrula performance will be favoured by intensive cropping systems - seed (and rhizobia) will persist through pasture(P)/crop(C)/pasture/crop (PCPC) and multiple crop rotations of up to three consecutive crops if initial (and subsequent) seed production is high.
4. Multiple crop rotations will minimise weed burdens and allow the use of preferential grazing to effectively clean up paddocks and generate legume dominance. Preferential grazing will be most successful with legume contents >70-80%.
5. High grazing pressure early in the growing season will optimise weed control. Biserrula can tolerate early grazing because of its early productivity and prostrate growth habit. Grazing pressure should be reduced if there are false breaks of season to ensure seedling survival.
6. Defer grazing in early spring to minimise the risk of photosensitivity and produce legume bulk. This will optimise the quantity of fixed nitrogen available for subsequent crops and also favour biserrula seed production to maintain seed reserves. Consider spraytopping established pastures (especially if grazing has been deferred) for control of any residual grass weeds. Spraytopping is not recommended in the year of biserrula establishment.
7. Attention to aphid control will be important to ensure high pasture productivity throughout the growing season, especially where grazing has been deferred in spring.
8. Graze dry pastures during early summer (this fills a feed gap before stubbles become available). An energy supplement is likely to be required to optimise animal growth rates.
9. Reduced or minimum tillage crop establishment systems will favour higher seedling densities of biserrula regeneration. Biserrula will present little in-crop weed competition when controlled with knockdown herbicides.
10. Little or no fertiliser nitrogen should be required in the first crop after productive legume pastures. Consecutive crops may require additional nitrogen, depending on the crop type. Multiple cropping will make the most effective use of residual nitrogen from pastures (for yield or grain protein) and nitrate leaching is less likely in medium rainfall environments on loamy soils.

In Western Australia, biserrula is likely to be most productive in the central and northern wheatbelt where winter temperatures are warmer during the growing season.

Changes in pasture composition for livestock systems need to be more subtle and legume dominance is less desirable than for cropping systems. A biserrula content of 60% or less will minimise the risk of photosensitivity in sheep. Livestock systems are likely to be based around longer pasture phases and, in practice, biserrula contents are not likely to become too elevated as non-legume components of the pasture will respond to increased nitrogen supply from the biserrula.

Issues of paddock selection, attention to pasture establishment, high grazing pressure early in the growing season and control of aphids in spring will also be important elements of a biserrula package for livestock systems. Extending the period of green feed will have important benefits for increased livestock performance. Long season annual plants like biserrula should improve hydrological balance, compared to shallow rooted plants like subterranean clover (though not to the same extent as perennial pastures).
Outcomes

ECONOMIC OUTCOMES

This project has demonstrated that the introduction of biserrula pasture is an effective and profitable strategy to help grain growers manage troublesome crop weeds. Well managed legume pastures can have additional benefits for cereal production through improvements in soil fertility, particularly the enhanced supply of nitrogen that becomes available over an extended period of time from organic sources.

Recent whole farm economic analysis using the MIDAS model for the central wheatbelt of Western Australia (Attachment 4) found that the change in profit per hectare could be as high as $48/ha when biserrula is introduced on to sandy loam and clay loam soils (valley floor and mid-slope soils). Biserrula was assumed to increase pasture production in winter by 10% and increase the green feed period in spring by three weeks (consistent with field observations in the dry season of 2006). The dominant rotations prior to adoption of biserrula were continuous annual pasture and continuous cropping. The introduction of biserrula improves the profitability of pasture/crop rotations relative to continuous rotations and invariably leads to a substitution of pulse and oilseed crops with pasture. Herbicide resistance was not considered in this analysis but its inclusion would further favour the selection of pasture/crop rotations.

The use of biserrula is applicable to more than five million hectares in the Western region but this will require development of cultivars that are early maturing and tolerant of aphids. Development of grazing management strategies that minimise the risk of photosensitivity in sheep will also be needed. Benefits will flow from improved productivity and sustainability of intensive cropping systems and are expected to continue post-project.

ENVIRONMENTAL OUTCOMES

Weed management is an important platform for sustainable cropping systems. This project has clearly shown that the inclusion of a biserrula pasture phase is an effective and profitable solution for managing herbicide resistant weeds. There are likely to be additional benefits across several rotational cycles for improving soil health and fertility. The use of long season annual pastures like biserrula may also provide incremental benefits for improved hydrological balance of cropping systems, but these are unlikely to be as high as well adapted perennial pastures.

SOCIAL OUTCOMES

The development of effective and profitable strategies for management of herbicide resistant weeds will empower grain growers to make better decisions when formulating individual farming systems. Growers will have an expanded array of management options at their disposal. The ability to multiple crop without compromising the persistence of annual legume pastures will provide growers with greater flexibility for paddock rotation and management. Mixed farming systems that incorporate livestock are also likely to be able to better spread the risk associated with climatic and economic uncertainty.

Achievements/Benefits

This project was designed to provide information about the productivity of biserrula pastures in a range of pasture/crop rotations and determine its potential for inclusion as a key pasture base to facilitate weed control with limited use of herbicides.

BACKGROUND

The rapidly growing occurrence of herbicide resistance in major weeds species, such as ryegrass and wild radish, continues to pose a serious threat to intensive cropping systems in Western Australia. Pastures are being used increasingly to provide additional management options for control of herbicide resistant weeds (such as intensive grazing). Preliminary experimental work and farmer observations have highlighted differences in the relative acceptability (palatability) of annual legume pastures to grazing animals at various times of the growing season. This characteristic may be able to be exploited in a pasture phase to directly increase the grazing pressure on weeds and reduce seed-set. Such a strategy has a number of important benefits. Firstly, it has the potential to reduce reliance on herbicides for weed control and, secondly, it should be a relatively simple technique to increase the legume content of pastures - with benefits of greater nitrogen fixation. Pasture species of interest in this regard include biserrula, a relatively new species to Australian and world agriculture. It is now important to start to develop appropriate farming systems to include the use of pasture species with low or variable
palatability (or acceptance by grazing animals).

Biserrula is adapted to a broad range of soil types, from loamy sands to clays. It has the capacity to produce a high proportion of hard seeds at maturity that allows a broad range of systems to be considered - from long pasture phases through to intensive cropping systems. Ryegrass and wild radish have persistent seed banks and their management inevitably needs to be considered over a period of more than one year. Thus pasture phases of two to three years are likely where weed levels are high. But self-regenerating pasture/crop rotations (such as PCPC or PCC) may be more attractive where weed levels are low. The capacity of such systems to deliver effective control of problem weeds needs to be researched, along with the effect on pasture productivity and subsequent crop performance.

OBJECTIVES

1. Investigate whether changes in the feeding preference of biserrula during the growing season can be exploited to enhance weed control in the pasture phase for the benefit of subsequent cereal crops.
2. Investigate whether biserrula and its rhizobia are sufficiently resilient to persist through a sequence of three consecutive crops and still produce a productive pasture.
3. Conduct a weed risk assessment for biserrula.
4. Work with leading farmers to assess their experiences with biserrula and document perceived strengths and weaknesses of this annual legume.

ACHIEVEMENTS

Weed management under grazing

A comparison between biserrula and other annual pasture legumes (including subterranean clover and French serradella) under grazing consistently showed over two years that sheep will preferentially remove a higher proportion of weeds from biserrula (Attachment 1). The change in pasture composition occurs over four to five weeks, presumably as sheep develop some aversion to biserrula. The proportion of weeds in biserrula declined from 46% to 28% in 2003 and from 77% to 40% in 2004. Both ryegrass and capeweed are selectively removed, although the impact on seed production is greatest for ryegrass (over 65% reduction in ryegrass seed production in 2003). The lower weed levels were carried through into the regenerating pasture phase following a cereal crop in 2005.

No decline in the proportion of weeds was evident when biserrula was sown in a mixture with other legumes. The benefit from preferential grazing of biserrula is clearly greatest when biserrula makes up a dominant proportion of the pasture (perhaps greater than 60% as in the year of establishment). Valuable grass control was also achieved in subterranean clover pastures (a function of its more prostrate growth habit and grazing tolerance) and was most pronounced in second year pastures when plant density of the legume was greater. Plant densities of second year biserrula pastures are normally low as a consequence of high hard seed levels and this reduces the effectiveness of the selective grazing option. The value of grazing biserrula pasture will be greatest in the year of establishment and in pasture phases regenerating after one or more cereal crops.

Animal performance was generally similar across all pasture treatments under the conditions of the grazing experiment. It was notable that biserrula pasture exhibited the highest legume contents, had the highest feed on offer at the end of the growing season in 2003 and was the most productive pasture in terms of the number of sheep grazing days in 2004. Sheep growth rates in spring tended to be high on biserrula pasture, consistent with higher pasture (legume) growth rates at this time. There was no evidence of photosensitisation in the sheep grazing biserrula in this experiment and blood tests for liver function showed no significant differences between pasture treatments. We suspect that photosensitivity is unlikely when there is > 30% non-legume in the pasture as an alternative feed source. The opportunity for low cost control of crop weeds combined with high livestock performance makes the use of biserrula a very attractive proposition for mixed farming systems.

Persistence and productivity of biserrula

A comparison of biserrula with other common annual legume pastures under two crop (C) / pasture (P) rotations at two sites (central and northern wheatbelt of Western Australia) revealed that biserrula has the greatest capacity to persist through very intensive cropping systems (Attachment 2). Assessments over five years have shown that biserrula can persist through a sequence of PCPCP (year-in year-out) systems as well as after a sequence of three consecutive crops (PCCCPC). In fact densities of biserrula regeneration after three crops at Cunderdin (sandy duplex soil) were at least as high (>1200 plants/m²) as the PCPCP rotation, despite one less pasture phase in the rotation. At the Miling site (loam soil), biserrula densities were still about...
400 plants/m² after three crops, compared with about 800 plants/m² in the PCPCP rotation. Biserrula was far more resilient in multiple crop systems than subterranean clover and yellow serradella but similar to nur ball medic in this respect.

Regenerating plant densities of most pasture species were consistently higher following reduced tillage crop establishment - sometimes as much as 50% higher compared to densities following cultivate/seed crop establishment. Biserrula, in particular, appears very responsive to reduced tillage systems, presumably because seedling emergence of this small seeded pasture species is favoured by shallow burial.

Another striking feature of biserrula is its pattern of germination. Biserrula germinates quickly and in high numbers on the first rains in autumn. In contrast, yellow serradella is slow to germinate at this time and germination is staggered over many weeks. Such contrasting patterns of germination have different implications for pasture production. Biserrula has the capacity to respond to good seasonal conditions at the break of season and lift pasture production relative to other species. Biserrula is very competitive under these situations and the proportion of weeds is consistently lower in biserrula pastures. At the Miling site in 2005, pastures regenerating after crop consisted of 3% weeds in biserrula (6.7 t/ha legume herbage) compared with 11% weeds in subterranean clover (3.6 t/ha legume herbage) and 17% in burr medic (3.8 t/ha legume herbage).

An additional advantage of such rapid germination in biserrula is that germination in crop years is easily controlled by knockdown herbicides and very few biserrula seedlings germinate late to compete with the cereal crop. In contrast, the slow germination of yellow serradella means it is poorly competitive in weedy pastures and relatively higher germinations occur in the cereal crop. The disadvantage of early germination in biserrula is a greater susceptibility to false breaks of season (a much lower risk in yellow serradella). But biserrula seedlings exhibit reasonable drought tolerance on sandy loam and loam soils.

Persistence of rhizobia

Rhizobial persistence through an extended cropping phase is critical if pasture legumes are to effectively nodulate in the year of regeneration. Collaboration with the Centre for Rhizobium Studies (Murdoch University) allowed rhizobial populations to be assessed at the Miling rotation site during 2005 and 2006 (across pasture and cereal phases). The data shows conclusively that not only has the biserrula inoculant strain WSM1497 persisted through the wheat rotation in high numbers to colonise its host in 2005, but that it has also colonised the wheat rhizospheres in 2005, as well as the neighbouring plots (Attachment 3). In contrast, the medic inoculant is only found in high numbers in its host rhizospheres. This is consistent with our understanding of the rhizobial ecology of these rhizobial species. This important result gives a high level of confidence that biserrula rhizobia will persist through multiple crop phases to effectively nodulate pastures (i.e. utilising both host plant and cereal rhizospheres).

Crop performance

The crop response to pasture management treatments in the grazing trial at Katanning was assessed in 2005. The bulk plot data indicated that in December only there was a significant difference between treatments in total crop biomass (20-27% higher after biserrula and serradella pasture compared to the other treatments). Grain yield was highest after biserrula pasture, but the difference in grain yield and grain quality parameters between pasture treatments was not significant as frost introduced considerable variability to crop performance (Attachment 1). The greater legume and lower weed content in biserrula based pastures may result in greater crop yields, but it will depend on the season.

Cereal crops in the two pasture/crop rotation trials were sown with a general application of starter nitrogen. Under these conditions, crops following biserrula pasture were at least as productive and of similar quality to those following other pasture legumes. In 2006, a more systematic analysis of the impact of pasture legumes on cereal production was conducted at the Miling rotation site (Attachment 2). Nitrogen rates were applied to crops in a PCCC rotation (i.e. third consecutive crop) and to crops in a PCPC (first crop after pasture). Preceding pastures in the PCPC rotation had the highest productivity and legume content for biserrula, followed by burr medic and subclover. Grain yields were severely impacted by a dry season and did not exceed 1.0 t/ha. However, important relationships were still observed. Grain yields in the PCCC rotation were similar for all pasture histories and did not respond to nitrogen. Protein levels increased from 13% (nil applied N) to 17% at 150 kg/ha Urea (U)). Grain yields in the PCPC rotation were highest after biserrula pasture at nil applied nitrogen (double those after medic and subclover) and there was again no response to additional nitrogen. Protein levels after all legume pasture treatments were 16.5% (nil applied N), increasing to 17.5% at the highest rate of nitrogen. Clearly, a productive biserrula pasture can produce much of the nitrogen requirements of a following cereal crop but the response will depend on season. It appears little nitrogen benefit from the pasture phase will flow through to a third consecutive cereal crop. It was also notable that crop establishment at Miling in the dry 2006 season was enhanced after a biserrula pasture phase, as the dry residue acted as valuable cover crop and reduced soil water evaporation.
OVERVIEW

Case studies of selected biserrula growers

Eight growers were surveyed in 2005 about their experiences with biserrula pasture. There was a consistency in the responses for benefits to the farming system and research gaps. Respondents indicated the benefits captured included: high productivity of the pasture; cleaning weeds from cropping paddocks; enhanced crop performance from nitrogen fixation; quality feed for weaning lambs; low cost pasture establishment; tolerance of lucerne flea; and ability to crop more than with subterranean clover. Most success was achieved on duplex and loam soils that may be quite acidic (pH as low as 4.8 in CaCl2), but which have some clay in the surface. Biserrula was regarded to be less successful on course sands and waterlogged soils.

Other problems or research needs include a lack of suitable broadleaf herbicide options (promotes growth of doublegees and silver grass), photosensitivity in grazing sheep, lack of early vigour under cold conditions, lack of tolerance to aphids and maturity too late in existing varieties for low rainfall regions of Western Australia.

The issue of photosensitivity in grazing sheep was investigated on three additional properties in 2003 and 2004. Mild signs of photosensitisation on the face and upper tail were apparent in early August 2003 in young Merino rams ten days after beginning to graze a dense pasture containing more than 95% Casbah biserrula. Over a period of 20 days grazing the sheep gained weight at an average of approx. 50 g/day, which is less than would be expected based on the nutritional value of the pasture. Blood tests performed before and after 20 days grazing showed that liver damage was unlikely to be the cause of the photosensitisation. Blood samples were also taken from sheep on two other farms where sheep had grazed biserrula-dominant pastures and had healing lesions of photosensitisation. Blood test results from these sheep also indicated that the condition was primary - due to some agent directly sensitising the skin to sunlight - and not secondary to liver damage. Further work is required to identify what appears to be a secondary plant compound in biserrula that can induce photosensitisation in some environmental circumstances.

Other research

Several research and development (R&D) opportunities have emerged from this project. It is clear that the risk of photosensitivity in grazing sheep is a constraint to the wider adoption of biserrula. Grazing management strategies need to be developed to minimise this risk. Research effort also needs to be directed towards the identification of the secondary compounds responsible for the condition and the factors that influence their concentration in the plant. This information will assist the design of appropriate grazing strategies and may also create opportunities for plant breeding and selection to develop cultivars with lower risk of photosensitisation.

Although many weeds in biserrula can be managed by grazing or crop rotation, it is evident that better herbicide options are required for broadleaf weeds - particularly doublegee and, to a lesser extent, silver grass. Flumetsulam and Imazamox can be used for doublegee control in many annual legume pastures, but biserrula is extremely sensitive to these herbicides. Alternative options need to be developed.

Opportunities exist for plant improvement in biserrula. Currently only two cultivars are commercially available but are mid-season (cv. Casbah) to late-season (cv. Mauro) maturity. Development of an early flowering variety would improve seed production and extend the range of biserrula into lower rainfall cropping regions (275-350 mm average annual rainfall). The lack of tolerance of biserrula to aphids is also a concern. Under conditions when aphid populations are high, stands of biserrula can collapse and fail to produce seed. The biserrula collection needs to be screened for variation in aphid tolerance to select improved lines or incorporate them into a crossing program to generate new cultivars.

It is clear that biserrula pastures can contribute to improved crop performance, but seasonal constraints in this project prevented adequate information being collected on the residual value of biologically fixed nitrogen and the yield boost to subsequent crops. Further work with pasture crop rotations incorporating biserrula - perhaps at the farm level with several producer groups - would be desirable to generate this information. The work could also include the impact of biserrula pasture on populations of soil-borne nematodes (Pratylenchus sp.) that are a constraint to cereal production.

The contrasting germination behaviour of biserrula and yellow serradella and its influence on early pasture production is also deserving of further research to investigate which strategy is more resilient over a range of years and seasonal conditions. Biserrula can respond quickly to favourable seasonal conditions and be very productive. Yellow serradella is more tolerant of...
false breaks of season but needs particular attention to weed management to prevent it from being out-competed by weeds. Exploiting its delayed germination behaviour and using early knockdown herbicides for weed control may provide a new opportunity to generate legume dominance in this species.

**Intellectual property summary**

The Outputs are in the form of knowledge and are not readily captured by normal commercialisation processes.

A weed risk assessment of biserrula was conducted and indicated that the species would pose little risk to agriculture or the environment. The analysis requires peer review before publication.

**Additional information**

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Additional information is provided as attachments to this project:

- Attachment 1 DAW00032 - Result Summary1
- Attachment 2 DAW00032 - Result Summary2
- Attachment 3 DAW00032 - Survival of *Biserrula pelecinus* and its root nodule bacteria through an extended cropping phase
- Attachment 4 DAW00032 - The value of new annual pastures in mixed farm businesses of the wheatbelt