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Pasture Science UWA

Abstract

MLA, along with GRDC and The CRC for Plant-based Management of Dryland Salinity, funded a 5 year project at The University of Western Australia to revitalise pasture science in Western Australia in relation to undergraduate teaching and postgraduate supervision. The project funded a Lecturer Level B at the University of Western Australia. During the course or the project ~130 undergraduate students were trained in pasture science, 13 postgraduate students were supervised, 9 journal papers and 10 conferences papers were published and greater than $1 million dollars of additional research funds obtained. A focus on development of native perennial species for pastures has resulted in substantial on-going research activity. The pasture science lectureship has now become a permanent position at The University of Western Australia, with on-going benefits to industry from training of undergraduate and postgraduate students and research outcomes.

Executive Summary

MLA, along with GRDC and The CRC for Plant-based Management of Dryland Salinity, funded a 5 year project at The University of Western Australia to revitalise pasture science in Western Australia in relation to undergraduate teaching and postgraduate supervision. The project funded a Lecturer Level B at the University of Western Australia. During the course or the project ~130 undergraduate students were trained in pasture science, 13 postgraduate students were supervised, 9 journal papers and 10 conferences papers were published and greater than $1 million dollars of additional research funds obtained. A focus on development of native perennial species for pastures has resulted in substantial on-going research activity, with *Cullen australasicum* entering a section/breeding program as part of a Future Farm Industries CRC project. A number of postgraduate students are working on this species, as well as other promising native perennials from the *Cullen* genus and other exotic new perennial pasture legumes. In particular, there is a focus on the drought tolerance of these species. Many species show promise for development as drought tolerant perennial pastures for the lower rainfall areas of the wheatbelt. Another area of focus, decline of subterranean clover pastures, is also producing interesting results, with two PhD students to finalise their studies over the next 12 months. As the holder of the lecturing position, Dr Megan Ryan, successfully applied for promotion to Level C, the pasture science lectureship has now become a permanent position at The University of Western Australia and will provide on-going benefits to industry from training of undergraduate and postgraduate students and research outcomes.

Contents

1 Background

In 2004 a need was identified to build capacity in pasture science in WA, particularly in the area of undergraduate teaching and postgraduate supervision. Thus this project was conceived. The project, co-funded between MLA (40%), GRDC (40%) and The CRC for Plant-based Management of Dryland Salinity (20%), funded a Level B pasture science lectureship at The University of Western Australia (UWA) for 5 years. The project in its entirety covered the wage of the lectureship and $10 000 /yr operating. A private bequest from Albany farmer Frank Ford provided sufficient funds for a PhD scholarship and some additional operating. Funding from MLA, GRDC and the Salinity CRC was provided on the basis that the successful applicant would apply for promotion to Level C and thereby secure tenure before the end of the project, allowing the lectureship position to then continue, funded by internal UWA funds.

2 Project Objectives

The MLA objectives for this project were to have delivered, by June 30, 2008:

1) The teaching six times of an undergraduate unit focused on pastures with an ecological and farming systems perspective especially in regards to perennial pastures, to around 20 students each year.

2) 100 students skilled in pasture science R&D

3) Annual reports on the research project "Using native perennial species in agriculture" conducted as a component of this project

4) Supervision of at least 12 undergraduate 4th year projects/honours projects focused on pastures – where feasible these will be linked with related MLA investments

5) Supervision of at least 8 postgraduate students on pasture-focused projects

6) Acquisition of external funds for pastures-related research

7) Publication of at least 10 scientific papers

3 Methodology

The lectureship was advertised (twice) and Dr Megan Ryan was appointed in June 2003.

4 Success in Achieving Objectives

4.1 Objective 1 – undergraduate teaching

The unit "Rainfed Pasture Systems" was developed and taught 5 times between 2003 and 2007. In 2008 the unit underwent substantial revision, primarily to allow inclusion of a new 2 week IPM section and was renamed "Pasture Systems". The unit covers the basics of pasture science, but also included a 2 week section on saltland pastures and a 2 week section on IPM. Student feedback was always positive and scores on the compulsory SURF survey were each year among the best in the school and faculty (evidence of student feedback has been provided in annual reports and is not again reported here). Strengths of the unit include its contributions from DAFWA and other non-UWA people which allow a broad range of information to be presented and provide students an opportunity to link with these external people. In addition, an "outcomes-based" approach to teaching was successfully adopted. In particular, this can be seen in the major assessment item – the farm project. In this project, students had to visit a commercial farm, talk to the farmer and other relevant people (e.g. local agronomist), set some goals for change (to improve environmental or production performance), research ways to meet the goals and write a 3000-5000 word report. Positive feedback was received from students and farmers,

The UWA Handbook entry for Pasture Systems for 2009 is supplied in Appendix 1.

4.2 Objective 2 – 100 students skilled in pasture science

A total of ~ 130 undergraduate students completed the undergraduate pastures unit over the 5 years of the project.

4.3 Objective 3 – Annual reports for "Using Native Perennial Species in Agriculture"

Annual reports for the CRC for Plant-based Management of Dryland Salinity project "Using native perennial species in agriculture" have been submitted each year and accepted by the CRC. The final year of this project was 2007/2008. As only $10 000 had been allocated for this year a Future Farm Industries (FFI) CRC transistion project was successfully applied for ($30 000). This project also finishes mid-2008. The major outcomes of this work are as follows:

1) A thorough survey of native perennial legumes for pasture potential lead to the identification of *Cullen* as a priority genus (along with the herb *Ptilotus polystachyus* for the WA wheatbelt). This work is summarised in a short paper that has been submitted to the 2008 Agronomy conference. (Appendix 2 – note this is an unpublished and not yet referred version).
2) The inclusion of *Cullen australasicum* as a priority species in the new FFI CRC breeding and selection project "Development of novel perennial forage legumes for cropping systems in low and medium rainfall Mediterranean zones"
3) A number of on-going PhD projects (Appendix 3)

4.4 Objective 4 – 4th year/honours projects

In the Faculty of Natural and Agricultural Sciences at UWA all agriculture students must complete a "4th year project" worth 50% of their marks and taking up 50% of their time in their final year (note that students in 3-year degree such as Botany can an optional 4th year "honours project"). These projects are a great opportunity for students to experience and be responsible for a real research project and to interact with researchers external to UWA. A total of 14 undergraduate projects were supervised by Megan Ryan during the 5 years of this project (note 2006 – maternity leave). Of these projects, 8 were linked to MLA investments; 6 to MLA's investment in development of native perennial species for pastures (via the Salinity CRC) and 2 to MLA's investment in development of perennial grasses (via Paul Sanford at DAFWA) (Appendix 4).

4.5 Objective 5 – Postgraduate supervision

Thirteen postgraduate students have been supervised, or are under supervision, as part of this project. One Masters student and 2 PhD students have had their degrees conferred, another 2 PhD students will submit in 2008 and 8 students will remain under supervision in 2009 (Appendix 3).

4.6 Objective 6 – Paper publication

Nine journal papers and 10 conference papers have been published as a result of activities associated with this project. These are listed in Appendix 5. The lag time associated with research activities being translated in publications means that the majority of journal publications resulting from this project are yet to be submitted. It is anticipated that a further 8 papers will be submitted in 2008 and 8-10 papers in 2009. Topics covered by papers yet to be submitted in 2008 include: P and N nutrition of the native herb *Ptilotus polystachyus*, molecular markers for *Cullen*, subclover pasture decline (3), variation in strawberry clover (2) and ecogeography of *Cullen* and will be the result of research conducted by PhD students including Lori Kroiss, Tim Scanlon, Tiernan O'Rourke, Kathi Davies, and Richard Bennett.

4.7 Objective 7 – External funds for pasture research

A substantial amount of funding (> $1 million) has been acquired for pastures research including two large ARC-linkage projects. Projects are listed in Appendix 6.

5 Impact on Meat and Livestock Industry – now & in five years time - Section

Substantial on-going benefits have accrued to the Meat and Livestock Industry from this project through the ~ 130 graduates which have been trained in pasture science and the 13 postgraduate students, some of whom will hopefully continue with a career in pasture research. The creation of a permanent Pasture Science academic position at UWA will allow for similar benefits to accrue indefinitely into the future.

6 Conclusions and Recommendations

This project has met all milestones and has successfully contributed towards a revitalisation of undergraduate teaching and postgraduate research in pasture science in Western Australia. A permanent Pasture Science academic position is now established at UWA.

7 Acknowledgements

Megan Ryan would like to especially thank the following people, among the many, who contributed towards the success of this project.

Mike Ewing for mentorship and support. Mike Ewing and Kevin Goss (Salinity CRC/FFI CRC) for their support of many aspects of the project.

For contributions to teaching, postgraduate and 4th year project supervision and project development:

- Clinton Revell, Phil Nichols, Daniel Real (DAFWA)
- Tim Colmer, Martin Barbetti, Hans Lambers, Mark Tibbett (UWA)
- Richard Bennett and Tammy Edmonds-Tibbett (UWA)

8 Appendices

8.1 Appendix 1 – UWA Handbook entry for Pasture Systems in 2009

Pasture Systems SCIE:3311

OUTCOMES
At the conclusion of this unit students will be able to recall important characteristics of the major pasture plant species grown in Western Australia; recall the major of aspects plant physiology that affect a plants ability to adapt to saline conditions; know the major pathogens that affect pastures in Western Australia and how they can be best controlled; demonstrate understanding of the ecological processes that underlie pasture diversity, persistence, productivity and profitability; discuss how pasture systems can be managed to achieve desired outcomes for plant and livestock productivity and the environment; construct a simple model of seed bank dynamics; write a laboratory report in the form of a scientific paper; and demonstrate critical thinking, including at a farming systems scale

CONTENT
Pastures are examined from an ecological perspective, covering processes at scales ranging from seed-bank dynamics through to pasture composition and livestock productivity. There is an emphasis on how a Mediterranean environment affects plants and livestock, and on how WA systems are rapidly changing in response to a need for improvements in economic returns and environmental outcomes. Key topics include the introduction of new annual pasture legumes, the use of perennial pasture species, saltland pastures, integrated pest management and the benefits of plant diversity. The role pasture management may play a role in addressing problems such as dryland salinity, the lack of green feed for livestock over summer, pest and disease outbreaks and a drying climate is emphasised. This is a key unit for students studying Agriculture, but also very relevant for students studying Animal Science, Genetics and Breeding or Natural Resource Management.

ASSESSMENT
The unit consists of 2-4 lectures per week. Handouts of slides for most lectures will be available on WebCT one week in advance and lectures will be recorded using the Lectopia system. A single day fieldtrip on a weekend will be used to introduce some of the major pasture species grown on commercial farms in the WA wheatbelt. Six hours of laboratory sessions are associated with the 3 week saltland pastures section of the unit (30% of assessment). A two hour laboratory will introduce you to the basic principles of modelling (5% of assessment). A farm-based project will contribute 40% of the assessment (group or individual work) and the final exam 25%.

8.2 Appendix 2 - Agronomy conference paper summarising research on natives

Searching for native perennial legumes with pasture potential

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Abstract

Native perennial herbaceous legumes for potential as pasture plants for the medium-low rainfall zones of the wheatbelt were collected and screened. The aim was to identify species with characteristics suited for domestication and adaptation for difficult environments, such as highly acid soils, poorly fertile soils, and areas with low rainfall or prone to drought. A literature search identified five target genera: *Cullen*, *Swainsona*, *Glycine*, *Kennedia* and *Lotus*. Around 400 accessions, primarily from these genera, were collected from NSW, Victoria, WA, SA and the NT. Most have undergone seed increase, and seed is now stored, at the Australian *Trifolium* GRC in Perth or the Australian *Medicago* GRC in South Australia. Root nodules were collected and > 500 root nodule bacteria isolated, many tested for symbiotic effectiveness on selected host plant species and select strains were placed in long term storage. A database is being developed that will contain linked information on collection sites, plant species and root nodule bacteria. Species of *Cullen*, especially *Cullen australasicum*, show most promise for domestication and have the ability to provide green feed over summer. Several research projects focussed on *Cullen* are now underway. Other genera with potential niche applications include *Lotus* in dry areas and *Glycine* as an understorey in fodder shrub systems. Further investigation of *Swainsona* may have merit as it contains a large number of diverse species.

Key Words
Native plants, rhizobia, *Cullen*, perennial pastures, dryland salinity, autumn feed gap

Introduction
The development of perennial legumes is considered crucial to increasing water use in pasture management and reducing the effects of dryland salinity in agricultural landscapes. Few perennial legumes are available for the drier areas of the Australian wheatbelt or for other situations where lucerne is not well suited. Native legumes may have good adaptation to such situations having often evolved under conditions such as low rainfall, frequent drought, short seasons, poorly fertile soils or highly acid soils. Development of natives may also be desirable as they do not face the quarantine restrictions faced by exotic germplasm, may enhance biodiversity of native flora and fauna and may be considered to have a reduced weed risk (although contamination of local populations by a cultivar

must be considered). Whilst on-going selection and breeding of existing cultivars of exotic perennial legumes, such as lucerne, tends to make incremental gains in adaptation, wild germplasm may be extremely diverse (Bennett et al. 2008) and it may be possible to make large improvements with a few generations of simple selection.

The agricultural potential of native legumes has been recognised for many years (Maiden, 1889; Millington 1958) and some research has been undertaken (Cohen and Wilson 1981; Dicker and Garden 1984,), notably on *Kennedia* (Silsbury 1958), *Cullen* (e.g. Gutteridge and Whiteman 1975, Britten and De Lacy 1979) and *Glycine* (Jones et al 1996). However, until the commencement of this project there had not been a systematic screen of herbaceous perennial legumes with pasture potential (Cocks 2001; Bennett et al. 2002). Following a literature search, target genera were identified: *Cullen*, *Swainsona*, *Glycine*, *Kennedia* and *Lotus.* Seed from species in these genera, along with a large number of other species, was then accessed from either existing collections in Genetic Resource Centres (GRCs) or was collected from the field.

Field collections

A total of 14 collections trips were conducted in South Australia, Victoria, Western Australia, New South Wales and the Northern Territory between 2002 and 2006 (Hughes *et al.* 2008) and were undertaken at suitable times of year for collection of viable seed. Plant collection permits where obtained from relevant State and local authorities. Herbarium records were used as a guide to try and ensure populations could be quickly found. For each suitable population, up to 20% of seed from each plant was collected from up to 100 representative plants or 10% of the population. Consideration was given to avoid oversampling or disturbing natural populations. Details of the site and populations were recorded on detailed passport collection sheets and photographs taken of the site and plants. A representative herbarium specimen was sometimes collected from each taxon and if possible 4-5 healthy, non-ruptured root nodule bacteria nodules were collected and stored on top of cotton wool in a vial of silica gel. Approximately, 400 g of soil from the top 10 cm was also collected and later used for isolation of root nodule bacteria and determination of pH. Both the seed, herbarium and root nodule bacteria were given unique accession numbers that can be linked back to the collection site via an electronic database. Around 400 plant accessions, primarily from *Cullen*, *Swainsona*, *Glycine*, *Kennedia* and *Lotus* were collected and most then underwent seed increase and characterisation at either the Department of Food and Agriculture, Western Australia, Medina Research station or at the Waite campus of SARDI. Characters recorded included: survival over two years, plant habit, productivity, phenology and pod maturity, seed yield, pod presentation, dehiscence and shattering, any other potentially deleterious aspects such as spines and strong odours. Seed and data are now stored at the Australian *Trifolium* GRC at Medina (WA) or the Australian *Medicago* GRC at Waite (SA) and are available for future research activities.

Priority species

Cullen was the most promising genus, with a number of promising species showing good productivity, seed characteristics conducive to mechanical harvesting, adaption to acid and alkaline soils, and good drought tolerance (Bennett et al. 2008) (Table 1). *Cullen australasicum* was the most promising for the medium-low rainfall zones (see Dear et al. 2007), although other species may yet prove equally promising under specific conditions (e.g. *C. palladium* and *C. patens* in very dry areas and *C. cinereum* and *C. graveolens* on heavy clay soils). *Cullen tenax* is a particularly attractive species, with a high seed yield from aerially presented seeds, good feed quality (Robinson et al. 2007) and a good response to frequent cutting (Robinson et al. 2007). However, it seems best suited to medium- high rainfall (Bennett et al. 2008).

Table 1. Characteristics of the five main genera examined and species considered most suitable for further development as perennial pastures for low – medium rainfall zones of the wheatbelt

	Cullen	*Glycine*	*Kennedia*	*Lotus*	*Swainsona*
Habit	Herbaceous to open sub-shrub (0.5-2 m)	Twinning	Groundcover or climbing	Herbaceous, short	Herbaceous to open sub-shrub (0.5- 2 m)
Productivity	Poor-Good	Medium	Poor to Good	Poor	Poor to Good
Retain leaves during summer	Yes	Yes	Yes	Yes	Yes
Seed retained	Yes	No	Varied	No	Varied
Aerial seeds	Yes	No	No	Yes	Varied
Ease of seedling establishment	Good	Good	Often difficult	Good	Good
Other	High variation between and within species	Possible role as a companion species to nurse shrubs	Many best suited to medium to high rainfall. May contain beneficial levels of tannins (Robinson et al. 2007)	Can contain cyanide, but low cyanide lines can be selected (Real *et al* 2005)	Not all species evaluated, may contain toxins
Priority species	*C. australasicum*, *C. pallidum*, *C. patens*, *C. cinereum*	*G. canescens, G. tabacina*	*K. prorepens*	*L. australis*	Further work required

Rhizobia

Rhizobia were isolated from nodules of legumes grown in the soil collected from the field or directly from nodules sampled in the field. Around 500 root nodule bacteria strains were isolated and selected strains have been placed in long term storage, to be available for future research, at the Department of Primary Industries, Rutherglen and at SARDI. To evaluate the effectiveness of rhizobia, plants were grown under aseptic conditions and inoculated with a single rhizobial strain. Comparisons were made with un-inoculated plants and nitrogen-supplied controls. Legume genera differed in their host-strain interactions: *Swainsona* had high specificity, while *Kennedia* and *Lotus* nodulated with a range of rhizobial isolates. Effective rhizobia were isolated for high priority legumes and some of these have performed well in field experiments. For instance, *C. australasicum* nodulated with rhizobia isolated from five speices of *Cullen* including *C. australasicum*, *C. tenax* and *C. cinereum.* The effectiveness of the rhizobial isolates with *C. australasicum* varied from only 66% of the mass of uninoculated plants to over five times the mass of uninoculated plants for the best performing strains after 16 weeks growth in controlled conditions. Thirty two out of a total of thirty four isolates produced effective associations with *C. australasicum,* indicating that this species has low specificity in its rhizobial requirements.

Discussion

How will these plants fit into farming systems?

The target farming system for the native plants is a livestock operation in the lower rainfall zones of the wheatbelt in situation where lucerne is not well suited. Adoption will only occur if the natives do not have to replace more profitable options, particularly cropping. Thus, the natives may be best suited to soils that are unsuited to cropping due to being poorly fertile, highly acid, rocky, or poor water holding capacity. Economic value to the system will be enhanced if the natives can provide green feed in the autumn feed gap and are persistent under grazing. Thus, species that hold onto leaves under drought stress better than lucerne may prove most beneficial. In this regard, plants that can grow, accumulate and retain during summer a reasonable amount of biomass without suffering negative impacts from infrequent grazing (ie slowed growth or senescence due to flowering or accumulation of large amounts on inedible woody biomass) may prove most beneficial. In this context medium to low palatability may be beneficial as it would allow the native perennial to accumulate biomass during winter and spring, whilst accompanying exotic annual legumes and grasses could be grazed.

On-going activities

There are a number of on-going research projects focussed on *C. australasicum*, other *Cullen* species and other native perennial legumes. These projects are examining the breeding system of *C. australasicum* and its ability to cross with other species (molecular markers have been developed for this purpose) and tolerance of herbicides for *C. australasicum*. Tolerance of phosphorus fertiliser, drought, waterlogging and soil acidity are being investigated for a variety of *Cullen* species and native species. Two species, *C. cinereum* and *C. graveolens*, will be trialled in 2008 on heavy clay soils with subsoil constraints at Mukinbudin (< 300 mm average annual rainfall). These two species show remarkable productivity under similar conditions in the Fortescue River Floodplain in northern Western Australia (Nicol 2006). Two accessions of *C. australasicum* will be trialled at three sites in the medium-low rainfall zone of the WA wheatbelt in 2008/09 at part of a RIRDC project. Impacts on productivity and survival of variation in plant density and grazing times will be examined. SARDI is investigating harvest technologies for *C. australasicum via* a RIRDC project. RIRDC will also commence selection and breeding of *C. australasicum* within a FFI CRC/GRDC project involving DAFWA, SARDI and UWA. This project will also investigate a range of exotic perennial legumes which show promise for medium-low rainfall areas. The use of unpalatable nurse shrubs to facilitate the growth of palatable climbing species (*Glycine canescens)* is being investigated with the FFI CRC Enrich project and this project is also investigating the regional adaption and bioactivity of *K. prorepens*. A small RIRDC project at UWA is investigating grain legume potential of selected native species.

Conclusion

This small project has identified Cullen as a *genus* with high agricultural potential and the commencement of breeding and selection on *Cullen australasicum* is an exciting outcome. In addition to the identification of promising native species, seed and rhizobia collected during the project is available to support future breeding and research programs with native legumes. The range of research activities now underway on native legumes may lead to further development of other species and, in addition, further exploratory research may be justified on many genera, notably *Swainsona*.

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8.3 Appendix 3 - Postgraduate students

Student	Degree Type	Title	Supervision	Institut-ion	Funding sources	Status
Lalith Suriyagoda	PhD	Response of *Cullen australasicum*, to soil moisture and phosphorus, interaction with non-legumes and modelling physiological processes under field conditions	Ryan, Lambers, Real	UWA, FFI CRC	SIRF, private bequest, FFI CRC	Started 2008
Kevin Foster	PhD	Drought tolerance of *Bitumanaria bituminosa* var *albomarginata*	Ryan, Real Lambers,	UWA, FFI CRC	FFI CRC	Started 2008
Padmaja Ramankutty	PhD	Auto-calibrating statistical models for predicting perennial pasture production	Renton, Lawes, Ryan	UWA, FFI CRC	FFI CRC	Started 2008
Dion Nicol	PhD	Adaptation of *Cullen cinereum* and *C. graveolans* to the WA wheatbelt	Ryan, Colmer, Lawes	UWA, CSIRO, FFI CRC	FFI CRC	Started 2007
Samantha Clarke	PhD	Native grasses for sustainable perennial pasture systems	Stevens, Ryan, Dixon	UWA, KPBG	RIRDC	Started 2006
Lori Kroiss	PhD	Genetic systems in species of *Cullen* endemic to non summer dominant rainfall regions of Australia	Ryan, Barker	UWA, FFI CRC	SIRF, UIS, FFI CRC, CALM	Started 2006
Richard Bennett	PhD	Adaptation and evaluation of Australian *Cullen* species for use as perennial pastures in Western Australia	Ryan, Colmer, Real	UWA, FFI CRC	APA, MLA, AW Howard, FFI CRC	Started 2006
Tiernan O'Rourke	PhD	Analysis of root rots in subterranean clover in southern Western Australia	Barbetti, Sivasitham-param, Ryan	UWA	AWI, private bequest	Started 2006
Tim Scanlon	PhD	Decline in subterranean clover-based pastures in Western Australia: causes and solutions	Ryan, Wade	UWA	Private bequest	Will submit 2008
Kathi McDonald	PhD	The ecology of herbaceous perennial legumes	Ryan, Ewing	UWA	CRC PBMDS	Will submit 2008

Student	Degree Type	Title	Supervision	Institut-ion	Funding sources	Status
Janet Paterson	PhD	The impact of mechanical defoliation and grazing on the morphology and seed production of annual medic and subterranean clover	Ryan	UWA	APA	Conferred 2006
Lindsay Bell	PhD	Prospects of *Dorycnium* species to increase water use in agricultural systems of southern Australia	Ryan, Ewing, Moore	UWA, DAFWA, CRC PBMDS	APA, CRC PBMDS, AW Howard	Conferred 2006
Suzanne Ehrenberg	MSc	The response to nitrogen and phosphorus of the Australian undomesticated herb *Ptilotus polystachyus*; a comparison with the pastoral herb *Chicorium intybus* 'Puna'	Ryan, Tibbett	UKassel, UWA	na	Conferred 2005

Institutional abbreviations: CSIRO=Commonwealth Scientific and Industrial Research Organisation, CSU=Charles Sturt University, KPBG = Kings Park and Botanic Gardens, UKas=University of Kassel, Germany, UWA=University of Western Australia. *Funding source abbreviations*: APA=Australian Postgraduate Award, AW Howard= AW Howard Memorial Trust, CALM=Department of Conservation and Land Management, CRC PBMDS= CRC for Plant-based Management of Dryland Salinity, FFI CRC=Future Farming Industries CRC, GRDC=Grains Research and Development Corporation, MLA=Meat and Livestock Australia, SIRF= International Research Fees, UIS=University International Stipend

8.4 Appendix 4 - Undergraduate pasture projects supervised at UWA

Year	Student	Degree Type	Title	Supervision	Institution /company
2008	Sharon Connis	Ag 4th YrP	Competitive interactions between subcover, biserrula and capweed	Ryan, Renton, Nichols	UWA, DAFWA
2008	Troy Faithful	Ag 4th YrP	Identifying polymorphic markers for hardseededness in subclover	Ryan, Nichols Ghamkhar,	UWA (CLIMA), DAFWA
2008	Fiona Kelly	Ag 4th YrP	Herbicide tolerance of new drought-tolerant perennial legumes with pasture potential	Ryan, Renton, Ferris	UWA, DAFWA
2008	Amy Goddard-Borger	Ag 4th YrP	The potential of Australian native legume species as a grain crop for southern Australia	Clarke, Ryan, Snowball	UWA (CLIMA), DAFWA
2008	Heidi Waddell	Botany Hons	Response of selected Australian native *Cullen* species to combined low water and phosphorus stresses	Lambers, Ryan, Pang, Ward	UWA, CSIRO
2007	Courtney Piesse	Ag 4th YrP	Examining rooting characteristics of perennial grasses to evaluate their potential for use in grazing systems.	Ryan, Tibbett, Sanford	UWA, DAFWA
2007	Holly Swarbrick	Ag 4th YrP	Investigating the efficacy of topdressing a dry granular legume inoculant (ALOSCA) onto subterranean clover pastures	Ryan, Brau	UWA, Murdoch, ALOSCA
2005	Camille Sasse	Ag 4th YrP	Impact of P-fertiliser on root depth and morphology of native legumes.	Denton, Tibbett, Ryan	UWA
2005	Daniel Gardiner	Ag 4th YrP	Feed quality and response to P and N fertilisers of the native perennial grass – curly windmill grass	Ryan, Henry, Tibbett	UWA, CSIRO
2005	Katie Robertson	Ag 4th YrP	Feed quality and response to cutting of native perennial legumes.	Ryan, Henry, Tibbett	UWA, CSIRO
2004	Deidre Kelly	LWM Hons	The effect of native species cover on the erosion of embankment surfaces	Tibbett, Ryan	UWA, Worsley
2004	Brooke Forsyth	Ag 4th YrP	Feed quality of perennial grasses under different grazing regimes	Ryan, Henry, Sanford	UWA, CSIRO, DAFWA
2004	Ryan Pearce	Ag 4th YrP	Impact of seed size on emergence of pasture legumes	Ryan, Nutt	UWA, DAFWA
2004	Nerida Robertson	An Sci 4th YrP	What causes sheep to have an aversion to biserrula?	Williams, Milton, Ryan	UWA

Institutional abbreviations: ALOSCA=ALOSCA Technologies Pty Ltd, CSIRO=Commonwealth Scientific and Industrial Research Organisation, DAFWA=Department of Agriculture and Food WA, UWA=University of Western Australia, Worsley=Worsley Alumina Pty Ltd. *Course abbreviations*: Hons=Honours, 4th YrP=Fourth Year Project, LWM=Land and Water Management, An Sci = Animal Science, Ag=Agriculture.

8.5 Appendix 5 - Papers published as a result of project activities

Journal

1. Bell LW, Moore GA, Ewing MA, Ryan MH, 2006, Production, survival and nutritive value of the perennial legumes *Dorycnium hirsutum* and *D. rectum* subjected to different cutting heights. *Grass and Forage Science* 61, 60-70.
2. Bell LW, Moore GA, Ryan MH, Ewing MA, 2006, Comparative water use of *Dorycnium hirsutum*-, lucerne- and annual legume-based pastures in the wheatbelt of Western Australia. *Australian Journal of Agricultural Research*, 57, 857-65.
3. Denton MD, Sasse C, Tibbett M, Ryan MH, 2006, Root distributions of Australian herbaceous perennial legumes in response to phosphorus placement *Functional Plant Biology* 33: 1091-102.
4. Robinson K, Bell LW, Bennett RG, Henry DA, Tibbett M, Ryan MH, 2007, Perennial legumes native to Australia - a preliminary investigation of nutritive value and response to cutting. *Australian Journal of Experimental Agriculture*, 47, 170-176.
5. Bell LW, Williams A, Ryan MH, Ewing MA, 2007, Water relations and adaptations to increasing water deficit in three perennial legumes, *Medicago sativa*, *Dorycnium hirsutum* and *D. rectum*. *Plant and Soil*, 290, 231-243.
6. Bell LW, Bennett RG, Ryan MH, Moore GA, Ewing MA, Bennett SJ, 2007, Germplasm collections, eco-geography and climate match modelling to southern Australia for *Dorycnium* species. *Plant Genetic Resource Newsletter*, 150: 1-9.
7. Bell LW, Ryan MH, Ewing MA, Moore GA and Lane PA, 2008, Prospects for three *Dorycnium* species as forage plants in agricultural systems: a review of their agronomic characteristics. *Australian Journal of Experimental Agriculture*, 48: 467-479.
8. Tibbett M, Ryan MH, Barker S, Chen Y, Denton MD, Edmonds-Tibbett T, Walker C, 2008, The diversity of arbuscular mycorrhizas of selected Australian Fabaceae. *Plant Biosystems*, i*n press*.
9. O'Rourke TA, Scanlon TT, Ryan MH, Wade LJ, McKay AC, Riley IT, Li H, Sivasithamparam K, Barbetti MJ, Severity of root rot in mature subterranean clover and associated fungal pathogens in the wheatbelt of Western Australia, *Journal of Crop and Pasture Science*, *submitted*

Conference

1. Bell LW, Ryan MH, 2004, *Dorycnium* species: Alternative perennial legumes for recharge control? *Proceedings of Salinity Solutions Conference*, 2-5 August, Bendigo, (A Ridley, P Feikama, S Bennet, M-J Rogers, R Wilkinson, J Hirth, Eds.) (published on CD).
2. Bennett R, Bennett SJ, Ryan MH, Slattery J, 2004, An ecogeographical analysis of some Australian native legumes; estimating their potential as pasture species for the low rainfall wheatbelt of southern Australia. *Proceedings of Salinity Solutions Conference*, 2-5 August, Bendigo, (A Ridley, P Feikama, S Bennet, M-J Rogers, R Wilkinson, J Hirth, Eds.) (published on CD).
3. Bell LW, Ryan MH, Ewing MA, 2006, Hairy canary clover: a case study for integrating semi-herbaceous forage plants into agricultural systems. *Proceedings of the 13th Australian Agronomy Conference*, 10-14 September, Perth (NC Turner, T Acuna, RC Johnson, Eds.). The Regional Institute Ltd.
4. Bennett R, Colmer T, D Real, Ryan MH, 2006, Hardy Australians: Ecogeography of *Cullen* reveals perennial legumes for low rainfall pastures. *Proceedings of the 13th Australian Agronomy Conference*, 10-14 September, Perth (NC Turner, T Acuna, RC Johnson, Eds). The Regional Institute Ltd.
5. Ellis S, Ryan MH, Angus JF and Pratley J, 2006, Wheat yields after perennial pastures under drought conditions. *Proceedings of the 13th Australian Agronomy Conference*, 10-14 September, Perth (NC Turner, T Acuna, RC Johnson, Eds.). The Regional Institute Ltd.
6. Scanlon T, Wade L, Ryan MH, 2006, Understanding productivity decline in subterranean clover-based pastures in south-western Australia. *Proceedings of the 13th Australian Agronomy Conference*, 10-14 September, Perth (NC Turner, T Acuna, RC Johnson, Eds.). The Regional Institute Ltd.
7. Ryan MH, Barker S, Chen Y, Denton MD, Edmonds-Tibbett T, Tibbett M, Walker C, 2007, Establishing the mycorrhizal status of native Fabaceae. Proceedings of the MEDECOS XI 2007, 2-5 September Perth WA.
8. Clarke S, Stevens J, Ryan M. Mitchell M, Chivers I and Dixon K. 2007. Enhancing native perennial grass germination for sustainable pasture systems. 5th National Native Grasses Conference *Native Grasses for a Thirsty Landscape.* 7-10 October, Mudgee NSW
9. Bennett RG, Ryan MH, Colmer TD, Real D. 2008. New perennial pasture legumes: persistence and productivity of Australian *Cullen* species on deep acid sands in WA's low-rainfall wheatbelt. 2nd International Salinity Forum. Salinity, water and society - global issues, local action. 30 March – 3 April, Adelaide.
10. Bennett RG, Ryan MH, Colmer TD, Real D. 2008. New perennial pasture legumes: Persistence and productivity of Australian *Cullen* species on deep acid sands in WA's low-rainfall wheatbelt. Grasslands Congress. *In press*.

8.6 Appendix 6 - Grants obtained to support project activities

Year	Years	Funding organisation	Title	Value Au$ ('000)
2008	3	RIRDC	Drought tolerance of novel perennial legumes	30
2007	1	FFI CRC	Developing native perennial legumes for agriculture	30
2007	2	RIRDC	Native legumes as a grain crop for diversification in Australia	40
2006	4	ARC Linkage	Molecular approaches for the exploitation of genetic diversity in subterranean clover (*Trifolium subterraneum* L.) for profitable Australian farming systems	358
2006	3	ARC Linkage	Phosphorus - a key factor in the development of novel perennial herbaceous deep-rooted pasture legumes	239
2005	3	AWI	Dysfunctional root systems - linking root pathogens and mineral nutrition in annual legume pastures	99
2005	3	RIRDC	Grass Roots – Native perennial grasses for sustainable pasture systems	260
2005	2	Australian Flora Foundation	Harnessing native Fabaceae for agriculture – the importance of mycorrhizal fungi	12
2004	1	FNAS funds for research initiatives	Phosphorus - a limitation to the development of native legumes for pastures?	10

Institutional abbreviations: DAFWA=Department of Food and Agriculture Western Australia, FNAS=Faculty of Natural and Agricultural Sciences, Worsley=Worsley Alumina Pty Ltd. *Funding source abbreviations*: AWI=Australian Wool Innovation, ARC=Australian Research Council, FFI CRC=Future Farm Industries CRC, MLA=Meat and Livestock Australia, RIRDC=Rural Industries Research and Development Corporation