Summary
This was a pioneering project in the search for alternative perennial legumes to lucerne for the agricultural areas of southern Australia. Over 700 accessions from 69 species were evaluated at Medina Research Station and in 14 field experiments. This project has identified a short list of successful species for further development for a range of soil and climatic niches.

A comprehensive bulletin, ‘Perennial pastures for WA’, covering all aspects of perennial pastures has been produced. This bulletin covers herbaceous perennial legumes, temperate grasses, sub-tropical grasses, herbs, fodder shrubs and saltland pastures and will be published by mid-2006 (five copies will be forwarded to GRDC).

Report Disclaimer
Conclusions

A number of alternative perennial legumes are showing promise for medium to high rainfall areas, especially for waterlogged soils where lucerne is less suited. Promising species include perennial Lotus (Lotus corniculatus, L. cytisoides, L. glaber, L. uliginosus, L. creticus), sulla (Hedysarum), Lotononis (Lotononis bainesii and L. coronarium) and, to a lesser extent, strawberry clover (Trifolium fragiferum) and Dorycnium species (D. hirsutum, D. rectum).

However, in all of the promising species accessions require improvement in one or more attributes before being released as a new commercial variety. In most cases this will require a breeding program dedicated to one species or genus. This result is not unexpected, as there are dedicated breeding programs for lucerne, white clover and all of the annual crops. Specific breeding programs have commenced for perennial Lotus and sulla.

On the other hand, where lucerne is well suited, there were no alternative perennial legumes close to matching lucerne for persistence, production, feed quality and responsiveness to out-of-season rainfall, especially in the annual rainfall zone of less than 500mm.

The results have highlighted that the Mediterranean Basin, which has been the source of the majority of the annual pasture legumes developed in Australia, is unlikely to be a useful source of perennial pastures for the wheatbelt of southern Australia. The perennial species in the Mediterranean Basin are often found at higher altitudes, in moisture gaining sites or on alkaline, medium-textured soils. To illustrate this point, the drought tolerant temperate perennial grasses developed from germplasm from North Africa are only suitable for areas in Western Australia (WA) where the growing season is 6.5 months or longer, which excludes the wheatbelt.

The research with both temperate and sub-tropical grasses has highlighted both the potential and the limitations for the various species in WA. The results of the extensive perennial grass evaluation program are summarised in ‘Perennial pastures for WA’, which also includes the new alternative perennial legumes being developed (L. corniculatus, L. glaber, L. uliginosus, sulla and Lotononis).

Output 2 is a comprehensive, user friendly publication, ‘Perennial pastures for WA’, with a target audience of growers, farm advisers, agribusiness and students. It covers all of the perennial pasture options (herbaceous perennial legumes, temperate grasses, sub-tropical grasses, herbs, fodder shrubs and saltland pastures) for WA, both current and in the pipeline. Each species description covers main features, current and potential use in WA, morphological description with colour photos,
seasonal growth pattern, establishment, soil and climate requirements, management and varieties.

The editorial team has brought in many leading pasture agronomists and scientists from related disciplines (a total of 20 authors) to contribute their expertise to this publication. The large number of authors with different areas of expertise has resulted in a high quality publication, but it has also been the cause of the project running behind schedule.

The aim is for a high quality publication, both in terms of information and presentation. It is in the final stages of production and design and should be printed by mid-2006. Five copies of the published bulletin will be forwarded to GRDC.

**Recommendations**

Future research on alternative perennial legumes

The need for alternative perennial legumes to complement lucerne is a high priority. Current breeding programs (perennial *Lotus*, *sulla*) will deliver options for high rainfall and probably waterlogged soils. However, there are limited options for low rainfall environments (less than 350mm). This is a difficult environment for herbaceous perennial pastures and two possible options are discussed under ‘Future R&D opportunities’.

Lucerne varieties for low rainfall environments

Lucerne was demonstrated to be the best option on well drained soils, especially in rainfall zones less than 500mm. This was achieved by growing standard lucerne varieties, which are developed for a wide range of environments including irrigation (i.e. they have in-built elasticity). What is the potential improvement in lucerne production and persistence if varieties specifically bred for low rainfall environments were available? There is currently a joint South Australian Research and Development Institute (SARDI) and Department of Agriculture and Food, Western Australia (DAFWA) project on developing new lucerne varieties for southern Australia and it is recommended that this continues to be a funding priority.

*Lotononis*

There are promising indications with *Lotononis* and it requires further field testing to determine its potential in ‘Mediterranean’ environments.

‘Perennial pastures for WA’ – update

The bulletin will be published in mid-2006 as a comprehensive and up-to-date guide on perennial pastures for WA. However, in about three years time, it would be desirable to have the bulletin based on the Web. This would be easier to update (e.g. update every 12-18 months) to keep the information current on new varieties and the results of current research. Moving the bulletin on to the web would require re-formatting to a Web-based page layout.

**Outcomes**

Economic benefits

There is widespread interest in perennial pastures in many regions of WA. Many leading growers are moving from the stage of having one or two paddocks of perennial pastures to large areas of their farms under a range of perennial pastures, because they are achieving significant increases in both carrying capacity and profit. Economic modelling with lucerne grown in phase rotations shows that whole-farm profitability can be increased by approx. 13% with a self-replacing cross-bred sheep flock (Flugge, 2006).

The new bulletin ‘Perennial Pastures for WA’ provides a comprehensive, user-friendly guide to all the current and future (under development) perennial pasture options for WA plus all aspects of their management. It will assist growers and their advisers on selecting an appropriate perennial pasture species to achieve livestock outcomes, as well as improving the sustainability of the farming system. This will help to continue the expansion in the area of perennial pastures.

Environmental benefits

Dryland salinity is the number one environmental issue facing agriculture in southern Australia. Phase farming with perennial pastures is particularly attractive because it allows the development of a high water use farming system that includes
cropping. This is a proven system with lucerne, in terms of both economics and water use (sustainability).

A range of new perennial legumes with the potential to complement lucerne were identified in this project. All the species-accessions require further development before they are commercialised and this is occurring in dedicated breeding projects. The expected benefits of alternative perennial legumes to complement lucerne include options for waterlogged soils where lucerne is less suited.

However, the largest benefit of alternative perennials to lucerne is less reliance on a single species. In particular, lucerne - for all of its strengths - is susceptible to a wide range of pests and diseases. The promising species identified in this project are far less susceptible to insect pests like aphids, lucerne flea and red legged earthmite (RLEM) than lucerne. This will allow more robust farming systems to be developed.

Social benefits

In high rainfall districts and on the south coast of WA, agriculture is being challenged by the expanding demand for rural land from the softwood plantation companies who are purchasing land well above its current agricultural value. This can have a negative impact on farming communities, as the number of agricultural properties decreases and growers and their families become more isolated.

Perennial pastures are well suited to the areas selected for plantation. There is the potential to make large increases in both carrying capacity and profit by growing a range of perennial pastures with complementary seasonal growth patterns. This helps to make agriculture a more viable option (return on capital (ROC) compared with selling the farm to a plantation company.

Achievements/Benefits

Background: Need for sustainable farming systems

Salinity has already adversely affected 10-15% of many shires in the WA wheatbelt. If annual crops and pastures are not substantially replaced with perennial species, hydrologists predict that more than 30% of the landscape could be affected by salinity before the water balance reaches a new equilibrium.

Phase farming with perennial pastures is particularly attractive because it allows the development of a high water use farming system that includes cropping. Experience with lucerne as the pasture component of phase rotations indicates that such strategies are both technically feasible and economically profitable. However, perennial pasture options for phase farming are presently restricted to lucerne, which is less suited to acid soils and waterlogged soils. In addition, reliance on a single species, particularly a perennial pasture is ecologically unsustainable. For example, the devastation to the lucerne industry by aphids in the 1970s being a case in point.

The project had two main objectives:
1) Identify alternative perennial legumes to lucerne for the 350-500mm rainfall zone for use in phase farming systems.
2) Identify the best perennial grass/annual legume mixes for the 350-500mm rainfall zone for use in phase farming systems.

Project development and Salinity Cooperative Research Centre (CRC)

To develop new prospective species there are a whole range of factors that need to be evaluated. Many of these were beyond the resources of this project, so an emphasis was placed on developing strong collaboration with other organisations and groups.

Some of these are listed below:

Phil Nichols (DAFWA) undertook RLEM screening of perennial legumes in both 2002 and 2003 as part of a National Annual Pasture Legume Improvement Program (NAPLIP) screening program.

Dr D. Henry (CSIRO) sampled 100 lines at Medina Research Station in both autumn and spring of 2000. The samples were tested for in vitro feed quality (dry matter digestibility, nitrogen (N) content, neutral detergent fibre, acid-detergent fibre) and condensed tannins.

S. Davies (PhD, University of Tasmania - UTas) undertook research on symbiosis of Dorycnium species as part of his PhD
studies at Murdoch University under the supervision of Dr J. Howieson (Centre for Rhizobium Studies (CRS), Murdoch University). In addition, project UWA337 contributed towards the cost of laboratory analysis of condensed tannins (CTs) as a cost effective method for obtaining detailed results on the seasonal pattern of condensed tannins in *Dorycnium* species.

From 1999 to mid-2001, the project largely had a WA focus - as the limited resources were stretched. However, links with interstate collaborators were developed and in 2001, prior to the Salinity CRC, seed of species showing promise was sent to Dr B. Dear (New South Wales Department of Primary Industries (NSWDPI), Wagga Wagga - 36 lines) and P. Evans (Department of Primary Industries Victoria, Hamilton - 45 lines) for field evaluation.

This project was included under the umbrella of the new Salinity CRC (i.e. ‘CRC for Plant-based Management of Dryland Salinity’) from July 2001. This resulted in a broader national focus for the project and opened up many new opportunities. A major benefit was that promising germplasm could now be evaluated across southern Australia, as a network of both recharge and discharge field sites was established in 2002 across southern New South Wales (NSW), northern NSW, Victoria (VIC), South Australia (SA) and WA. (GRDC project UWA397). G. Moore was the activity leader for alternative perennial legumes in Sub-program 5 from 2002 to 2004. This project, together with SARDI, organised all of the national nursery trials (general nursery (x12), waterlogged nursery (x8), acid soils nursery (x2)) in 2002 and 2003.

The primary responsibility for the seed increase of alternative perennial legumes was transferred to the Genetic Resource Centres (CRC) in SARDI and Perth from July 2002. Seed harvested between 1999 and 2001 was also transferred to the GRCs.

Dr M. Ewing and G. Moore were supervisors for Lindsay Bell (Salinity CRC PhD student) who studied prospects for *Dorycnium* species to increase water use of agricultural systems in southern Australia.

A collaboration with T. Lacey (GRDC Million hectares project) resulted in an A3 extension handout summarising the properties of temperate and sub-tropical grasses.

Achievements

Output 1 - A short list of species and priority lines of herbaceous perennial legumes at an advanced stage of development (towards commercialisation) to meet a range of soil and climatic niches.

This was a major task, as the project essentially started in 1999 with few options and little seed. Germplasm acquisition was very successful and more than 700 accessions were obtained, largely from a range of national and international GRCs. Work was done with the Australian Quarantine and Inspection Service (AQIS) and Quarantine WA to minimise the risk of introducing species with ‘weed’ potential. All species had to pass the rigorous weed risk assessment and the weed risk is further reduced because the exotic perennial legumes are not effectively nodulated by the native rhizobia in the soil. More than 650 lines of perennial legumes (69 species) were grown at Medina Research Station under irrigation for seed increase and preliminary agronomic evaluation between 1999 and 2001.

Effective rhizobia strains have been identified for these new species by the CRS at at Murdoch University. It also undertook research to ensure any rhizobium for new species would not compromise the symbiosis of important commercial species, in particular perennial *Trifolium*.

Promising species were evaluated at a suite of field sites across the agricultural area in WA including: Cascades, Tenterden, Cranbrook, Katanning, Narrogin, Wongan Hills, Dandaragan and Bibby Springs. Agronomic experiments were undertaken on herbicide tolerance and time of sowing to improve the post-seeding weed control options and establishment. In addition to the WA trials, starting in 2002 there was a network of sites across southern Australia through the Salinity CRC-GRDC National Field evaluation program.

The Salinity CRC General G x E nursery trials contained a large number of species (approx. 30) and were generally sown on soil types which were suitable for growing lucerne. The high frequency lucerne controls performed well in these trials as expected. Using a weighted index scale (establishment, persistence and biomass) the results from four Salinity CRC general nursery trials from across southern Australia (NSW, south west VIC, SA and WA) were analysed. Lucerne scored 26 points to be equal highest with the perennial herb chicory, while the next best was sulla (*H. coronarium*) with 16 points. Chicory growth was satisfactory in WA, but it showed more potential in NSW. A new project to develop a more drought tolerant chicory is being undertaken through the Salinity CRC from Wagga Wagga.
In medium to high rainfall (400-550mm) regions on soils where lucerne is well suited, there are at present no alternative perennial legumes that can compete with lucerne.

In higher rainfall regions, or on waterlogged soils, the results are different. The highest ranked species-accessions from four waterlogging tolerant nursery trials (NSW, south west VIC and WA - x2) was *T. fragiferum* (Palestine) 21 points; *Lotus glaber* (S 2840) 20 points; *L. corniculatus* (833) 19 points; *L. corniculatus* (CPI 70533) 17 points while lucerne was equal ninth with 14 points.

Promising species-accessions

A number of perennial *Lotus* species showed good potential. However, a problem with almost all *Lotus* species is seed production, as they are prolific seeders but the pods are highly prone to shatter.

At Medina Research Station, under irrigation, *L. cytisoides* was a standout against the lucerne controls (e.g. 2003 autumn biomass was outstanding - with four accessions scoring 4.4-5.0 of lucerne av. 3.1 from 2002 selection-harvest area). However, it struggled at many field sites in both WA and eastern Australia and appears to be unsuited to the climate in southern Australia. Promising accessions include M6, M7 and M8, collected in Sicily as part of CLIMA’s Italy collection mission in 1999, and SA 12955. Seed of promising accessions of *L. cytisoides* was sent to Dr J. Ayres (NSWDPI, Glen Innes) as the northern Tablelands - with a higher incidence of summer rainfall - may suit this species.

*L. corniculatus* (Birdsfoot trefoil) is another species which showed some promise at both Medina Research Station and in the field. In contrast to many other species tested, it is used commercially in the USA, Europe and New Zealand (variety ‘Goldie’). Birdsfoot trefoil is less drought tolerant than lucerne, as it produces a smaller taproot and partitions less carbohydrate reserves to the taproot than lucerne. However, it contains desirable levels of condensed tannins and has good waterlogging and acid tolerance. A number of accessions tested were far superior to ‘Goldie’, which is generally poorly adapted to WA conditions. Promising accessions include: 833 and CPI 70533, however they require improvement in seed retention, resistance to root rot and drought tolerance.

*L. maroccanus* was a standout at Medina Research Station under irrigation and showed good potential in field trials in the first year. However, it repeatedly failed to persist over summer at field sites and behaved as an annual species.

*L. creticus*, from the Mediterranean Basin including North Africa, grew well at Medina Research Station under irrigation and established well in field trials, but the plants never developed into a substantial size. Considering its origin, it is probably suited to neutral to alkaline, medium to fine-textured soils, rather than the acid, coarse-textured soils in WA.

*L. glaber* (syn. *Leucopogon tenuis*), or narrow-leaf trefoil, has good waterlogging tolerance and some salt tolerance, but overseas is mainly grown on alkaline, medium to fine-textured soils. Some promising accessions were grown (e.g. S 2840, S 3148), but its potential role in WA needs to be more fully explored.

*L. uliginosus* (syn. *Lotus pedunculatus*), or Greater lotus, is grown in high rainfall coastal areas in NSW and Queensland (QLD). It is highly tolerant of both acid soils and waterlogging, but has low drought tolerance. There are two varieties grown commercially in Australia, ‘Sharne’ and ‘Maku’ from New Zealand.

A promising accession - ‘12,952’ - was identified, which under WA conditions appears to have superior drought tolerance, persistence and production compared with the commercial varieties. However, lotus is a ‘niche species’ in WA, suited to winter waterlogged and summer moist sites where the rainfall is more than 600mm (similar to strawberry clover). There is a dedicated breeding project to develop new perennial *Lotus* for southern Australia for areas of more than 600mm annual rainfall.

Sulla (*H. coronarium*) was a standout at Manjimup in the herbicide trial and showed promise at Narrogin and in some of the field nursery trials. The low rainfall sulla trials on alkaline soils at Lake Grace failed to establish for two years in succession due to very dry conditions in spring, while sulla performed moderately well at Cascades. The most promising accessions were the Lake Grace ‘ecotype’ and HRN83A, which had previously been selected by R. Yates.

A promising accession of Strawberry clover (*T. fragiferum*) - ‘CIZ10fra’ - was identified, which had excellent seed production at Medina Research Station. However, in field trials on a waterlogged site at Bibby Springs, production and persistence was inferior to that of the main commercial variety ‘Palestine’.

*D. rectum*
(Canary clover) showed outstanding biomass production in the field nursery trials, equal to or superior to lucerne. However, it was difficult to establish from seed as it had poor persistence over summer (Bell et al. 2005). Subsequently, Canary clover has been assessed as a prohibited species by AQIS (formerly unassessed by AQIS and permitted by Quarantine WA). It also contains consistently high levels of condensed tannins (S. Davies PhD-UWA337). Following these latest findings, further research has been put on hold.

*D. hirsutum* (hairy canary clover) came to notice when it showed outstanding biomass production in the field nursery trials and persisted through a 6.5-7 month dry period at Narrogin after being grazed to ground-level. It recovered well at this site and appeared to have potential as an alternative to lucerne.

Research in collaboration with this project subsequently found the feed quality was consistently lower than had been reported elsewhere in the literature and that stock could lose weight grazing on this species (Bell et al. 2006b). This important finding has effectively ended *D. hirsutum* as a possible alternative to lucerne. Elite selections of Tasmania 1002 had previously been sent to Tasmania (TAS) for inclusion in the breeding program.

A number of other species grew well at Medina Research Station under irrigation, but show little or no potential as alternatives to lucerne in southern Australia.

Species with little or no potential in WA include: *Medicago marina*, *Hedysarum carnosum*, *Lathyrus* spp., *Galega orientalis* and all of the perennial clovers tested from Africa, America and the Europe-Mediterranean Basin (except *T. fragiferum*) and many of the biennial *Melilotus* spp.

Output 2
The results of the numerous perennial grass and alternative legume trials have been summarised into a comprehensive and user friendly guide to perennial pastures in WA. ‘Perennial pastures for WA’ (a DAFWA Bulletin) is a major publication undertaken as part of project UWA337. It covers all of the current commercial species of herbaceous perennial legumes, temperate grasses, sub-tropical grasses, herbs, fodder shrubs and saltland pastures, plus the perennial legumes in the pipeline. There are some 20 authors, including many experienced pasture agronomists plus other scientists, covering a wide range of disciplines. The plan is for a full colour publication of approx. 200 BS pages.

Other research
Many research and development (R&D) opportunities have emerged from this project. As indicated, breeding-selection programs for specific species/genus have commenced for sulla and perennial *Lotus*.

A perennial legume showing promise in medium to high rainfall areas is *Lotononis* (*L. bainesii*). To become a viable commercial option, new improved selections for southern Australia need to be combined with a reliable establishment package. This work is currently not funded.

The ‘Perennial pastures for WA’ bulletin, which covers all perennial pasture options (legume, grass, herb, shrub) current and in the pipeline, highlights the limited options in low rainfall areas (less than 350mm). This project demonstrated that herbaceous perennial legumes are going to be very difficult to find for low rainfall areas. A successful plant needs to have a combination of extreme heat and drought tolerance, good feed quality, tolerance of acid soils and be responsive to out-of-season rainfall events. This combination does not seem to occur in a single species. In low rainfall environments, many species have one or more of the following attributes: conservative growth rates, woody or shrub habit, thorns or anti-nutritional factors to dissuade grazing, strongly summer dormant and/or are suited to medium to fine textured soils with a neutral to alkaline soil reaction trend.

The two most likely opportunities for low rainfall areas (less than 350mm) are native legumes (but often they contain anti-nutritional factors) or ‘wild’ relatives of lucerne with low-set crowns and better drought and grazing tolerance. Both of these are likely to require considerable breeding/selection for multiple factors if they are to have a major impact in low rainfall areas. Preliminary research has commenced through the Salinity CRC, but there will need to be a long-term commitment to funding.

The great potential of temperate perennial grasses in high rainfall areas of WA was highlighted both in this project and in the Salinity CRC-GRDC National Field Evaluation Project (UWA397). The spatial area where temperate grasses are well suited has
been identified in ‘Perennial pastures for WA’ (growing season more than 6.5 months). However, the current level of adoption is low, so what is required to achieve widespread adoption? More small plot research, even if it demonstrates outstanding biomass production will probably not achieve the desired result. A farming systems approach demonstrating that integrating a range of perennial pastures, including temperate perennial grasses, can result in a major increase in both stocking rate and profit is likely to have more impact on adoption. One idea is to have a satellite project in the high rainfall ‘cold zone’ (identified in ‘Perennial pastures for WA’) connected with the main ‘Evergraze’ site (on the south coast near Wellstead) to show the net benefits to the farming systems in both profit and sustainability.

Intellectual property summary

Outputs generated in this project are in the form of information, rather than products, and IP is not readily captured by normal commercialisation processes.

The bulletin, ‘Perennial pastures for WA’ will be a saleable publication. It is proposed to use the proceeds from sales for a revision/reprint of the document in three to four years time.

Additional information

Books

Journal articles and conference papers


