National Annual Pasture Legume Improvement Program - WA

Summary
This project addressed several sustainability and economic challenges to current and emerging farming systems through the development of new annual pasture legumes. Eleven varieties (and one with major input from the Rural Industries Research and Development Corporation - RIRDC) were commercialised; four varieties were under consideration for release at the end of this project; and seven new cohorts were undergoing field evaluation. Six of these species were new to world agriculture. Inputs from a range of supporting disciplines were paramount to this success. Adoption of the new varieties was high, particularly in Western Australia (WA), and preliminary economic analyses for use of serradella and biserrula varieties indicated typical profit increases of $13 to $71 per hectare were attainable.

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Conclusions

This project focussed on solving a number of sustainability and economic challenges to current and emerging farming systems through the development of new annual pasture legumes. Eleven new varieties (and one with major RIRDC input) were commercialised, four varieties were under consideration for release and seven new cohorts were undergoing field evaluation. Six of these species are new to world agriculture. Inputs from the disciplines of rhizobiology, pasture ecology and agronomy, plant pathology, entomology, plant chemistry and animal science were paramount to this success.

Issues addressed through breeding and selection of new annual pasture legumes included:

1. Poor adaptation of subterranean clover and annual medicos to difficult soils, particularly deep acid sands and soils subject to waterlogging.
2. Poor adaptation of subterranean clover to false breaks.
3. Sustainability challenges to the ley farming system, notably herbicide resistant weeds and seed bank depletion of soft-seeded pasture legumes from increased cropping frequencies.
4. Environmental concerns from soil erosion caused by vacuum harvesting subterranean clover and annual medic seeds.
5. The need for low cost seed for re-sowing pastures, particularly for short-term phase pastures.
6. The need for specialist fodder legumes.
7. The need for longer season plants to maximise productivity in long growing season areas.
8. The need for deeper rooted plants to reduce groundwater recharge and the potential for dryland salinity.
9. The need for greater annual legume diversity within paddocks to stabilise productivity within and between seasons.
10. The need to overcome deficiencies in existing subterranean clovers, particularly susceptibility to clover scorch and root rot diseases in mid-season and late flowering varieties and soft seededness in varieties for cropping rotations.

Grower interest in the new varieties was high, particularly in WA where more than 1.5 million hectares is estimated to have already been sown to French and yellow serradellas, biserrula and aerial seeding clovers. This trend is likely to increase as more seed becomes available from newly released varieties. Preliminary economic analyses for use of new serradella and biserrula varieties indicate increases in profit of between $13 and $71/ha on a typical WA wheatbelt farm. Benefit cost analyses also indicate a high rate of return on investment in the project, with benefit to cost ratios ranging from five to 29.

The continuing decline in terms of trade for agricultural commodities creates an imperative for continuing productivity improvements. A healthy research and development (R&D) sector remains crucial for this to occur. Pasture plant breeding will continue to increase productivity and present new opportunities for farm businesses. While the private sector is likely to become increasingly involved in developing varieties of mainstream species, the higher risk - but more innovative - breakthroughs will continue to come from the public sector, provided the skills base and funding of plant breeders and related disciplines are maintained.

Recommendations
While adoption and interest is high among WA growers, there is a need to develop extension packages to maximise potential benefits from the new varieties and best manage these on a whole farm basis. Management strategies need to be fine-tuned for individual species to maximise productivity and persistence, particularly for many of the aerial seeding legumes. The compatibility of species and varieties for pasture mixtures, including perennial plants, also needs further work. The economic advantages for crop and animal production and the effects on the environment through use of new varieties also need better quantification. Such information will lead to greater confidence among producers and higher adoption in the long term.

Although several new annual pasture legumes were developed in this project, a large number of agro-ecological niches across southern Australia still need better adapted legumes. Consideration needs to be given to the multi-dimensional matrix of: soil type (texture, pH and fertility); environmental considerations (waterlogging and salinity); rainfall distribution; length of growing season; and farming system. The need to increase within-paddock biodiversity; through use of mixtures to improve and stabilise long-term pasture performance, further accentuates the need for a large suite of varieties. Continued support of plant genetic resources and the disciplines of rhizobiology, pasture ecology and agronomy, plant pathology, entomology, plant chemistry and animal science are essential to this development.

Most annual pasture legume breeding and selection to date has been aimed at the medium and high rainfall areas. The low rainfall zone still has limited options, due to the much narrower availability of early flowering germplasm. While this zone has traditionally had the least investment in pastures, the issues of herbicide resistant crop weeds and the rising cost of inorganic nitrogen (N) will increasingly draw growers towards the need to increase legume content in their pastures. An appropriate array of pasture legume options will be needed to satisfy this demand. Recent collection missions to dry areas of the Mediterranean basin have expanded the range of available short season germplasm and are likely to yield promising material for this zone. Exploitation of naturalised legumes from low rainfall areas provides another option.

Environmental constraints to pasture production need to be addressed through pasture legume breeding and selection. There appear to be opportunities to select varieties of *Melilotus* species and *Medicago polymorpha* with improved tolerance to salinity. Climate change also needs consideration. Incremental plant breeding and technological changes will be needed to lessen the effects on agriculture.

There are future prospects for biotechnology to identify genes of interest and incorporate these into agriculturally important pasture legume species. However, for the immediate future, it appears that the most cost-effective genetic improvement of most annual pasture legumes will come from exploiting the natural genetic diversity present within each species.

**Outcomes**

The outcome of this project is more profitable and sustainable mixed farming systems in acid-neutral soils across a range of climatic zones in southern Australia through the development and subsequent utilisation of new higher producing, and better adapted, annual pasture legume varieties.

Eleven new varieties (plus an additional one developed primarily with RIRDC funding) were successfully commercialised during the project, two varieties are undergoing final Duty of Care evaluation prior to a final variety release decision and eight new cohorts have been developed for field evaluation.

Identifiable benefits from the utilisation of these legumes include: increased levels of pasture productivity with high nutritional value and absence of anti-nutritional factors; improved soil fertility through increased levels of biologically-fixed N; and diminished weed problems. Many of the new legumes also have characteristics that encourage rapid and wide-scale adoption using low input systems. Some of the prior limitations and new opportunities these address include:

1. Adaptation to soils and environments not suited to traditional pasture varieties (low rainfall zones, deep acid sands, waterlogged soils).
2. Suitability to phase pasture and integrated weed management (IWM) systems.
3. Improved tolerance of false breaks.
4. Improved autumn-winter productivity.
5. Extending the growing season and reducing groundwater water recharge.
6. Improved tolerance to pests and diseases.
7. Suitability for production of conserved fodder.
8. Reduced pasture establishment costs.
Preliminary economic analyses for use of new serradella and biserrula varieties indicate increases in profit of between $13 and $71/ha on a typical WA wheatbelt farm. Benefit cost analyses also indicate a high rate of return on investment in the project - with benefit to cost ratios ranging from five to 29.

Adoption of newly released varieties has been high, particularly in WA where more than 1.5mha is estimated to have been sown to French and yellow serradellas, biserrula and aerial seeding clovers. A survey among WA growers in low and medium rainfall areas supports this adoption rate. This trend is likely to increase as more seed becomes available from newly released varieties.

**Achievements/Benefits**

**Background**

Annual pasture legumes are widely used in Australian farming systems. Benefits include the ability to fix atmospheric N, increase both soil fertility and structure and capacity to break crop disease and pest life cycles. Until recently, annual pasture legume options in southern Australia were largely confined to subterranean clover (*Trifolium subterraneum*) and annual medics (*Medicago* spp.). Since then, a number of sustainability and economic challenges to existing farming systems have emerged - exposing shortcomings in these species and a lack of legume biodiversity. Pasture legume breeding and selection has consequently focussed on solving farming system problems, rather than on the traditional species alone, and to provide new farming system opportunities. This project continued the development of new legumes that commenced in the National Annual Pasture Legume Improvement Program (NAPLIP) project UWA269.

**Variety development**

Eleven new varieties were commercialised during the project: Prima gland clover (*T. glanduliferum*), Urana<sup>4</sup>, Napier<sup>4</sup>, Coolamon<sup>4</sup> and Izmir<sup>4</sup> subterranean clovers; Mauro<sup>4</sup> biserrula (*Biserrula pelecinus*), Yelbini<sup>4</sup> yellow serradella (*Ornithopus compressus*), Erica<sup>4</sup> and Margurita<sup>4</sup> French serradellas (*O. sativus*); South Australian Research and Development Institute (SARDI) Persian clover (*T. resupinatum*); and AGWEST Sothis eastern star clover (*T. dasyurum*). Electra purple clover (*T. purpureum*), which was a RIRDC product with some NAPLIP input, was also commercialised.

A further two varieties (CFD27 Bartolo bladder clover - *T. spumosum* - and SA5045 - *Trigonella balansae*) underwent the final stage of Duty of Care grazing trials prior to a variety release decision.

The project contributed field evaluation data to aid selection for release of KRC-2 balansa clover (*T. michelianum*) and H14216 Moroccan clover (*T. isthmocarpum*). Seven additional cohorts underwent different stages of field evaluation: early, mid-season and late flowering subterranean clovers with redlegged earth mite (RLEM) cotyledon tolerance; rose clover (*T. hirtum*); purple clover; mid-season and late flowering French serradella; and *Lotus ornithopodioides*. Six of these species are new to world agriculture.

**Plants for deep, infertile acid sands**

Yellow serradella is very productive and persistent on deep, infertile acid sands. However, adoption of earlier varieties was constrained by high seed costs due to the need for suction harvesting and difficulty in de-hulling seed from the pods. This constraint has been tackled by selection of plants combining good pod retention with straight, non-segmenting pods - allowing reduced seed processing costs. An early flowering variety - Yelbini - was selected in this project for use in rotation with crops or as permanent pasture in low rainfall environments.

French serradella is adapted to similar soils, but is a lower-cost alternative due to its aerial seeding and retentive pods - enabling direct header harvesting. The first variety, Cadiz<sup>4</sup>, has been widely adopted. Its major weakness is that it is completely soft-seeded, making it very susceptible to false breaks and unable to be used reliably in cropping rotations without re-sowing after each crop. The development of the hard-seeded varieties Margurita<sup>4</sup> and Erica in this project overcomes this problem.

**Plants for phase farming**

A range of plants specifically adapted to phase farming, which enable provision of low-cost seed for re-sowing, have been selected. Common features are an upright growth habit and aerial seeding (allowing direct heading), ease of seed extraction from the pod, high seed production capacity and softer seededness than legumes adapted to ley farming. The upright
growth habit also makes these suited to fodder production.

Margurita and Erica French serradellas are suited to deep, infertile acid sands; CFD27 (cv. Bartolo) bladder clover is suited to fine textured acid soils; SAS045 *Trigonella* (*T. balansae*) is suited to alkaline soils; while Prima gland clover is suited to moderately acid soils. Prima also has the advantage of resistance to RLEM and to bluegreen and cowpea aphids. A more hardseeded cohort of rose clovers with better seed harvestability than cv. Hykon was evaluated. Electra purple clover (largely funded by RIRDC) was also released as a dual purpose grazing and fodder species for high to very high rainfall areas, while an additional cohort of earlier flowering lines started field evaluation. AGWEST Sothis eastern star clover is particularly innovative. It germinates very late in the season and provides the opportunity to control crop weeds during the pasture phase in the year after establishment.

Plants for ley farming

With the poor persistence of subterranean clover in many cropping rotations, more hardseeded species adapted to acidic soils have been developed. Casbah biserrula has proved to be very successful on low-medium rainfall acid soils. This species has delayed seed softening and is deeper rooted than most other annuals. It also provides an option for herbicide-free weed management, as sheep tend to preferentially graze weeds and other plants in spring. This project resulted in the commercialisation of the later flowering and less hard-seeded variety Mauro for medium-high rainfall areas.

Two new species for ley farming systems were considered for commercialisation. CFD27 (cv. Bartolo) bladder clover is adapted to fine-textured hard-setting soils, in which subterranean clovers are unable to bury their burrs. *Lotus ornithopodioides* cohort was evaluated. It has similar adaptation to bladder clover, but there are prospects of selecting earlier flowering genotypes. Both species are considerably more hardseeded than subterranean clovers, have a delayed seed softening pattern and seed can be harvested with commercial headers. *L. ornithopodioides* is also deep-rooted and resistant to RLEM and aphids.

Plants for grazing

Four subterranean clovers were commercialised. Izmir and Urana are more hardseeded than other varieties and replace Nungarin and Daliak, respectively in low rainfall cropping systems. Coolamon is a replacement for Junee in high rainfall mixed farming systems, while Napier is a replacement for Larisa on high rainfall waterlogged soils. Both varieties have resistance to both races of clover scorch and to major races of *Phytophthora clandestina*. Three cohorts of ssp. *subterraneum*, with cotyledon resistance to RLEM, have been selected for field evaluation. Variety release decisions will be made in late 2007 for cohorts of late flowering and mid-season lines. A cohort of early flowering lines is ready for field evaluation.

Plants for waterlogged soils

SARDI Persian clover was released as an earlier flowering variety suited to lower rainfall areas than Nitro Plus and Persian Prolific. KRC-2 balansa clover was short-listed for release as a more productive and root rot resistant replacement for Paradana. Moroccan clover is also adapted to waterlogged soils, but is more hardseeded and has better false break tolerance than balansa and Persian clovers. H14216 has been short-listed for release to complement the softer seeded species - subject to satisfactory Duty of Care testing.

Benefits to industry

Adoption of newly released varieties has been high, particularly in WA, where more than 1.5mha are estimated to have been sown to French and yellow serradellas, biserrula and aerial seeding clovers. A survey among WA growers in low and medium rainfall areas supports this adoption rate. This trend is likely to increase as more seed of the newly released varieties becomes available.

Preliminary economic analyses for use of new serradella and biserrula varieties indicate increases in profit of between $13 and $71/ha on a typical WA wheatbelt farm. Benefit cost analyses also indicate a high rate of return on investment in the project with benefit to cost ratios ranging from five to 29.

The project has resulted in the publication of 35 scientific journal papers, 48 conference proceedings and 20 technical and extension publications (105 in total).
Other research

This project was integrated with the other state-based, GRDC-funded NAPLIP projects and to a national Australian Wool Innovation (AWI) project titled ‘Fast tracking cultivar development in the National Annual Legume Improvement Program for wool producers’ (EC300) and coordinated nationally.

Other projects linked to this project include:

- ‘Plant Genetic Resources: Enhancing Germplasm Conservation for the Australian Grains Industry’ (DASS2) - GRDC;
- ‘NAPLIP Extension Western Australia - product pipeline support’ (WP058) - AWI;
- ‘Seed production limits sulla and purple clover as fodders’ (UWA65A) - RIRDC;
- ‘Improving the utilisation of pasture germplasm by the development of a core collection using eco-geographical and molecular techniques’ (UWA00005) - GRDC;
- ‘Germplasm collection of Trifolium and other pasture legume species from short season, low latitude regions in the Mediterranean’ (UWA00040) - GRDC;
- ‘National field evaluation and selection of new pasture plants from the salinity CRC to improve hydrological stability’ (UWA397) - GRDC;
- ‘Investigation into legumes with pharmaceutical and aquaculture potential’ (UWA73A) - RIRDC;
- ‘Evaluation and cultivar selection for herbicide tolerance in annual legume pastures’ (DAW00031) - GRDC;
- ‘Improving weed management with biserrula in the pasture phase of WA cropping systems’ (DAW00032) - GRDC;
- ‘Developing sustainable fodder crop systems with new annual pasture legumes’ (DAW103A) - RIRDC and regional Grain and Graze projects in WA.

Three new projects that are about to commence have arisen as a result of this project. This includes two projects awarded by Pastures Australia, titled ‘Commercialisation of the first subterranean clovers with cotyledon resistance to redlegged earth mites’ and ‘Working with growers to overcome the constraints to adoption of new annual pasture legumes in the medium and low rainfall mixed farming zone of southern Australia’. A new Australian Research Council (ARC) linkage grant has also been awarded for a project titled ‘Molecular approaches for the exploitation of genetic diversity in subterranean clover (Trifolium subterraneum L.) for profitable Australian farming systems’ (LP0669766).

Several new R&D opportunities have been identified for further work. These include:

- developing new pasture plants for low-cost pasture systems for low rainfall areas;
- economic analyses to demonstrate benefits of new pasture options to growers;
- developing pasture legume mixtures for annual and annual-perennial pasture systems;
- appointing a specialist pasture extension officer to liaise between researchers, agribusiness and growers to promote adoption of new pasture legume varieties; and
- collaborative projects with national and international model legume genetic mapping and genomics projects.

Intellectual property summary

An agreed commercialisation process is in place for all varieties developed from this project. DAFWA is the lead commercialisation agency for nine of the varieties commercialised in this project, while DPI Victoria is the lead agency for the variety Napier®. DAFWA will maintain breeder's seed for all varieties. Licensees to produce and market seed of each variety have been selected following public tender applications, with contracts specifying seed production and promotion targets. An agreed royalty split between GRDC and other project stakeholders applies for all varieties developed in this project. Nine varieties have been granted protection under Plant Breeders Rights (PBR), while a trademark is being sought for Sothis eastern star clover. Further varieties developed as part of this project will be commercialised in a similar way.

Additional information

Scientific journal articles


Barbetti, M.J. and Nichols, P.G.H. (2005). Field performance of subterranean clover germplasm in relation to severity of...
Cercospora disease, Australasian Plant Pathology 34: 197-201.


Norman HC, Loi A, Wilmot MG, Rintoul AJ, Nutt BJ and Revell CK (2013). Sheep grazing bladder clover (Trifolium spumosum L.) had similar productivity and meat quality to sheep grazing subterranean clover (Trifolium subterraneum L.) Animal Production Science http://dx.doi.org/10.1071/AN12185


