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Perennial grass improvement for low-medium rainfall recharge environments

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Abstract

Developing perennial grasses that are adapted to the low-medium rainfall environments in temperate Australia is highly desirable, but challenging, due to lack of suitable cultivars in the market and extremely unreliable rainfall patterns in these regions. The current trend of climate change will exacerbate the problems. This project aims to improve cocksfoot, tall fescue and sub-tropical grasses for the wheat sheep zone of Victoria, New South Wales, South Australia and Western Australia. Over 400 accessions selected from a large pool of germplasm collected or resourced worldwide have been screened and evaluated on multiple sites in Victoria, New South Wales and Western Australia for 5 years. Through extensive selection and breeding, 11 elite lines of cocksfoot, tall fescue and sub-tropical grasses have been developed. These elite lines (sub-tropical grasses) or their parental materials (breeding lines of cocksfoot and tall fescue) exhibited superior performance compared with their relevant control cultivars. Further field validation and commercialisation of the lines are under way. It is expected that the new grasses developed from this project will significantly improve pasture yield, persistence and nutritive value, and expand the area of improved perennial pastures sown in the target environments where current commercial cultivars do not adapt.

Executive Summary

The "Perennial grass improvement for low-medium rainfall recharge environments' project, starting from January 2004, has been funded by Meat and Livestock Australia (MLA), CRC for Plant-based Management of Dryland Salinity (now FFI CRC), Victorian Department of Primary Industries (VDPI), New South Wales Department of Primary Industries (NSWDPI) and Department of Agriculture and Food Western Australia (DAFWA).

The overall aim of the project is to develop perennial grasses for low-medium rainfall recharge environments in temperate and Mediterranean climate regions of Australia, mostly dominated by annual species. Major perennial grass species in these environments include phalaris, cocksfoot, tall fescue and sub-tropical grasses. Considerable research on developing new phalaris cultivars has been conducted by CSIRO; therefore this project has focused on developing new cultivars/lines of cocksfoot, tall fescue and sub-tropical grasses.

The objectives were:

1) Develop a persistent summer active tall fescue variety so as to extend its area of adaptation into lower and less reliable rainfall regions receiving a high proportion of their annual rain in summer (500-600mm per year). Relative to Demeter fescue, the elite line will have increased green biomass over summer by 20% leading to improved water use, total annual biomass by 25%, and plant persistence by 20%.
2) Develop a persistent winter active cocksfoot variety with some summer activity and selection for nutritive value for low input recharge areas and acid soils in areas receiving 400-600mm per year. Elite genotypes will increase the digestibility by at least 2%, cool-season dry matter yield by 10% and summer vigour/growth by 5-10%, relative to Currie cocksfoot.
3) Develop varieties of sub-tropical grasses suitable for profit driven adoption in temperate and Mediterranean climatic regions. Elite lines will have two of the following: 20% greater persistence, 20% greater October to May dry matter production, 20% greater spring dry matter and 3% increase in digestibility relative to nominated control cultivars.

Two methodologies were used to develop new lines of the grasses. For tall fescue and cocksfoot, selection and cross pollination were adopted to breed new synthetic varieties whereas, for sub-tropical grasses, field evaluation and screening were used to identify elite lines. During the breeding process of tall fescue and cocksfoot, preparation, evaluation and selection of parental materials for the new lines took 2-3 years, cross pollination and production of synthetic 1 (syn1) seed took one year and establishment of isolation blocks and production of synthetic 2 (syn2) seed took over one year. Therefore, the new elite cocksfoot and tall fescue lines could not yet be evaluated by the project according to the proposed breeding plan, and data presented below are from their parents. The project completed the objectives as follows:

1) Development of three elite tall fescue lines. The lines include two summer-active and one winter-active lines, which had been tested for five years with low rainfall. In comparison with Demeter, the commonly sown cultivar in the northern tablelands of NSW, the parents of the two summer-active lines had improvements in total pasture yield by 21-30%, summer yield by 14-26% and persistence by 15-22%. The parents of the winter-active line had similar total yield, lower summer yield, but 11% higher winter yield and 10% higher persistence than Demeter under the environment with summer rain. The average digestibility of the parent plants of the selected Sardinian lines was slightly below that of Demeter but was significantly higher than most of the other cultivars.
2) Development of four elite cocksfoot lines. The lines include two hispanica sub-species and two temperate to intermediate type of cocksfoot. After two summers the four

Mediterranean accessions (the parents of the two hispanica lines) had a mean vigour score 34% higher than the best cultivars and 40% higher than the control cultivar Currie. The plant survival of these lines was 100% compared to the commercial cultivars which ranged from 31-97% in plant survival. Plants from the three best cultivars (Jana, Medly and Currie) were selected to be the parents for a Currie replacement candidate cultivar. The hybrid, Portuguese, accession 'AVH48' performed well as it has in previous central Victorian studies. The best plants of AVH48 will make up the fourth candidate cultivar.

3) Development of four elite sub-tropical grass lines. Four panic grass (*Panicum maximum*) lines have been identified with outstanding performance over the control cultivar. These include two short, upright type of panic grass with fine leaves and two medium to large-sized type. In WA both the elite panic lines and the control varieties had excellent persistence (>95%) at all five sites. However, this was not the case in NSW where two lines had persistence of 70-72% compared with only 26% for the control. The elite lines had spring biomass which was 22-59% higher, while the overall biomass production was 14-37% higher at Badgingarra and 15 to 67% higher at Muresk. Apart from yield and persistence, the four elite lines of *Panicum maximum* also have favourable growth habit and morphology and good seed yield potential.

Development of these elite lines was achieved by three linked components focused on each of the grass categories – tall fescue, cocksfoot and sub-tropical grass. The tall fescue component is led NSWDPI, cocksfoot by Victorian DPI and sub-tropical grass by DAFWA. Eleven sites have been established in target environments of NSW, Vic. and WA since 2004. Although sites in each state have a clear focus on individual species/category, promising lines have been evaluated on multiple sites across states.

A Material Transfer Agreement (MTA) has been progressed between the FFI CRC and Heritage Seeds, allowing Heritage to evaluate the elite lines of tall fescue, cocksfoot and panic grass for up to 2 years to assist further decisions on commercialisation. To ensure maximum benefit from the collaboration, details of expected work, performance and communication processes have been negotiated with Heritage Seeds, including future work on PBR and DUS test of the new lines.

Two new projects, 'Improved perennial grass cultivars for the inland slopes of the Great Dividing Range' and 'Productive, persistent tropical grasses in farming systems', will continue to evaluate and commercialise these new lines from 2009 to 2011, in collaboration with Heritage Seeds under the MTA. New cultivars will be released, which will potentially adapt well to the following regions/environments: 1) northern tablelands, northern slopes and central tablelands of NSW with a high proportion (40-50%) of summer rain (summer-active tall fescues and panic grasses); 2) low rainfall temperate zone from southern NSW, Vic., to SA with low proportion (<30%) of summer rain (cocksfoots and winter-active tall fescue); and 3) the Mediterranean environments in southwest WA (primarily panic grasses).

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1 Background

Livestock production has dramatically increased in the temperate zone of southern Australia; however, the feedbase in this zone does not generally support higher animal production. The options to replace low water use annual pasture with a perennial system are very limited – market failure has occurred for perennial species adapted to higher rainfall conditions with increased productivity. This project has sourced and identified elite parent with key traits for cultivar development to reduce recharge and will target environments where current cultivars are unsuitable and poor in persistence due to drought, grazing sensitivity or soil constraints such as acidity.

The research will widen the area of adaptation of Australia's cool season temperate grass cultivars, and where perennial grasses can reliably be established, it is expected that ground water recharge will be significantly reduced. The target species are tolerant of strong acidity (cocksfoot - *Dactylis glomerata* L.) and waterlogging (tall fescue - *Festuca arundinacea* Schreb.) – conditions that significantly restrict the potential of many herbaceous species. The catalogue of perennial grass cultivars on the market will be expanded, particularly in the category of persistent low rainfall cultivars. The adaptation range is around 10 million ha in the 450-600 mm rainfall belt.

Recharge management using profitable perennial plants requires an array of plant species and cultivars suited to the widely contrasting climatic, soils and farming systems within the target zones. Temperate perennial grasses that feed into livestock production systems already exist for some circumstances. An opportunity exists to extend their application, particularly on the drier margins of current use and to increase their effectiveness by creating a larger buffer of dry soil during the summer.

A scoping study by the CRC Salinity identified candidate species to be developed to achieve the multiple aims of addressing recharge, providing ground cover and persistence. A plant-breeding program was required, which involves a development phase regarding the target species tall fescue, cocksfoot and summer-active perennial grasses of sub-tropical origin.

An increase in the area sown to perennial grasses would significantly reduce ground water recharge. There is substantial data to show that perennial grasses can be 70 to 100% as effective as lucerne in reducing recharge. In many areas lucerne is not an option and perennial grasses the only viable alternative. The new plant cultivars would also assist in the development of new phased farming systems providing a viable alternative to shallow rooted annual pastures.

2 Project Objectives

The overall aim of the project is to develop perennial grasses for low-medium rainfall recharge environments in temperate and Mediterranean climate regions of Australia, mostly dominated by annual species. Major perennial grass species in these environments include phalaris, cocksfoot, tall fescue and sub-tropical grasses. Considerable research on developing new phalaris cultivars has been conducted by CSIRO; therefore this project has focused on developing new cultivars/lines of cocksfoot, tall fescue and sub-tropical grasses.

By 30 December 2008:

1. Develop a persistent summer active tall fescue variety so as to extend its area of adaptation into lower and less reliable rainfall regions receiving a high proportion of their annual rain in summer (500-600mm per year). Relative to Demeter fescue, the elite line will have increased green biomass over summer by 20% leading to improved water use,

total annual biomass by 25%, and plant persistence by 20%.

2. Develop a persistent winter active cocksfoot variety with some summer activity and selection for nutritive value for low input recharge areas and acid soils in areas receiving 400-600 mm per year. Elite genotypes will increase the digestibility by at least 2%, cool-season dry matter yield by 10% and summer vigour/growth by 5-10%, relative to Currie cocksfoot.
3. Develop varieties of sub-tropical grasses suitable for profit driven adoption in temperate and Mediterranean climatic regions. The elite lines will have two of the following: 20% greater persistence, 20% greater October to May dry matter production, 20% greater spring dry matter and 3% increase in digestibility relative to nominated control cultivars.
4. Develop at least 1 new fast-tracked tall fescue cultivar derived from line 358 (MRC Project No. DAV.095) for commercial release of an Australian adapted temperate perennial grass species suited to medium to low rainfall regions and improved for water use, nutritive value, summer/winter growth and persistence. Selected genotypes will show a 20-30% improvement in winter and summer herbage yield compared to Demeter fescue; a 20% increase in seedling vigour compared to Demeter and improved digestibility (3%) compared to Demeter in spring, at maturity and in autumn.
5. Establish an arrangement, approved by MLA, with a commercial partner, approved by MLA, for the fast-tracked fescue and selected sub-tropical lines, and develop a commercialisation plan for elite lines of fescue and cocksfoot.
6. Subject to clause 5.5, seek interim protection from the plant breeder's rights (PBR) office and provide a commercial brief suitable for attracting expressions of interest from potential licensees, who will be expected to pay for PBR application, extended merit-testing, seed increase and marketing costs.

By agreement of the Project Management Committee, Objective 4 was not progressed due to wild type endophyte contamination (67%) of the accession proposed for the tall fescue fast-track option.

3 Methodology

3.1 Project protocol and scoping study

Full details of the methodology for cocksfoot, tall fescue and sub-tropical grasses are given in the project protocol (Appendix 1) and in Harris *et al.* (2006) (for tall fescue and cocksfoot). The project was developed based on a scoping study (Appendix 2) on perennial pastures for the recharge areas of southern Australia. The study identified candidate species to be developed to achieve the multiple aims of addressing recharge, providing ground cover and persistence.

3.2 Sites and Conditions

The project has 3 linked components focused on each of the 3 grass categories – tall fescue, cocksfoot and sub-tropical grass. Eleven sites have been established in target environments of NSW, Vic. and WA since 2004. Although sites in each state have a clear focus on individual species/category, promising lines have been evaluated on multiple sites across states. The sites and conditions are described briefly below.

Tall fescues sites in NSW

The North-West Slopes of NSW are typical of non-traditional tall fescue locations where past and present cultivars have been disappointing. Sites were selected near Barraba and Inverell, based on soil type and fertility, annual average rainfall, altitude and paddock history.

The Inverell site established a year later than the Barraba site due to drought is not considered as a primary source of data for plant selection; however, it is considered important for confirmation of data from Barraba. Descriptions of the sites are presented in Table 1.

Both the sites experienced very dry conditions throughout the evaluation period and monthly rainfall totals were below average rainfall 54% and 64% of the time for the Barraba and Inverell sites respectively. Both sites were characterised by very dry autumns and above average maximum temperatures in most months.

Table 1. Site descriptions of the tall fescue breeding nurseries in North-West NSW

	Barraba	Inverell
No. of plant entries	100	115
Location	20 km NW of Barraba	Bukkulla 34 km NW of Inverell
Latitude	30° 24’ S	29° 21’ S
Longitude	150°24’ E	151° 07’ E
Altitude	450 m	520 m
Long-term Annual Average Rainfall	689 mm	767 mm
Soil pH ($CaCl_2$)	4.8	5.0
Phosphorus ppm (Bray)	8.0	10
Sulfur (KCl_{40})	4.0	4.0
Organic Carbon (%)	2.2	1.2
Cation Exchange Capacity (c mol(+)/kg)	17	16
Potassium (c mol(+)/kg)	0.27	0.63
Aluminium (c mol(+)/kg)	0.13	0.10

Cocksfoot sites in Victoria

The selection of the cocksfoot sites was concentrated on the Central Highlands of Victoria between Ararat and St Arnaud. Sites were selected at Bealiba and Warrak. Deep cores were removed from candidate sites to determine soil structure, acidity, and aluminium levels. The selected sites were then chosen on the basis of high soil aluminium, low pH, average annual rainfall and history of poor perennial grass persistence. Descriptions of the two cocksfoot sites are presented in Table 2.

Table 2. Site descriptions of cocksfoot breeding nurseries in central western Victoria

	Bealiba	Warrak
No. of entries	83	83
Location	5 km SE of Bealiba	15 km east of Ararat
Latitude	36° 49’ 23.4” S	37° 14’ 23.2” S
Longitude	143° 35’ 07.0” E	143° 06’ 59.7” E
Altitude	260 m	330 m
Annual Average Rainfall	472 mm	601 mm
Soil pH (CaCl2)	4.6	4.2
Phosphorus	3 mg/kg (Olsen)	7 mg/kg (Olsen)
Potassium	170 mg/ka	100 mg/kg
Aluminium	21 mg/ka	22 mg/kg
Electrical Conductivity	0.05 dS/m	0.06 dS/m

Sub-tropical grass sites in WA and NSW

A wide range of species and germplasm of sub-tropical grass were assessed across diverse environments in order to assess genotype by environment effects. Germplasm evaluation row and plot trials were established initially at two sites in WA followed by the evaluation of promising germplasm at three satellite sites (Muresk, Buntine, Mingenew) in 2006 and three sites in northern NSW. A summary of these sites, including average annual rainfall, soil type, and the number of germplasm evaluation trials established from 2004 to 2007 is provided in Table 3.

Table 3. A summary of the sub-tropical grass germplasm evaluation sites and trials in WA and northern NSW

Site	Average rainfall (mm)	Soil type	Trial
		Trial sites in Western Australia	
Badgingarra	490	Grey sand over gravel at 30 cm	6x row and 3x plot trials
Wellstead	425	Grey sandy duplex	4x row and 2x plot trials
Muresk	450	Red-brown loamy soil	Promising panic grass row nursery
Buntine	~350	Deep yellow loamy sand	Promising panic grass row nursery
Mingenew	~450	Deep pale sand	Promising panic grass row nursery
		Trial sites in northern New South Wales	
Yetman	660	Sandy loam	6 x row trial, 3x plot trials
Warialda	688	Red loam	4x row trial
Inverell	767	Black earth, alluvial	4 x row trial

3.3 Development of elite cocksfoot lines

Cocksfoot is a productive and versatile grass that has been widely used in tablelands and slopes districts of NSW and Victoria since the early days of pasture improvement. It is hardy, non-toxic to stock and better adapted to low pH, high aluminium soils than most other temperate grasses. It also combines well in pasture mixtures with other grasses and legumes. While responsive to added fertiliser, it is better able to cope with lower levels of soil fertility than perennial ryegrass. However, it does not thrive on poorly drained or saline areas where tall fescue or phalaris are preferred and has a slightly lower nutritional value than some of the other perennial grasses. Present commercial use of cocksfoot in Australia is dominated by two cultivars Currie and Porto, which were both derived from Mediterranean accessions.

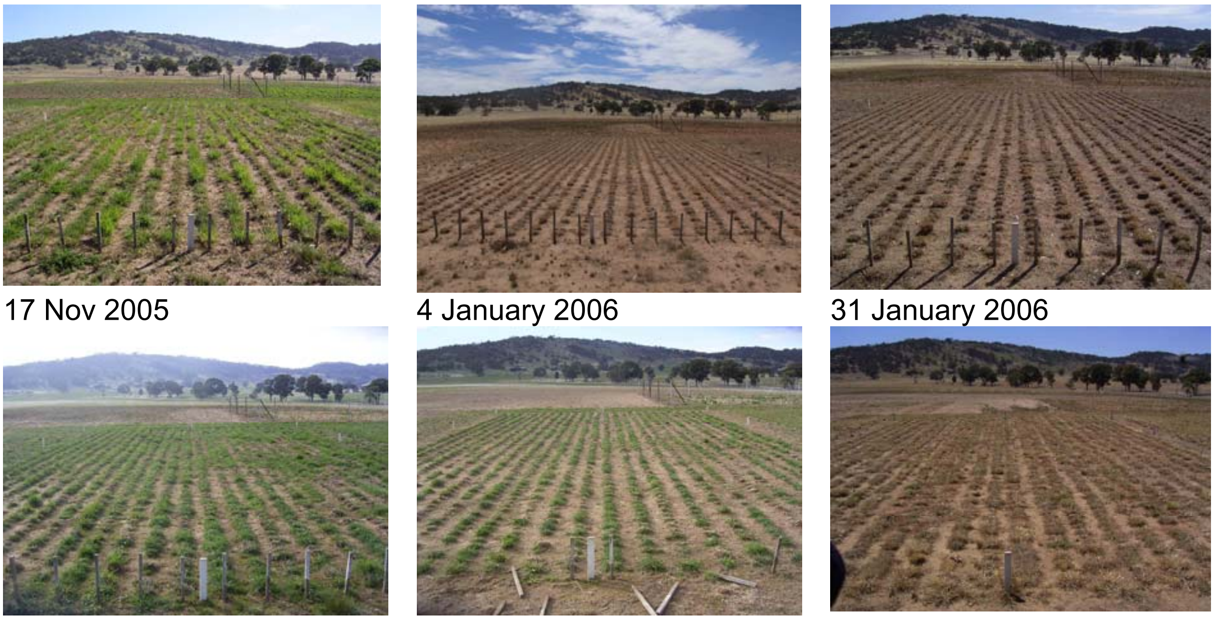
Research in central western Victoria (Figure 1) has emphasised the value of Mediterranean plants and research in Victoria and Tasmania has characterised and evaluated an extensive collection - approx 150 accessions including 40 from low rainfall locations in the Mediterranean basin. This work has identified some valuable populations and promising genotypes compared to Currie and Porto.

Figure 1. A Google Earth view of the Bealiba research site (100m x 100m square) in April 2007 showing the landscape we are targeting for the new cocksfoot cultivars.

The initial germplasm comprised a total of 84 cocksfoot accessions, experimental varieties and cultivars. The cocksfoot accessions included material from North Africa, Sardinia and the Tasmanian DPI cocksfoot breeding program. These accessions were chosen on the basis of soil pH and rainfall at collection sites and on information pertaining to drought and grazing tolerance. The cultivars included all those commercially available in Australasia and some recent cultivars from Italy and France, developed for temperate and Mediterranean climates.

Two breeding nurseries were established at Bealiba and Warrak, central western Victoria. Each breeding nursery was planted as a row-column design with 8 replicates and 30 cm column spacing. Each row comprised four individual plants spaced 15 cm apart. Buffer plants of Currie cocksfoot were planted in rows and columns around the edge of both nurseries. The densely arranged spaced plant design was used to facilitate evaluation of individual plants under conditions approximating the inter-plant competition experienced in a sward.

In May 2004 seeds of the candidate treatments were germinated and grown as seedlings at DPI Hamilton until mid-August 2004 when they were transplanted into the field nurseries. Between August 2004 and August 2006 the entries were assessed for seasonal yield, persistence, growth habit, flowering intensity, leaf width and nutritive value (Figure 2). This information was used to select the parents for the breeding component of the project.



17 Nov 2005 | 4 January 2006 | 31 January 2006

18 May 2006 | 27 June 2006 | 3 November 2006

Figure 2. Bealiba spaced plant nursery.

In September 2006 the best 44 plants to meet the breeding objectives were removed from the field sites and transferred to the glasshouse facility (crossatron) at DPI Hamilton for cross-pollination. Seed from all 44 plants was collected and cleaned in Feb-March 2007. In April 2007, seed from each plant was germinated and seedlings were grown in preparation for the Syn1-2 bulk-up in 2007-08. Isolation areas were prepared for each of 4 lines in a Triticale paddock at DPI Hamilton and at Glen Innes, NSW, and seedlings were transplanted in late winter 2007. Syn2 seed was harvested both in autumn 2008 (not fully representative to their parents) and summer 2008-09 (fully representative).

3.4 Development of elite fescue lines

Tall fescue was identified for improvement for low to medium rainfall (400-700 mm) environments where the persistence of common cultivars has been unreliable. Over 80 accessions and experimental varieties of tall fescue were screened over two years at sites on the North-West Slopes of NSW. These lines were compared with some locally naturalised plants and most of the cultivars available in Australasia as well as cultivars developed for warm temperate and Mediterranean climates in Italy, France, Uruguay and the USA.

The initial germplasm used in this improvement program comprised a total of 115 tall fescue accessions, experimental varieties and cultivars. Experimental varieties included material from the Tasmanian Institute of Agricultural Research and the Experimental Institute of Forage Crops Italy. The Institutes for National Agricultural Research in Uruguay and France provided seed of cultivars that they had developed.

The tall fescue accessions were chosen from an Australian collection made in North Africa and Sardinia, the USDA collection and a collection of Mediterranean populations. In choosing accessions, there was an emphasis on material originating from the Mediterranean basin. Some naturalised plants that had been removed from old tall fescue pastures (> 12 years old) that had survived grazing and drought pressure on the Northern Tablelands of NSW were also included. The cultivars of tall fescue included all those commercially available in Australasia and some recent cultivars from Italy, France, Uruguay and the USA, developed for temperate and Mediterranean climates.

The tall fescue entries were propagated in the glasshouse at Glen Innes until transplanted into the field sites. The tall fescue nurseries were planted in a row-column design with 8 replicates and 30 cm column spacing. Each row comprised four individual plants spaced 15 cm apart. Buffer plants of Demeter tall fescue planted in rows and columns around the edge of the nurseries. The densely arranged spaced plant design was used to facilitate evaluation of individual plants under conditions approximating the inter-plant competition experienced in a sward.

General site description data including weather and management were recorded, as well as, regular photographic records. The main measurements were seasonal yield and persistence but other characters recorded were growth habit, maturity, disease tolerance, leaf size and texture. Plant samples were also collected from selected entries to determine nutritive value and endophyte status.

Measurements of seasonal yield were conducted at least 4 times a year at the change of season. Yield was assessed by calibrated visual ratings on a scale of 1 (low) to 9 (high). To calibrate ratings at least 12 cuts were taken at each assessment within each replicate to measure the dry matter yield over the 1-9 range of ratings. Persistence was measured twice a year (autumn and spring) by counting the number of plants surviving.

Assessment of flowering (maturity) was carried out over spring/summer in the second year of the experiment. At each observation (approximately once a week), the average stage of flowering for a maximum of five tillers per plant (20 tillers of each line per replicate) was recorded. The stages recorded were vegetative growth, flowers in boot, emerging heads, flowers open and anthesis. The mean date for the various stages of development for each line was determined.

About a third of all the tall fescue lines were tested for nutritive value in spring 2005; the lines were selected based on 2005 yield, persistence and tiller density data. Fifteen grams fresh leaf and stem material was collected, dried at 65°C and ground to pass through a 1 mm screen. Crude protein, estimated *in vivo* dry matter digestibility, nutrient detergent fibre and water soluble carbohydrate concentrations were determined by NIR.

A selected number of plants (~33% of all lines) were tested for endophyte by screening 6 tillers/plant in July and September 2006 using an Agrinostics Phytoscreen field tiller test kit – a solid phase, stacked immunoblot assay.

In October 2006, plants of the best performing tall fescue accessions were collected from the Barraba tall fescue nursery.

These plants were potted and transferred to crossatron at DPI Hamilton for controlled cross-pollination. Like cocksfoot, seed of these synthetic tall fescue lines were increased in isolation 2006/2007. The seed from each plant was harvested, cleaned and tested for germination. Seed weight from these tall fescue plants ranged from 1 to 17 grams and germination of the seed ranged from 58 to 100%. Syn 2 seed were produced in isolation in 2008-09 at Glen Innes and Hamilton.

3.5 Development of elite sub-tropical grass lines

The sub-tropical grass improvement project started from a different position than either the cocksfoot or tall fescue which are both proven commercial species in temperate environments. The growing of sub-tropical or warm season grasses in temperate and Mediterranean environments is a new development in farming systems. From limited field evaluation mainly on producers' properties the sub-tropical grasses were showing considerable promise to increase the carrying capacity of deep sandy soils which were marginal for cropping. They were also showing potential to have major NRM benefits in terms of reducing deep drainage and reducing the risk of erosion through increased groundcover. However, the only commercial varieties available were developed for a totally different environment, i.e. summer rainfall regions in sub-tropical and tropical Queensland. New varieties specifically developed for the soils and climate of southern Australia would have superior performance and persistence in the target environments.

There were broadly two types of experimentation, species evaluation and germplasm evaluation, which are described separately below:

Species evaluation across south-western Australia

The objective of this work was to develop guidelines as to where the various sub-tropical grass species are well suited, where they are marginal and where they are not suited across the agricultural area of Western Australia. In WA there was no clear understanding of the most suitable species or their area of adaptation, so there was a need to confirm species ranking using commercially available varieties. There was minimal data on the seasonal production and quality of sub-tropical (warm season) grasses, except for kikuyu which was extensively studied on the south coast in the Sustainable Grazing Systems project. In northern NSW a G x E study had previously been undertaken by L. McCormick and B. McGufficke.

Five trials were established in spring 2004 (Buntine, Irwin, Badgingarra, Kojonup) and in spring 2005 (Esperance) across the agricultural area of WA to measure the seasonal production of sub-tropical grasses both for quantity and feed quality in a collaborative arrangement between this project, AWI-Evergreen Project and Grain and Graze in the northern agricultural region. This collaboration had added value to enhance our research capacities.

The replicated plot trials (row-column design with 3 reps, plots 7 m x 3.6 m) had between 12 and 20 treatments including a range of commercial varieties of sub-tropical grasses and an annual volunteer control, lucerne and, where appropriate, temperate grasses (i.e. perennial veldt grass, tall wheat grass, tall fescue). In addition, in autumn 2005 an annual pasture trial was established adjacent to the perennial pasture trial.

Germplasm evaluation

The sub-tropical grass germplasm evaluation first needed to develop a working collection of germplasm. A seed increase program was then undertaken prior to evaluation in the field. In addition, a number of submissions were made to AQIS/WAQIS for species which had not previously been assessed by quarantine.

For the development of a working collection, sub-tropical grass species were prioritised into ‘core’, ‘promising’ and ‘exploratory’ species at a project planning workshop (Dec. ‘03) with collaborators from Queensland. Prior to this project many of the sub-tropical grass species had never been grown in WA, so the rankings were based on very limited field data plus expert knowledge of the performance of the various species in other environments.

Most of the germplasm was sourced from the Australian Tropical Forages Genetic Resource Centre in Biloela, Queensland through curator Dr Peter Lawrence (Qld DPI). This was the start of an invaluable collaboration with QDPI who undertook the initial seed increase of the lines. More than 250 perennial grass lines were seed increased in north Queensland in collaboration with Dr Kendrick Cox from Queensland DPI at the Walkamin Research Station. A small number (~20) of *Digitaria eriantha* lines were sourced from the USDA and introduced into Australia after being grown in AQIS post-entry glasshouse facilities.

The sub-tropical grass lines were subsequently evaluated at a range of field sites in northern NSW and WA which were established between 2004 and 2007 (Table 3). All of the species were evaluated in northern NSW; however only a smaller suite of species were evaluated in WA as WAQIS prohibits the entry of some sub-tropical grass species into WA.

Row trials were established with a row-column design from SPADES or similar programs and were replicated 4 to 6 times. Most of the row trials were established from seedlings with 6 plants per 1.5 m row with the inter-row spacing varying from 0.3 to 0.8 m depending on the environment and growth habit. In WA row trials were established each year from 2004 until 2007. The row trials were regularly measured for persistence, seeding, biomass, feed quality and opportunistically for stresses such as cold damage, moisture stress and green leaf over summer. Other characters recorded included growth habit, leaf size and tiller number. General site description including weather and management were recorded, as well as regular photographic records.

In 2005 a seed increase program commenced at Medina Research Station near Perth to provide additional seed for field evaluation and to evaluate the seed production potential of the germplasm which was showing promise in field trials. More than 170 lines of sub-tropical grasses were seed increased in small plots between 2005 and 2008. In 2006 11 large plots (50 m x 2.5 m) were established from seed using a cone seeder to evaluate the seed production potential of a range of promising *Panicum maximum* lines compared with the two commercial control varieties (Gatton, green panic). The large plots were harvested with a small plot harvester. The seed maturity was studied using x-ray technology to develop a methodology to refine the time of harvesting in collaboration with researchers from Kings Park BGPA.

The WA field data was analysed using Residual Maximum Likelihood (REML) IN GenStat by Padmaja Ramankutty (DAFWA biometrician). Persistence data and production data were analysed separately. Initially, a mixed model was fitted to each data set with accession, row, column and the row by column interaction as random effects. Correlations between rows and between columns were modelled as autoregressive processes with lag 1 (AR1). The number of plants alive at establishment was used as a covariate. Average persistence (or production as appropriate) of the two adjacent row plots and average persistence (or production as appropriate) of the two adjacent column plots were also used as covariates because plots adjacent to missing plots tend to show improved growth in these grasses. Spatial effects were examined by fitting linear trends across both rows and columns. The significance of fixed spatial effects and the correlations were examined and non-significant effects were removed from the model before estimating accession means.

The model assumes that the error terms are normally and independently distributed with zero mean and constant variance.

The persistence data were transformed before analysis using the angular transformation to ensure that the model assumptions were met. Where necessary the production data were transformed before analysis using either the square root or the cube root transformation to ensure that the model assumptions were met.

4 Results and Discussion

4.1 Results and Discussion - Cocksfoot

Mean yield score data for the commercial cultivars and the four best Mediterranean accessions are summarised in Tables 4 and 5. Currie was the control cultivar at each site. It is generally more persistent in dry environments than Porto, the other common Australian cultivar.

At Bealiba the four best cocksfoot accessions recorded the highest yield scores in 2006, the driest year for the life of the project, and the mean of these was 34% higher than that recorded for the best performing cultivars (Jana and Medly) and 40% higher than that recorded for the control cultivar Currie. At Warrak the four best cocksfoot accessions had yield scores comparable to Currie in 2006.

Table 4. Mean yield, persistence, tillering, flowering and leaf width scores for cocksfoot cultivars and select accessions at Bealiba

Cultivar / accession	Yield[A] 2004/05 (7)	Yield 2006 (3)	Persistence[B] 27.06.06	Tillering[C] 11.08.05	Flowering[D] 07.10.05	Flowering 17.11.05	Leaf width[E] 10.08.06
Currie	6.8	5.0	94	4.0	63	100	2.6
Grasslands Kara	5.4	0.4	31	3.3	0	25	2.8
G. Tekapo	6.5	1.6	56	4.8	25	100	2.8
G. Vision	7.0	0.5	34	4.2	135	88	2.7
G. Wana	6.0	1.1	50	5.0	0	63	2.8
Gobur	7.3	2.9	91	4.0	63	100	3.5
Jana	6.7	5.2	88	4.5	13	100	2.8
Kasbah	3.7	4.2	97	3.6	100	13	2.1
Ludac	7.1	1.5	56	6.2	13	75	2.3
Luron	6.5	0.9	50	5.0	0	38	2.7
Medly	7.2	5.1	91	3.7	100	100	2.5
Oberon	6.6	2.6	66	4.6	13	100	3.1
Padania	6.0	1.2	66	2.8	38	100	3.1
Porto	7.7	3.2	88	5.0	25	100	2.9
Yarck	7.0	2.2	75	4.1	13	88	3.6
AVH 48	7.4	5.0	93	5.4	14	100	2.7
Mediterranean 1	6.2	7.5	100	8.5	63	88	1.1
Mediterranean 2	5.8	6.9	100	6.9	50	100	1.6
Mediterranean 3	6.4	7.2	100	6.8	50	100	1.2
Mediterranean 4	7.6	6.5	100	6.0	38	100	2.0
l.s.d. (p=0.05)	0.92	1.27	20.6	1.16	19.6	13.2	0.49

[A]Yield score scale 1 to 9 where 1=poor & 9=excellent. The number in brackets in column title indicates the number of scores in each period.
[B]Persistence=% plants surviving at a nominated date.
[C]Tillering score scale 1 to 9 where 1=poor & 9=excellent.
[D]Flowering = percentage of plant tillers in full flower at a nominated date.

[E]Leaf width score scale 1 to 4 where 1=very fine, 2=fine, 3=medium (average) & 4=broad.

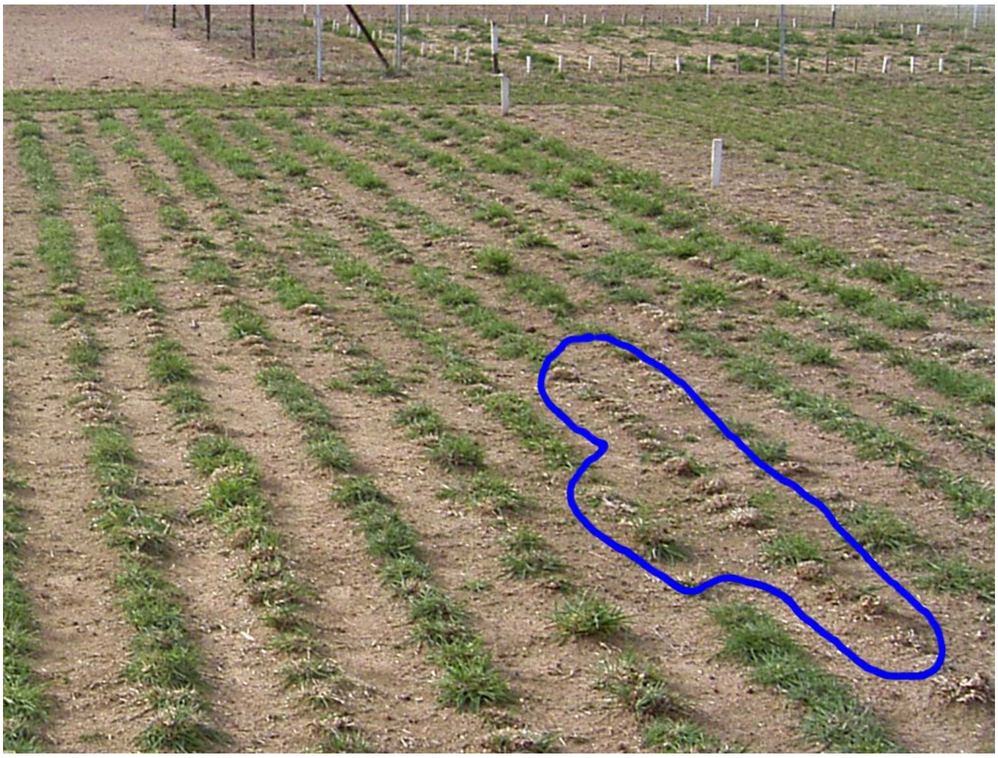
Table 5. Mean yield, and forage quality of cocksfoot cultivars and select accessions at Warrak

Cultivar / accession	Yield[A] 2004/05 (6)	Yield 2006 (2)	CP[B]	NDF[C]	WSC[D]	IVVDMD[E]	ESTME[F]
Currie	5.8	5.1	31.4	39.6	5.5	83.8	12.8
Grasslands Kara	7.5	0.8	29.2	41.8	5.2	77.7	11.7
G. Tekapo	7.6	2.6	27.4	47.9	5.2	74.9	11.3
G. Vision	8.2	1.9	31.6	41.3	6.5	82.9	12.6
G. Wana	8.0	1.8	30.2	43.1	4.3	78.6	11.9
Gobur	7.6	2.4	35.6	41.9	1.2	81.1	12.3
Jana	7.1	6.2	27.4	43.4	5.9	79.2	12.0
Kasbah	3.3	3.7	27.6	44.7	6.2	76.5	11.6
Ludac	8.0	0.7	30.5	41.0	7.7	82.3	12.5
Luron	8.1	1.2	29.6	42.0	7.0	81.7	12.4
Medly	7.3	6.8	27.7	42.5	10.2	82.7	12.6
Oberon	8.4	3.0	29.8	40.6	7.7	81.0	12.3
Padania	6.5	2.2	29.7	36.9	11.5	86.0	13.2
Porto	8.1	2.2	28.5	44.7	6.3	79.0	12.0
Yarck	7.4	2.2	31.4	36.7	6.9	84.0	12.8
AVH 48	7.8	3.8	30.4	39.8	6.7	80.9	12.3
Mediterranean 1	4.7	5.6	33.0	40.7	4.3	79.3	12.0
Mediterranean 2	3.6	4.6	30.9	43.8	4.5	79.4	12.0
Mediterranean 3	4.4	4.9	32.0	37.1	8.0	82.8	12.6
Mediterranean 4	6.0	5.0	29.8	40.6	7.5	82.6	12.6
l.s.d. (p=0.05)	0.81	1.22	3.76	4.61	3.84	3.79	0.64

[A]Yield score scale 1 to 9 where 1=poor & 9=excellent. The number in brackets in column title indicates the number of scores in each period.
[B]CP = Crude Protein % of DM.
[C]NDF = Neutral detergent fibre % of DM.
[D]WSC = Water soluble carbohydrate % of DM.
[E]IVVDMD = Digestibility % of DM.
[F]ESTME = Metabolisable energy MJ/kg DM.

The four best cocksfoot accessions were all more densely tillered and finer leaved than Currie. Persistence of the cultivars ranged from 31 to 97% of plants surviving by June 2006 (Figure 3).

November 2005



June 2006

Figure 3. Poor persistence of some cocksfoot lines at Bealiba through the 2005/06 summer.

The four selected Mediterranean accessions all had 100% of plants surviving at this time. Most, but not all cultivars were in full flower by mid November.

All four Mediterranean accessions were in full flower by mid-November.
Some other Mediterranean lines that were otherwise similar in production and growth habit did not produce many flowering tillers and were not considered as candidates for the breeding program.

Measurements of nutritive value of the four best cocksfoot accessions were comparable to Currie for crude protein, neutral detergent fibre and water soluble carbohydrate. However two of these accessions had slightly lower digestibility and metabolisable energy levels than Currie.

In early September and October 2006, plants of the best performing lines were collected from the two cocksfoot sites. These plants were potted and transferred to pollen-proof glasshouse chambers at DPI Hamilton Victoria for controlled cross-pollination. Four synthetic cocksfoot candidate cultivars were developed (Figure 4):

1. A very fine-leafed, densely tillered line based on the select Mediterranean *D. glomerata ssp. Hispanica* accessions;
2. A fine-leafed line based on the select Mediterranean D. *glomerata ssp. hispanica* accessions;
3. A Currie replacement line based on select plants of the *D. glomerata ssp. glomerata x hispanica* hybrids;
4. A line based on select plants of AVH48 which has also shown promise in previous Victorian evaluation sites.


1. Fine-leafed, densely tillered


2. Fine-leafed, densely tillered


3. Currie replacement


4. AVH48

Figure 4. Representative plants of each synthetic candidate cultivar in the glasshouse at DPI Hamilton.

Seed of these synthetic cocksfoot candidate cultivars has been undergoing bulk-up at Hamilton, Victoria and Glen Innes, NSW in 2007/08-2008/09. In Autumn 2008, seed of 320, 160 and 230 g was harvested for lines 1, 2 and 4, respectively, at Hamilton (no seed harvested for line 3). At Glen Innes, all 4 cocksfoot lines were harvested with seed of 350, 105, 420 and 1420 g for lines 1 – 4, respectively. These seeds were not fully representative because a proportion of the parent plants did not go flowering. Fully representative syn2 seed was harvested at Hamilton in summer/autumn 2009, with the amount of seed being 2900, 5200, 2840 and 690 g for lines 1 – 4, respectively. At Glen Innes, seed harvested in summer/autumn 2009 was 5.8, 4.6, 2.4 and 4.0 kg for lines 1 – 4, respectively. Further evaluation and commercialisation will be carried out in the new FFI CRC project.

4.2 Results and Discussion – Tall fescue

Barraba nursery
Figure 5 illustrates the variability in production and persistence of the tall fescue accessions, experimental varieties and cultivars evaluated at Barraba.
The least persistent lines (<20%) also had low average yield scores; in comparison the most persistent lines (>90%) generally had high productivity.

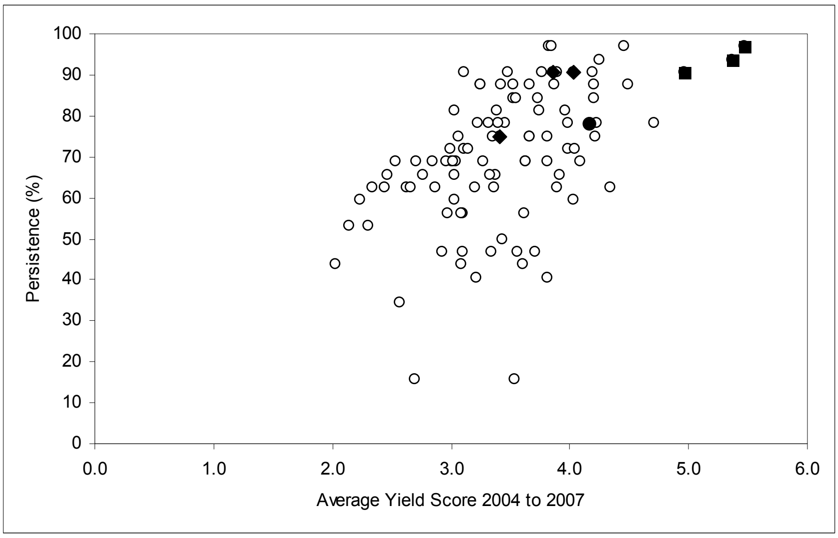


Figure 5. Average yield (visual score) from November 2004 to October 2006 of all tall fescue accessions, experimental varieties and cultivars (○) plotted against persistence in October 2006 at Barraba. The cultivar Demeter is represented by ●, the Sardinian lines by ■ and the best performing Mediterranean lines by♦.

Plant establishment, seasonal yield (visual score), persistence, rust tolerance, leaf characteristics, endophyte status and nutritive value data are presented for best performing accessions, experimental varieties, GI accessions and commercial cultivars from the Barraba site in Tables 6 and 7.

Table 6. Seasonal and annual average yield, growth habit, rust tolerance, flowering, nutritive value, and endophyte status for tall fescue cultivars and select accessions (6/83) at Barraba

	Summer Yield[1] 2004/05 (3)	Winter Yield[2] 2005 (2)	Average Yield[3] 2005 (7)	Summer Yield 2005/06 (3)	Winter Yield 2006 (2)	Average Yield 2006 (5)	Growth Habit[4]	Leaf Width[5]	Rust[6]	Flower-ing[7]	Digesti-bility[8]	Crude Protein[9]	Endophyte Status[10]
Demeter	4.9	5.1	5.0	3.9	2.7	3.3	SE	4	1	78	67.83	8.18	Negative
AU Triumph	4.9	5.3	5.0	3.8	2.5	3.2	SE	3	1	48	63.20	8.18	Negative
Centurion	4.2	4.8	4.3	2.7	2.8	2.8	SE	2	0	79	*	*	*
Ceres Torpedo	3.8	4.5	4.1	1.9	0.8	1.3	SE	2	0	16	*	*	Negative
Ceres Typhoon	4.7	5.8	5.1	3.4	2.0	2.7	SE-E	3	1	97	63.20	5.93	*
Dovey	5.5	4.8	5.2	4.0	2.8	3.5	E	3	1	72	64.23	8.43	Negative
Estanza-Tacuabe	4.8	4.5	4.6	3.0	1.9	2.5	SE	3	0	64	67.05	8.12	*
Grasslands Advance	5.1	5.4	5.1	2.9	1.8	2.3	E	3	0	88	*	*	Negative
G. Advance MaxP	4.3	4.7	4.3	2.8	2.0	2.4	E	3	0	81	*	*	Positive
Grasslands Flecha	4.4	4.6	4.5	2.9	3.4	3.2	SE	2	0	67	*	*	Negative
G. Flecha MaxP	3.8	4.5	3.9	2.5	3.1	2.8	SE	2	0	74	*	*	Positive
Fraydo	3.9	5.7	4.6	2.8	3.3	3.1	E	2	0	73	59.05	6.28	Negative
Jesup	4.3	4.2	4.2	3.1	1.9	2.5	SE	2	1	81	*	*	Negative
Jesup MaxP	5.0	4.9	5.0	4.3	3.7	4.0	SE	3	1	88	64.30	6.45	Positive
Lunibelle	3.5	3.8	3.6	1.9	1.3	2.6	SE	3	0	69	*	*	*
Lutine	3.2	4.2	3.7	3.4	2.6	3.0	SE	3	0	78	67.78	8.13	*
Magno	4.3	5.2	4.6	3.3	1.9	2.6	E	3	2	58	67.92	8.21	*
Prosper	4.0	4.3	4.0	1.7	2.3	2.0	SE	2	0	66	*	*	*
Quantum	4.9	6.0	5.4	4.5	3.4	4.0	SE-E	3	1	80	60.43	4.60	Negative
Quantum MaxP	4.8	5.4	4.9	3.7	2.5	3.1	SE-E	4	1	74	61.80	5.38	Positive
Resolute	3.8	5.0	4.2	2.9	2.9	2.9	SE	2	0	76	55.63	5.23	Negative
Resolute MaxP	4.4	5.8	5.0	3.1	3.8	3.5	SE	2	0	82	*	*	Positive
Tanit	4.0	4.3	4.0	2.7	2.2	2.4	SE	2	0	84	*	*	*
Vulcan II	5.1	5.6	5.3	2.5	1.0	1.7	SE	2	0	94	59.78	7.33	Negative
FA005	4.8	5.8	5.4	5.7	5.2	5.6	SE	3	1	99	63.23	8.35	Variable
FA006	4.7	5.2	4.8	5.1	4.9	5.1	SE	3	1	78	57.25	5.08	Variable
FA009	4.5	6.0	5.4	5.7	4.8	5.4	SE	3	1	100	66.58	7.15	Variable
Mediterranean 4	3.8	5.1	4.2	3.8	3.8	3.8	SE	3	0	99	55.95	8.93	Negative
Mediterranean 5	4.1	5.3	4.5	3.2	3.2	3.2	SE	3	0	94	56.48	7.50	Negative
Mediterranean 6	3.1	4.3	3.6	3.2	3.2	3.3	SE	3	0	78	52.03	5.60	Negative
l.s.d. (0.05)	0.4	0.4	0.6	0.5	0.3	0.4	-	-	-	-	1.01	0.36	-

1. Summer yield = average of yield scores over each summer, score scale is 1 to 9, where 1 is lowest & 9 is highest. The number in brackets in column title indicates the number of scores in each summer period.
2. Winter yield = average of yield scores over each winter, score scale is the same as summer yield. The number in brackets in column title indicates the number of scores in each winter period.
3. Average yield = average of all seasonal yield scores for each year, score scale is the same as summer yield. The number in brackets in column title indicates the number of scores in each year.
4. Growth Habit, SE=semi erect, E=erect
5. Leaf width = width of leaf at broadest part of the blade, score scale is 1 to 4, where 1=very fine, 2=fine, 3=medium (average) and 4=broad.
6. Rust = score of rust incidence, 0=no rust, 1=low, 2=medium & 3=high
7. Flowering = percentage of tillers in full flower at 26/11/05
8. Digestibility =% of DM, plants sampled in Spring 2005
9. Crude Protein = % of DM, plants sampled in Spring 2005
10. Endophyte Status = presence or absence in tillers, sampled in autumn/winter 2006. A variable result indicates that some plants were positive & some were negative – all plants of these lines were re-sampled in September 2006 to identify negative plants

* = not sampled

Table 7. Plant establishment and plant survival for tall fescue cultivars and select accessions (6/83) at Barraba

	Establishment[1] 2004	Persistence[2] 2005	Persistence[2] 2006
Demeter	91	81	78
AU Triumph	88	81	69
Centurion	81	81	81
Ceres Torpedo	81	72	16
Ceres Typhoon	100	97	63
Dovey	94	91	63
Estanza-Tacuabe	84	78	47
Grasslands Advance	91	84	47
Grasslands Advance MaxP	78	81	47
Grasslands Flecha	88	81	81
Grasslands Flecha MaxP	84	81	81
Fraydo	94	97	97
Jesup	84	81	63
Jesup MaxP	94	88	88
Lunibelle	63	69	34
Lutine	63	78	66
Magno	88	91	44
Prosper	59	66	66
Quantum	94	91	78
Quantum MaxP	94	88	59
Resolute	91	81	81
Resolute MaxP	88	88	88
Tanit	81	84	63
Vulcan II	100	94	16
FA005	100	100	97
FA006	94	94	91
FA009	100	100	94
Mediterranean 4	84	97	91
Mediterranean 5	94	94	91
Mediterranean 6	69	78	75
l.s.d. (0.05)	8.0	7.5	9.8

1. Plant establishment = the number of plants alive after 8 weeks, expressed as a percentage
2. Persistence = the number of established plants alive at October 2005 & October 2006, expressed as a percentage.

Of the 83 tall fescue accessions and experimental lines tested at Barraba, three select accessions (FA005, FA006 & FA009) of east Sardinian origin showed the most potential when compared to the commercial cultivars. These lines exhibited higher establishment (8% greater than Demeter), superior year-round production (64% greater than Demeter in 2006 and 34% higher than that recorded for the best performing summer active cultivars (Jesup MaxP and Quantum)), and superior persistence compared to Demeter. Selected endophyte-free plants of these accessions also exhibited enhanced summer and winter production (40% and 84% greater than Demeter respectively) in 2006. While there were a number of endophyte-infected plants within these lines, there were more high yielding, endophyte free plants than endophyte positive plants to select.

The selected Mediterranean accessions 4, 5 & 6 (all of North African origin) had only comparable yield to Demeter but they were of interest because of their greater persistence, winter production (11% > than winter-active cultivars) and apparent facultative summer dormancy (28% > than winter-active cultivars).

The winter-active cultivars - Fraydo, Grasslands Flecha, Grasslands Flecha MaxP, Prosper, Resolute, and Resolute MaxP persisted well, without loss of plants, from 2005 to 2006. In regions that experience a relatively long growing season (or receive summer rain such as Barraba and Tamworth), winter-active cultivars may not provide as much production as summer active cultivars.

At Barraba, there was little significant difference between Demeter, Resolute, Resolute MaxP, Fraydo and Grasslands Flecha. However, yield of Grasslands Flecha MaxP and Prosper were generally lower than that of Demeter.
The Mediterranean cultivars were noticeably more tolerant of rust. Their performance at the Barraba site suggests that they would be suitable for the North-West slopes - particularly because of their persistence.

Of the summer-active cultivars, Jesup MaxP had high persistence, productivity and quality compared with Demeter. Quantum, Dovey and AU Triumph were also productive (especially in 2005) but only moderately persistent. Although Ceres Typhoon and Vulcan II had excellent establishment, productivity and persistence in 2005, they declined dramatically in 2006.

Other overseas cultivars Centurion, Estanza-Tacuabe, Lunibelle, Lutine, Magno and Tanit all had moderate to high persistence but only moderate productivity. While these cultivars may not perform as well as the current commercial cultivars in the low to medium rainfall areas of the summer rainfall zone, they could be considered for evaluation in the winter rainfall zone.

Tall fescue plants with “safe” endophyte are reported to have the potential to extend the zone of adaptation of tall fescue into lower rainfall and less reliable areas, through increased summer growth and drought tolerance. At Barraba, all commercially available “safe” endophyte cultivars (traded as MaxP) and their nil endophyte comparisons were established. Apart from Jesup (yield & persistence 2006) and Resolute (yield 2006), endophyte infected cultivars (MaxP) showed no advantage in productivity or persistence over their nil endophyte counterparts.

In late 2006, plants of the best performing tall fescue lines were collected from the tall fescue site at Barraba. These plants were potted and transferred to pollen-proof glasshouse chambers at DPI Hamilton Victoria for controlled cross-pollination. Seedlings of the resulting synthetic (syn1) tall fescue varieties were planted in isolation in 2007 at Glen Innes and Hamilton. In autumn 2008, syn2 seed of 220 and 970 g was harvested for synthetics 1 and 2, respectively, at Hamilton (no seed harvested for synthetic 3). At Glen Innes, all 3 tall fescue synthetics were harvested with seed of 725, 825 and 75 g for synthetics 1 – 3, respectively. These seeds were not fully representative because a proportion of the parent plants did not go flowering. Fully representative syn2 seed was harvested in summer/autumn 2009, with the amount of seed being 2.1, 4.4 and 2.1 kg from Hamilton, and 7.8, 4.4 and 4.1 kg from Glen Innes, for synthetics 1 – 3, respectively. This seed will facilitate evaluation of syn2 varieties at a number of regional target sites commencing in 2009. These experimental varieties of tall fescue will be evaluated as grazed swards for persistence, nutritive value, seasonal production, drought tolerance and disease tolerance.

Barraba screening experiment
In July 2005, an experiment was established at Barraba to screen additional tall fescue germplasm. The experiment consists of 100 accessions, experimental varieties and cultivars of tall fescue sown in drill rows by 4 replications. The drill rows are arranged in a row by column design each replicate consisting of 4 blocks of 25 drill rows 30 cm apart and 1 m long. The sowing rate of the tall fescue was 15 kg/ha.

Figure 6 illustrates the variability in production and persistence of the tall fescue accessions, experimental varieties and cultivars evaluated at Barraba as drill rows. The cultivars with the highest persistence and yield are Resolute MaxP and Fraydo. The selected Sardinian and Moroccan accessions from the nursery are also in this experiment. The Sardinian lines have shown evidence of high production and persistence, with one line FA009 consistently ranking second or third.

The selected Moroccan accessions are persisting but not ranking as highly for yield. A number of other accessions have exhibited high persistence and yield and warrant further investigation.

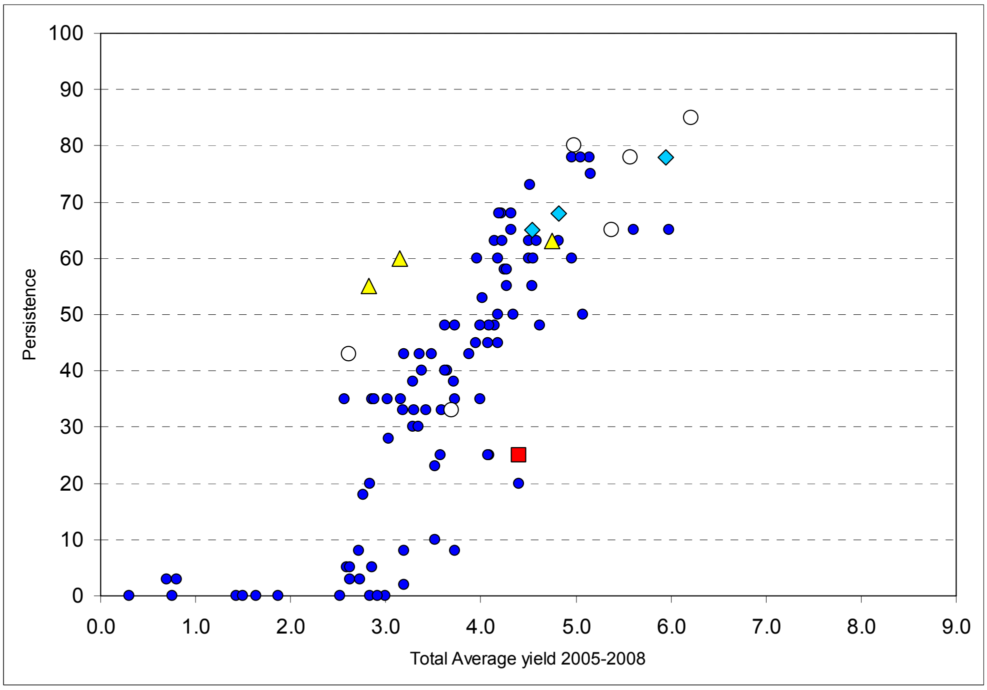


Figure 6. Average yield (visual score) from November 2005 to October 2008 of all tall fescue accessions, experimental varieties and cultivars (●) plotted against persistence (number of plants survived) at October 2008 at Barraba. The cultivar Demeter is represented by ■, winter active cultivars by ○, the Sardinian lines by ♦ and the best performing Mediterranean lines by ▲.

Inverell nursery

Figure 7 illustrates the variability in production and persistence of the 115 tall fescue accessions, experimental varieties and cultivars evaluated at Inverell. Despite the dry conditions at the Inverell site, a number of lines persisted well and/or ranked highly for yield. The control cultivar, Demeter persisted poorly at 40% with only 15% of lines having persistence below this. Resolute, Resolute MaxP and Fraydo are the most persistent and high yielding cultivars. The selected Sardinian lines (from Barraba nursery) are all above average with respect to persistence but yield has been variable (ranging from low to high) especially over the very dry autumn of 2008. The persistence and production of the selected Moroccan lines (from Barraba nursery) has been variable at this site. A number of other accessions have exhibited high persistence and yield at Inverell – these were the same lines that performed well in the Barraba screening experiment, confirming the need for further investigation of these lines as potential parent material for future breeding programs.

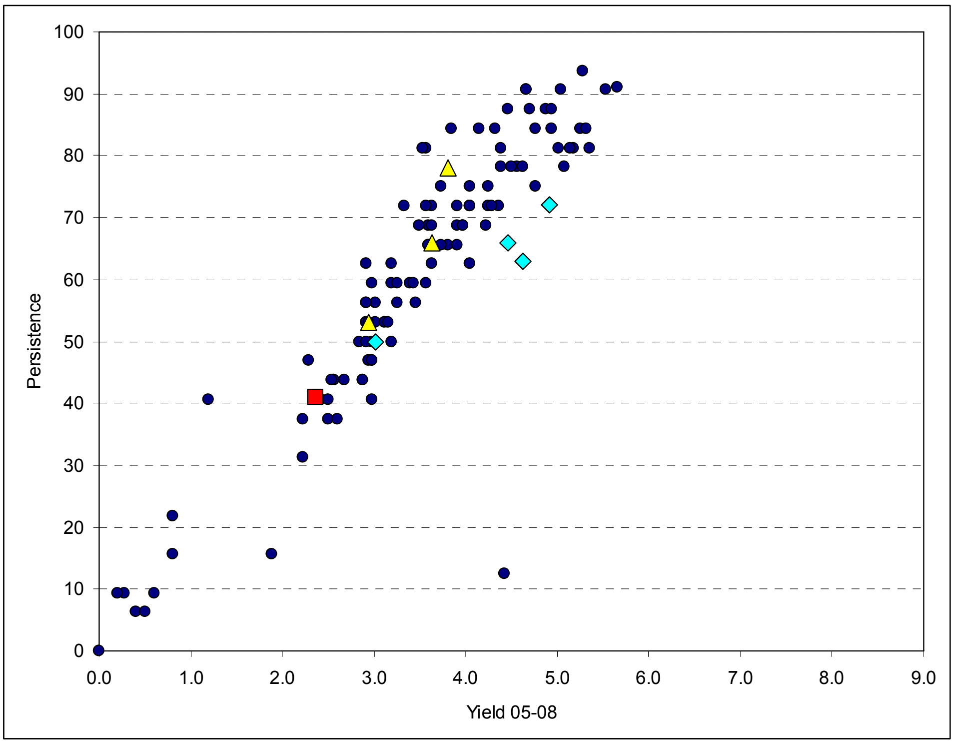


Figure 7. Average yield (visual score) from November 2005 to September 2008 of all tall fescue accessions, experimental varieties and cultivars (●) plotted against persistence (number of plants survived) at October 2008 at Inverell. The cultivar Demeter is represented by ■, the Sardinian lines by ♦ and the best performing Mediterranean lines by ▲.

4.3 Results and Discussion – Sub-tropical grasses

The sub-tropical grass component of the project has identified elite sub-tropical grass germplasm for southern Australia which will be commercialised in the follow-on project. The project has also provided a clear picture of where sub-tropical grasses are well suited, marginal or unsuitable for the different regions in south-western Australia.

Species evaluation

The series of Quantity and Quality (QnQ) trials together with the results from the germplasm evaluation trial have provided some clear guidelines as to where the various sub-tropical grass species are well suited, where they are marginal and where they are not suited.

Water use efficiency (WUE) is a useful way of summarising the data from the QnQ trials as the seasonal conditions varied considerably between sites and years. WUE is defined here as the biomass of the sown species per mm of rainfall over the duration of the trial from seeding until autumn 2008. Well adapted species have WUE of at least 5-10 kg/ha.mm while species which are marginally adapted have WUE of <5 kg/ha.mm (Table 8). For example, green panic had WUE of 11.3, 11.4 and 11.2 kg/ha.mm at Badgingarra, Mingenew and Esperance respectively. On the other hand, the WUE of green panic at Buntine was only 2.2 kg/ha.mm even though it had fair to good persistence at this site. The best performed sub-tropical grass species across a range of sites (with the exception of the 'cold zone') are the panic grasses (*Panicum maximum* cv. Gatton, green panic) and Rhodes grass (*Chloris gayana*). These species had the highest water use efficiency (>10 kg/ha.mm) at the Esperance, Badgingarra and Irwin sites.

On balance, the panic grasses have out-performed the Rhodes grass in the northern agricultural region (NAR), particularly in 2007 and 2008. Rhodes grass had the highest biomass production in the first two years across most sites, but its persistence was adversely affected by the extended dry conditions in the northern agricultural region of WA from December 2006 which continued into early winter 2007. For example, the frequency (groundcover) for Callide Rhodes grass and Katambora Rhodes grass declined from 100% to 51% and 100% to 24% respectively at the Badgingarra site over this period. However, there were minimal or no deaths of *Panicum maximum* in the QnQ trials across the three sites in the NAR and they subsequently showed good spring growth at Badgingarra and Irwin.

Table 8. The estimated water use efficiency of perennial species (kg/ha.mm) from seeding until autumn 2008 at the Quantity and Quality sites. Calculated using the biomass data from the spatial analysis together with the total rainfall at the sites from seeding until autumn 2008

Species	Quantity and quality site				
	Badgingarra	Buntine	Mingenew	Kojonup	Esperance
Bambatsi panic	5.0	3.7	1.3	0.4	3.7
Callide Rhodes grass	11.8	5.2	11.3	1.3	16.7
Finecut Rhodes grass	-	-	-	2.0	19.1
Gatton panic	11.2	-	10.0	0.9	13.0
Green panic	11.3	2.2	11.4	1.4	11.2
Katambora Rhodes	11.9	5.7	9.1	2.4	-
Kikuyu	6.9	-	2.1	4.8	12.2
Lotononis	0.0	-	1.1	0.2	0.7
Lucerne - Autumn	0.7	0.8	0.4	3.2	3.2
Lucerne - spring	1.4	0.9	2.2	5.7	1.8
Narok setaria	6.2	-	-	1.5	17.5
Premier digit grass	5.4	1.4	4.5	0.9	9.3
Signal grass	5.5	0.3	5.4	1.3	3.0
Siratro	-	0.2	2.9	0.6	0.2
Splenda setaria	5.0	0.8	4.1	1.8	16.1
Strickland finger grass	4.1	-	5.2	0.4	11.6
Tall fescue - Autumn	-	-	-	6.1	1.7
Tall wheat grass - Autumn	-	-	-	1.6	3.7
Tall wheat grass - Spring	-	-	-	-	4.5
Veldt grass	5.2	1.8	5.6	-	-

The best performed species across a range of sites (with the exception of the 'cold zone') are the panic grasses (cv. Gatton, green panic) and Rhodes grass (*Chloris gayana*). In Table 9 there is a summary of the relative performance of sub-tropical grasses in three broad regions of south-western Australia. There are three categories; (a) species that are persistent and productive over a range of environments; (b) species that are adapted to a narrow range of soils or have marginal performance in comparison with group (a); and (c) species that are generally poorly adapted at most sites in the region.

On the south coast, kikuyu is the most widely sown species. Kikuyu did not produce the highest biomass of the sub-tropical grasses at the Esperance QnQ site, however it is the preferred option by many farmers because of the ease of grazing management and because its growth habit minimises the risk of wind erosion (Table 9).

Table 9. The relative performance of sub-tropical grasses in three broad regions of south-western Australia. Taken from the network of QnQ sites and MLA sub-tropical grass improvement project sites

		Agricultural region in WA	
Category	Northern agricultural region	'Cold zone'	South coast
A) Persistent and productive over a range of environments	panic grass, Rhodes grass	kikuyu (>500 mm)	kikuyu, panic grass, Rhodes grass, setaria
B) Narrow range of soils or climate adaptation (or marginal performance in comparison with above group)	Signal grass, Setaria, Bambatsi panic, Digit grass, Strickland finger grass, kikuyu	Rhodes grass (diploid varieties)	Digit grass, Strickland finger grass, Bambatsi panic, Signal grass
C) Generally poorly adapted at most sites	Sabi grass (*Urochloa* spp.) Buffel grass, *Bothriochloa* spp.	Panic grass, Setaria, Signal grass, Bambatsi panic, Digit grass, Strickland finger grass, Buffel grass, *Bothriochloa* spp.	Buffel grass, *Bothriochloa* spp.

The QnQ trials highlighted the potential production following summer rainfall (rule of thumb was developed) and demonstrated the resilience of sub-tropical grass based pastures in the northern agricultural region in years with highly variable rainfall (e.g. 2006, 2007 growing season rainfall at Badgingarra) to produce more biomass than annual pastures. They also identified a cold zone in the Great Southern Region where the persistence of most grasses is problematic with the exception of kikuyu (cold zone was mapped using temperature maps).

Germplasm evaluation - New panic grasses

The general consensus at the commencement of the project was that the digit grasses (*Digitaria* species) were likely to be the most promising species for southern Australia. However, the digit grasses (especially *D. milanjiana*) have not performed as well as expected, particularly in WA. On the other hand, the panic grasses have shown considerable promise in the row trials as well as the species-variety trials.

In WA, the Badginarra site was an effective test of the drought tolerance of the germplasm as there were prolonged hot, dry periods over summer in most years. The dry period extended for more than 6 months over the 2006/07 summer. The winters were mild and only the most cold sensitive lines were adversely affected by the winter temperatures. All of the promising lines plus many of the controls had 100% persistence at Badgingarra (e.g. Figure 8).

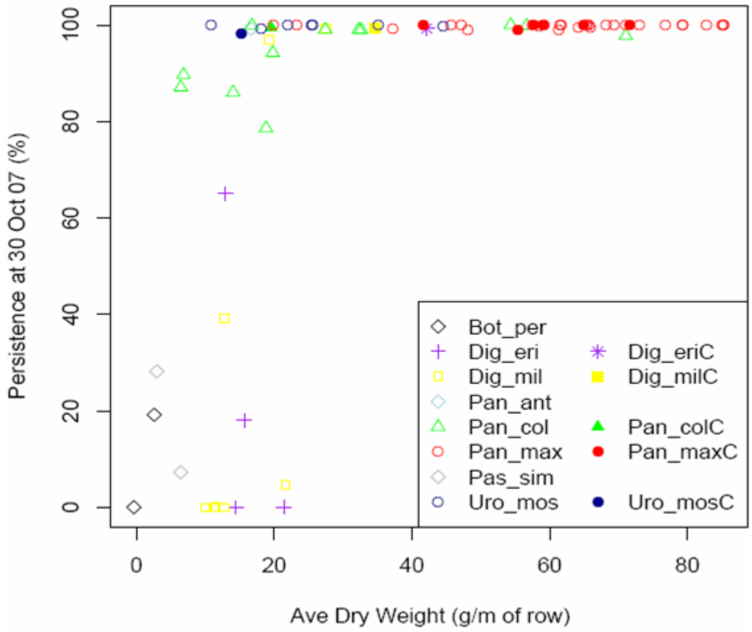


Figure 8. A comparison of the predicted average dry weight plotted against the persistence as at 30th October 2007 (% of plants surviving) for the eight species and associated commercial varieties (solid colour) of sub-tropical bunch grasses in the Badgingarra 2005 bunch grass trial.

At Wellstead, only drought sensitive lines died over the summer which was relatively mild in rainfall compared with the conditions at Badgingarra. However, many lines failed to persist over winter due to a combination of cool, wet soils and occasional frosts. Wellstead appears to lie on the southern edge of the 'cold zone' and the overall persistence was much lower (Figure 9).

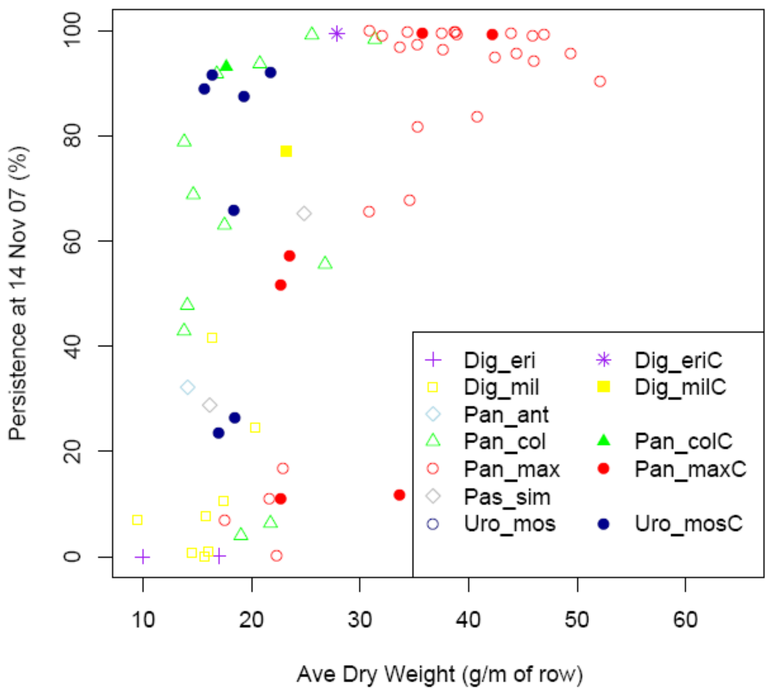


Figure 9. A comparison of the predicted average dry weight plotted against persistence as at 14th November 2007 (% of plants surviving), for the seven species and associated

commercial varieties (solid colour) of sub-tropical bunch grasses in the Wellstead 2005 bunch grass row trial.

In 2006 the promising germplasm (11 panic grass lines plus 2 controls) were evaluated at three satellite sites to broaden soils and environments where the germplasm was evaluated. The Muresk site has seen the highest biomass production of the satellite sites. The Buntine site has had relatively low biomass production with a series of dry years, but has been a good test of drought persistence as the grasses have been highly stressed on a number of occasions. In spite of the very dry conditions there have been few deaths at this site.

The sub-tropical grass component has identified four elite panic grasses which are known by the generic codes: Pan_max-049, 050, 057 and 059 (Figure 10). These lines exceed the plant improvement targets in persistence and biomass production:

Persistence: In WA both the elite panic lines and the control varieties had excellent persistence (>95%) at all five sites. However, this was not the case in NSW where P_max_050 had persistence of 72% and P_max_057 70% compared with only 26% for green panic (Gatton panic not in trial) (Table 10).

Spring biomass: At Badgingarra site where there is potential for good growth in spring due to the mild conditions, overall the elite lines had higher spring biomass than the Gatton panic controls (Table 11). The spring biomass was similar to Gatton in 2006, except for P_max_059 (+19%), but in 2007 the spring biomass was on average 41% higher for P_max_049; 22% for P_max_050; 28% for P_max_57 and 59% for P_max_059.

Dry matter production from October to May: In NSW P_max_050 and P_max_057 had summer production of 6.13 and 5.00 respectively compared with green panic 2.81 (Table 10). The overall dry matter production is a good indicator of the out-of-season production. The overall production at Badgingarra was 32% higher for P_max_049 than Gatton panic; 14% for Pmax_050; 19% for P_max_057 and 37% for P_max_059. The elite lines are much higher average biomass at Muresk in WA (Table 12: varied from +15% to +67%) compared to Gatton panic and again at Yetman in northern NSW (Table 10).

The elite lines also had higher green leaf in summer (Table 10) and P_max_057 and P_max_049 have much high tiller numbers (Table 12) which is an indication of leafiness and probably palatability. The dry matter digestibility was measured on a number of occasions and we are currently waiting on a large batch of results to come back from CSIRO.

Table 10. Seasonal production and persistence of promising *Panicum maximum* and *P. coloratum* lines compared to controls Green panic, Bambatsi panic and Katambora Rhodes grass at Yetman in Northern NSW from February 2005 to February 2008. Table sorted according to persistence

	Seasonal production[1]				GLOW[2]	Persistence[3]
	Spring	Summer	Autumn	Total		
Pan_max_050	4.00	6.13	6.20	6.3	30	72
Pan_max_066	4.00	4.90	5.10	5.7	34	71
Pan_col_019	3.63	5.42	5.00	4.5	38	71
Pan_max_057	3.21	5.00	4.83	5.2	36	70
Pan_max_062	3.30	5.00	5.39	4.5	34	70
Pan_col_020	3.13	5.00	4.20	3.9	39	70
Katambora	5.21	6.75	5.39	6.0	42	70
Green Panic	2.70	2.81	2.70	2.3	20	26
Bambatsi	2.04	2.80	2.30	2.5	28	25

[1] Average visual yield score over each season and annual total (score scale is 1 to 9 where 1 is lowest and 9 is highest).
[2] GLOW - Green leaf over winter (%).
[3] Survival of established plants in drill row still alive at February 2008 (expressed as a percentage).

Table 11. The spring biomass (dry matter back transformed) of the elite panic grasses (bold) in the 2005 bunch grass nursery at Badgingarra in 2006 and 2007 compared with Gatton panic control

Accession/Variety	Spring '06	Early spring '07	Spring '07	Total spring 07
Pan_max_069	133.0	141.3	194.2	161.8
Pan_max_059	119.3	130.2	203.4	158.7
Pan_max_062	132.6	142.8	180.9	157.6
Pan_max_066	141.1	142.0	169.4	152.7
Pan_max_011	127.7	133.2	161.7	144.3
Pan_max_055	118.5	141.0	146.8	143.2
Pan_max_049	99.3	125.1	166.7	141.3
Pan_max_057	100.7	112.9	152.0	128.1
Pan_max_cvGreen	100.1	116.3	136.3	124.1
Pan_max_050	100.3	98.3	160.3	122.4
Pan_max_045	98.3	115.6	121.0	117.7
Pan_max_cvGatton	100.0	100.0	100.0	100.0
Dig_eri_cvPremier	65.3	42.8	103.8	66.6
Pan_max_010	58.7	63.0	68.4	65.1
Pan_max_Natsukaze	86.4	65.0	54.4	60.9
Dig_mil_cvStrickland	43.4	40.0	31.4	36.7
Pan_col_cvBambatsi	26.6	21.4	22.2	21.7
Uro_mos_cvNixon	11.7	11.9	12.6	12.2

Apart from yield and persistence, the four elite lines of *Panicum maximum* also had favourable growth habit and morphology and good seed yield potential. An outline of their morphology and field performance is outlined in Table 13 and more details on yield and persistence are given in Table 14. These lines were included in the MTA between FFI CRC and Heritage Seeds and seed (150 g with >50% germination), and supplied to Heritage Seeds in September 2008. They have subsequently established small plot evaluation trials at a number of sites in south-east Queensland and northern NSW.

The seed yield potential of the promising *P. maximum* lines were evaluated over 2007/08 summer in large irrigated plots at Medina Research Station, south of Perth. These plots were harvested with a small plot harvester and the seed yields were: P_max_057 - 2,400 g, P_max_050 - 2,280 g, P_max_059 - 1,595 g and P_max_049 – 525 g compared with 1,460 g and 360 g for Green and Gatton panic controls respectively. The seed yield of accession P_max_049 was comparatively low, but this plot was half the size (60 m^2 cf 120 m^2).

Table 12. A summary of the persistence, average dry weight (8 measurements) and average number of tillers/plant (autumn '06) at the Muresk satellite nursery

Accession/Variety	Back-transformed Persistence Means (percentages)	Ave Dry Weight Means (g/m of row)	Av dry weight cf Gatton panic (%)	Ave Tiller Means (tillers/plant)
Panmax062	100	115.2	198.1	31.6
Panmax011	100	100.1	172.1	26.8
Panmax057	99.5	97.2	167.2	42.9
Panmax055	100	93.3	160.4	19.1
Panmax050	100	90.5	155.5	26.1
Panmax049	100	88.4	151.9	30.5
Panmax067	100	83.6	143.7	21.7
Petrie-Green	100	78.3	134.6	24.5
Panmax045	100	70.3	120.9	31.0
Panmax060	100	68.9	118.5	23.5
Panmax059	100	67.2	115.6	17.3
Panmax010	100	64.6	111.0	16.2
Gatton	100	58.2	100.0	16.2
Average LSD (5%)		12.4		6.4

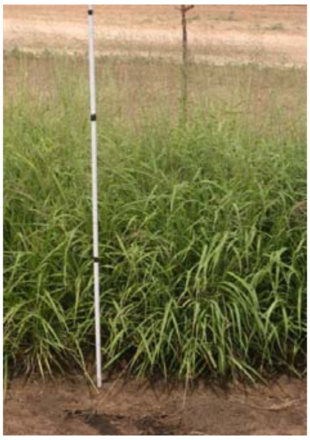
The final stage prior to commercialisation is to evaluate the persistence and production of these elite panic lines under grazing. Grazing trials have been established in WA (trial at Badgingarra Research Station established in September 2008) and in northern NSW (Tamworth, Bingara) in late 2008 as part of the continuing project, 'Persistent, productive, tropical grasses in farming systems' (CRC FFI FP07). The new project will take the elite germplasm identified in this project (PAST.001) and evaluate the persistence and productivity of these lines under grazing in both northern NSW and WA. The project plans to release a new *Panicum maximum* variety under Trademark in collaboration with a commercial partner. It also will investigate companion legumes to provide nitrogen to drive the grass production and put together a high production package based around tropical grasses. As part of the continuing project, larger scale seed increase plots (50 m x 18 m) of the four panic grasses were established at Medina Research Station under irrigation in spring 2008.

Table 13. An outline of the four advanced lines of *Panicum maximum* which have been selected for the Material Transfer Agreement with Heritage Seeds for widespread evaluation

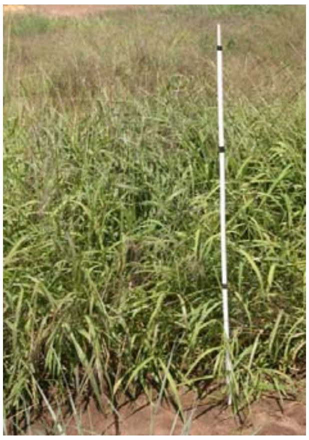
Generic code	General description and morphology	Field performance
Pan-max_049	Short, upright type with fine, soft foliage, fine stems and with a high tiller number. Highly productive line with excellent persistence. Origin: Zimbabwe - 450 mm average annual rainfall (AAR).	Excellent persistence under extended dry conditions (Badgingarra – 100%), and over winter (Wellstead – 96%); Badgingarra av. biomass (+32% cf. Gatton panic (Table 14). Performed well in NSW.
Pan_max_057	Short, upright type with fine leaves, fine stems and with a very high tiller number. Good production in autumn and spring, with excellent persistence. Origin: South Africa - 500 mm AAR.	Excellent persistence under extended dry conditions (Badgingarra – 100%), and over winter (Wellstead – 100%); Badgingarra av. biomass +19% cf. Gatton panic (Table 14). Highest seed production at Medina 07/08. NSW 3rd ranked panic grass and was the only panic grass to persist over winter at Inverell (NSW) with no deaths despite some heavy frosts.
Pan_max_050	Medium-sized panic grass with very good persistence. Highly productive compared with control varieties in a range of conditions. Origin: South Africa - 500 mm AAR.	Best performed panic grass in NSW. Excellent persistence under extended dry conditions (Badgingarra – 100%), and over winter (Wellstead –96%); and 14% higher av. biomass cf. Gatton panic at Badgingarra and 17% higher at Wellstead. Very good seed production.
Pan_max_059	Medium to large-sized panic grass with very good persistence. Highly productive compared with control varieties in a range of conditions. Origin: South Africa.	Excellent persistence under extended dry conditions (Badgingarra – 100%), and over winter (Wellstead – 95%); Badgingarra av. biomass +37% cf. Gatton panic (Table 14). It is the 6th ranked panic grass in the NSW trials.

Panicum maximum 057

Panicum maximum 050



Panicum maximum 049



Panicum maximum 059

Figure 10. The four elite lines of *Panicum maximum* (P_max_049, 050, 057 and 059) in irrigated field plots.

Table 14. Persistence and average dry weight values (average of 9 measurements) for the accessions and varieties of sub-tropical bunch grasses - Badgingarra 2005 bunch grass row trial

Accession*	Back-transformed Persistence Means (%)	Back-transformed Average Dry Weight Means (g/m of row)	% Biomass cf Gatton panic
Pan_max_011	100.0	86.0	148.4
Pan_max_066	99.9	85.0	146.6
Pan_max_062	100.0	84.5	145.8
Pan_max_069	100.0	81.1	140.0
Pan_max_059	100.0	79.5	137.2
Pan_max_049	99.9	76.5	131.9
Pan_max_055	100.0	75.0	129.4
Pan_col_015	97.9	72.0	124.2
Pan_max_046	99.9	71.6	123.5
Pan_max_057	100.0	69.0	119.1
Pan_max_cvGreen	99.9	68.5	118.2
Pan_max_050	100.0	65.8	113.5
Pan_max_Mombaca	99.9	63.8	110.0
Pan_max_045	100.0	61.9	106.7
Pan_max_cvGatton	100.0	58.0	100.0
Pan_max_cvTanzania	99.2	57.0	98.3
Dig_eri_cvPremier	99.2	40.2	69.4
Pan_max_cvMakueni	100.0	39.6	68.3
Dig_mil_cvStrickland	99.2	33.2	57.2
Pan_col_cvBambatsi	99.1	19.0	32.9
Uro_mos_cvNixon	97.8	13.5	23.2

*In descending order of average dry weight.

5 Success in Achieving Objectives

Through extensive research in the past 5 years, 4 cocksfoot, 3 tall fescue and 4 Panicum lines have been developed. Their characteristics and general performance (performance of their parents for cocksfoot and tall fescue lines) are briefly summarised in Table 15. The results have demonstrated that the parents of the elite lines of cocksfoot and tall fescues generally exceeded the control cultivars and met the breeding objectives in productivity and persistence. It is expected that there will be further improvements in their progeny (the elite lines) with cross-pollination. The four panic grass lines have met or exceeded the improvement objectives. Seed production of these elite lines is underway and seed has been or will be available for field test by early 2009. The new perennial grasses have the potential to grow and adapt well to the low-medium rainfall environments in southern Australia, where there is currently few commercial cultivars available in the markets. It is expected that these grasses will fill the gaps in these environments and play a significant role in boosting the livestock industries in a productive, profitable and sustainable manner.

Table 15. Characteristics and general performance of the new grass lines

Tall Fescue

Product	Comment	% Improvement on cv. Demeter			
		Total yield	Summer yield	Winter yield	Persistence
Synthetic 1	Based on line FA006, good year round production and persistence. Endophyte free.	21%	26%	22%	15%
Synthetic 2	Based on lines FA005, FA008 and FA009. Similar to line FA006. Good year round production and persistence. Endophyte free.	30%	14%	23%	22%
Synthetic 3	Based on lines M6, M14 & M15 of Moroccan origin. Similar overall yield to Demeter but good winter production & good retention of green leaf over summer. Endophyte free.	Similar	Lower but best of Moroccan lines at retaining green leaf	11%	10%

Cocksfoot

Product	General description	Characteristics relative to Currie
Synthetic 1	A fine-leafed, densely tillered line based on the best performing Mediterranean accessions	Based on plants from the four best Mediterranean accessions, which were 34% more productive than the best cultivar with 100% plant survival. Low rainfall persistence, very fine leafed and densely tillered
Synthetic 2	A second not-so-fine leafed line based on the best performing Mediterranean accessions	Based on plants from the four best Mediterranean accessions, which were 34% more productive than the best cultivar with 100% plant survival.. Low rainfall persistence, fine leafed and densely tillered
Synthetic 3	A replacement for Currie based on the best performing plants from Jana, Medly and Currie	Jana, Medly and Currie were the most productive and persistent of the cultivars with a mean year 2 vigour score of 5.1 compared to all 15 cultivars with mean of 2.5 on average. Persistence score was 91% for Jana, Medly and Currie compared to 69% for all 15 cultivars
Synthetic 4	A line based on the best plants of AVH48 which has shown promise in previous Victorian studies	AVH48 was as productive and persistent as the best cultivars with a mean year 2 vigour score of 5.0 compared to all 15 cultivars with mean of 2.5 on average. Persistence score was 93% for AVH48 compared to 69% for all 15 cultivars

Sub-tropical grasses

Product	**General description**	**Performance relative to Gatton panic control**		
		Persistence	**Dry matter in mid-spring**	**Overall dry matter**
Pan-max_049	Short, upright type with fine, soft foliage, fine stems and a high tiller number. Origin: Zimbabwe with 450 mm average annual rainfall (AAR).	In WA same as control as both are >95% at all sites	+41%*	+32%*
Pan_max_057	Short, upright type with fine leaves, fine stems and a very high tiller number. Origin: South Africa with 500 mm AAR.	In WA same as control as both are >95% at all sites NSW 70% cf 26% green panic	+22%*	+14%*
Pan_max_050	Medium-sized panic grass. Origin: South Africa – 500 mm AAR.	In WA same as control as both are >95% at all sites NSW 72% cf 26% green panic	+28%*	+19%*

Pan_max_059	Medium to large-sized panic grass. Origin: South Africa	In WA same as control as both are >95% at all sites	+59%*	+37%*

* These results are typical, but they do vary between sites and between years.

A Material Transfer Agreement (MTA; Appendix 3) has been progressed between the FFO CRC and Heritage Seeds allowing Heritage to evaluate the elite lines of tall fescue, cocksfoot and panic grass for up to 2 years to assist further decisions on commercialisation. To ensure maximum benefit from the collaboration, details of expected work, performance and communication processes were discussed between the project team and Heritage Seeds, including future work on PBR and DUS test of the new lines. Seed of the four panic grass lines (100 g each) was transferred to Heritage Seeds in September 2008, and seed of the tall fescue and cocksfoot lines will be transferred in March 2009.

6 Impact on Meat and Livestock Industry – now & in five years time

Over 60% of Australia's total land area is grazed by sheep and cattle. However, only 6% of Australia's grazing lands have been improved by the introduction of improved plant species and use of fertiliser, although these improved pastures support 41% of our domestic livestock. This project targets the low to medium rainfall environments in southern Australia (including a large part of the sheep wheat belt) where few commercial cultivars of perennial grasses are well adapted and pastures are dominated by annual species.

During the course of the project, over 40 scientific papers, media articles and reports have been published, which not only improves the technical understanding of the relevant fields for the science community, but also raises the public awareness for the use of perennial grasses in the targeted environments to achieve multiple benefits in productivity, profitability and sustainability. Numerous field days, workshops and farm walks on or near the experimental sites in NSW, Vic., and WA have provided landholders with the opportunities to observe and better understand what can be achieved by using new and improved perennial grasses in their farming systems. This, and interactions with a commercial provider at an earlier stage, will help to enhance the commercialisation and adoption of the new grasses developed by the project.

The new elite lines will be evaluated in system scale by two new FFI CRC projects – 'Improved perennial grass cultivars for the inland slopes of the Great Dividing Range' and 'Productive, persistent tropical grasses in farming systems'. Under the MTA between FFI CRC and Heritage Seeds, the lines will also be tested in comparison with other commercial cultivars and preparation for cultivar release such as DUS test and PBR application will be negotiated and conducted. It's expected that, in five years time, new cultivars of tall fescue, cocksfoot and panic grass will be released. The new cultivars will potentially adapt well to the following regions/environments: 1) northern tablelands, northern slopes and central tablelands of NSW with a high proportion (40-50%) of summer rain (summer-active tall fescues and panic grasses); 2) low rainfall temperate zone from southern NSW, Vic., to SA with low proportion (<30%) of summer rain (cocksfoots and winter-active tall fescue); and 3) the Mediterranean environments in southwest WA (primarily panic grasses). Theses new cultivars will play a significant role in expanding the area of sown perennial pastures, lifting livestock production of sheep and cattle, and improving the sustainability of the grazing systems in the target environments.

7 Conclusions and Recommendations

A series of experiments were undertaken across multiple sites in NSW, Vic. and WA for 5 years to develop perennial grasses for low-medium rainfall recharge environments in temperate and Mediterranean climate regions of Australia. Over 400 accessions selected from a large pool of germplasm collected from target environments were evaluated. Two methodologies were used to develop new lines of the grasses, including selection and cross-pollination for tall fescue and cocksfoot, and field evaluation and screening for sub-tropical grasses. Eleven elite lines of cocksfoot, tall fescues and panic grasses have been developed. These lines or their parents demonstrated performance that have met or exceeded the breeding objectives.

The 3 elite tall fescue lines include two summer-active and one winter-active lines, In comparison with Demeter, the parents of the two summer-active lines had improvements in total pasture yield by 21-30%, summer yield by 14-26% and persistence by 15-22%. The parents of the winter-active line had similar total yield, lower summer yield, but 11% higher winter yield and 10% higher persistence than Demeter under the environment with summer rain. The four elite cocksfoot lines include two *ssp. hispanica* types and two hispanica x glomerata types of cocksfoot. After two summers the four Mediterranean accessions (the parents of the two *hispanica* lines) had a mean vigour score 34% higher than the best cultivars and 40% higher than cv. Currie. They were also superior in plant survival. Plants from the three best cultivars (Jana, Medly and Currie) were selected to be the parents for a Currie replacement candidate cultivar. The hybrid, Portuguese, accession AVH48 performed well as it has in previous central Victorian studies. The best plants of AVH48 will make up the fourth candidate cultivar. The four elite panic grass lines, two short, upright type of panic grass with fine leaves and two medium to large types, have outstanding performance over the control cultivar. In WA both the elite panic lines and the control varieties had excellent persistence (>95%) at all five sites. However, this was not the case in NSW where two lines had persistence of 70-72% compared with only 26% for the control. The elite lines had spring biomass which was 22-59% higher, while the overall biomass production was 14-37% higher at Badgingarra and 15 to 67% higher at Muresk than the Gatton panic control. Apart from yield and persistence, the four elite lines also have favourable growth habit and morphology and good seed yield potential.

Due to the time required to complete the breeding cycle, the project did not evaluate the progeny of the cocksfoot and tall fescue lines; however, a succession plan was worked out through earlier engagement with commercial partners and development of new projects, which will lead to release of new cultivars of these perennial grasses in coming years. The MTA executed between the FFI CRC and Heritage Seeds allows Heritage Seeds to evaluate the elite lines of tall fescue, cocksfoot and panic grass for up to 2 years to assist further decisions on commercialisation. Details of expected work, performance and communication processes have been negotiated with Heritage Seeds, including future work on PBR and DUS test of the new lines. Two new projects, 'Improved perennial grass cultivars for the inland slopes of the Great Dividing Range' and 'Productive, persistent tropical grasses in farming systems', will continue to evaluate and commercialise these new lines from 2009 to 2011, in collaboration with Heritage Seeds under the MTA.

The low rainfall conditions during the entire experimental period and some extremely dry years (e.g. 2006) provided challenges as well as opportunities for the evaluation and breeding program. On one hand, enormous efforts have been made to ensure success in trial establishment and plant survival. On the other hand, drought in some years presented a condition for natural selection of the plants to meet the breeding/improvement objectives. A detailed work plan, regular inspection and assessment of field trials, and timely reaction according to field and weather conditions are needed for the stressful circumstances.

The project called for expression of interests from potential commercial partners for commercialising the products to be developed. This led to early engagement with seed companies and their awareness/interests of our new grass lines. The formation of management group with Heritage Seeds to oversee the commercialisation process and the MTA progressed between FFI CRC and the company before the seed of the new lines was produced have placed us well in a position to commercialise the new grass cultivars. For a conventional breeding program, it often takes a long time for the new breeding lines to reach the markets. Early engagement with potential commercialisation partners will speed up the process from development to adoption.

8 Bibliography

8.1 Publications from this project

Australia Research Update. Evergreen Newsletter, November-December 2006.

Clark S (2006) Persistence pays off with Cocksfoot. Focus on Salt September 2006.

Clark, S. Persistence pays off with cocksfoot. Grassland Society of Southern Australia Inc. Newsletter. January 2007.

Clark S, Harris C (2009) Summer dormancy for perennial grasses in the temperate regions of Australia. The International Workshop on Summer Dormancy in Grasses, Ardmore, Oklahoma, USA, April 6-8, 2009 (invited plenary speaker).

S Clark, Z Nie, B Clark, J Smith (2007) Breeding Cocksfoot for marginal environments in south-eastern Australia. In 'Proceedings of the Plant Production Science Mini-conference'. Warrnambool, April 2007.

Clark S, Nie Z, Smith K, Clark B, Smith J (2008) Breeding and selecting Cocksfoot for drier environments. Proceedings of the 49th Annual Conference of the Grassland Society of South Australia Inc. pp109-114.

Harris CA (2008) New Panicum cultivars on the horizon for northern NSW. In 'Proceedings of the 23rd Annual Conference of the Grassland Society of NSW, Tamworth'. (Eds J Ayres, S Boschma) p.114 (Grassland Society of NSW Inc.: Orange).

Harris C, Clark S, Moore G (2006) Perennial grass improvement for low-medium rainfall environments: project protocols. Available at http://www.crcsalinity.com.au/documents/uploads/protocolpublicn%20 Aug06.doc [Verified 8 January 2008]

Harris CA, Clark SG, Reed KFM, Nie Z, Smith KF (2008) Novel Festuca arundinacea Shreb. and Dactylis glomerata L. germplasm to improve adaptation for marginal environments. Australian Journal of Experimental Agriculture 48 436-448.

Harris C, Culvenor R (2004) Use and improvement of tall fescue and phalaris for the North-West Slopes. In 'Proceedings of the 19th Annual Conference, Grassland Society of NSW, Gunnedah NSW 2004'.

Lloyd D, Johnson B, Crocker G, Harris C (2008) Selecting the right pasture – for your soil and environment. In 'Managing mixed farms in the Maranoa-Balonne and Border Rivers'. (Eds L Bell, B O'Mara and I Partridge) pp 8-13.

Milestone reports 1 – 10 (2004 – 2008) submitted to MLA and FFI CRC (formerly CRC Salinity).

Moore G (2006) No cold comfort for tropical grasses 'Focus on Salt' No. 36.

Moore, G. (2007). Chapter 5 'Sub-tropical grasses' In Perennial Pastures for Western Australia. DAFWA Bulletin No. 4690, p.123-166.

Moore, G. 'Sub-tropical grasses in WA. What is their potential?' Agribusiness Livestock Updates, Perth, July 24 '07.

Moore, G (2008). Key findings from the Quantity and Quality trials in the Northern Agricultural Region. Grain and Graze Workshop, Jurien Bay, April 6 2008.

Moore, G. (2008). Key findings from the Quantity and Quality trials in the Northern Agricultural Region. Part of Final report for Grain and Graze NAG.
Moore G, Albertson T, van Gool D (2006) Poor persistence of sub-tropical grasses over winter In 'Proceedings of the 13th Australian Agronomy Conference' Perth WA, September 2006.
Moore, G. and Albertsen T. 'Role of sub-tropical grasses on the south coast of WA. What is their potential?' Ravensthorpe Agribusiness Livestock Updates, August 8 '07.
Moore, G. and Albertsen T. 'Role of sub-tropical grasses on the south coast of WA. What is their potential?' Esperance Agribusiness Livestock Updates, August 9 '07.
Moore, G. Quantity and Quality trials - Key results to date. Evergreen Newsletter September 2007, p. 6-7.
Moore G, Butler K (2006) Rhodes grass cultivars. Esperance Agmemo 2006.
Perennial Pasture Improvement, MLA Newsletter, 2007.
Moore, G. Titterington, J. Wintle, B. Sanford, P. Wiley, T. and Henry, D. (2008). Germplasm evaluation in WA. Future Farm Industries workshop CRC 'Productive persistent tropical grasses in farming systems'. Tamworth, March 2008.
Nie Z (2008) Project concept, implementation and key findings – workshop handout. Perennial Grass Workshop, November 19th 2008 Inverell, NSW.
Nie ZN and Clark B (2008) Establishment and growth of tall fescue (Festuca arundinacea) cultivars with spring sowing in southern Australia. Proceedings of the XXI International Grassland Congress, Hohhot, China. Volume II, p354.
Nie Z, Norton M (2009) Stress tolerance and persistence of perennial grasses - the role of the summer dormancy trait in temperate Australia. The International Workshop on Summer Dormancy in Grasses, Ardmore, Oklahoma, USA, April 6-8, 2009 (invited plenary speaker).
Reed K (2006) Pasture species and cultivars. In 'Greener Pastures for south west Victoria' (Eds Z Nie, G Saul), Victorian Department of Primary Industries.
Reed K (2007) Endophyte strengthens grass In "Perennial Pastures' (Eds G Moore, P Sanford, T Wiley). Department of Agriculture and Food Western Australia. DAFWA Bulletin No. 4690.
Reed K, Nie Z, Clark B (2008) Field evaluation of phalaris, tall fescue and cocksfoot cultivars and accessions in western Victoria, Australia. *Australian Journal of Agricultural Research* 59: 971–981.
Titterington J, Moore G (2006) Summer production from sub-tropical grasses. Evergreen Newsletter, June 2006.
Titterington, J. (2008). Seed production of promising Panicum maximum. FFI CRC workshop 'Productive persistent tropical grasses in farming systems'. Tamworth, March 2008.

8.2 Other relevant publications

Anderson MW, Cunningham PJ, Reed KFM, Byron A (1999) Perennial grasses of Mediterranean origin offer advantages for central western Victoria sheep pastures. Australian Journal of Experimental Agriculture 39, 275–284.
Bennett SJ, Ayres J, Dear BS, Ewing M, Harris C, et al. (2003) Perennial pastures for the recharge zones of southern Australia. CRC for Plant-based Management of Dryland Salinity Scoping Document No 1.
Clark SG, Snell FJ, Goss L, Avery AL, Latta RA (1993) Pasture grasses and legumes '93: annual summary of recent grass and legume cultivar trial results. Department of Agriculture, Victoria, Australia.
Cunningham PJ, Graves WL, Chakroun M, Mezni MY, Saidi S, Bounejmate M, Porqueddu C, Reed KFM (1997) Novel perennial forage germplasm from North Africa and Sardinia. Australian Plant Introduction Review 27, 13–46.

Dear BS, Ewing MA (2008) The search for new pasture plants to achieve more sustainable production systems in southern Australia. Australian Journal of Experimental Agriculture 48, 387–396.
Harris CA (1998) Tall fescue ecotype collection on the Northern Tablelands of NSW. In 'Proceedings of the 13th Annual Conference of the Grassland Society of NSW, Orange'. (Eds F McRae, D Michalk) p. 77. (Grassland Society of NSW Inc.: Orange)
Lolicato S, Rumball W (1994) Past and present improvement of cocksfoot (Dactylis glomerata L.) in Australia and New Zealand. New Zealand Journal of Agricultural Research 37, 379–390.
Nie ZN, Miller S, Moore G, Hackney B, Boschma S, Reed KFM, Mitchell M, Albertsen TO, Clark SG, Craig AD, Kearney G, Li GD, Dear BS (2008) Field evaluation of perennial grasses and herbs in southern Australia. 2. Persistence, root characteristics and summer activity. Australian Journal of Experimental Agriculture 48:424-435.
Oram R, Lodge G (2003) Trends in temperate Australian grass breeding and selection. Australian Journal of Agricultural Research 54, 211–241. doi:10.1071/AR02137
Pecetti L, Romani M, Carroni AM, Annicchiarico P, Piano E (2007) The effect of endophyte infection on persistence of tall fescue populations in 2 climatically contrasting Italian locations. Australian Journal of Agricultural Research 58, 893–899. doi:10.1071/AR06423
Piano E, Pecetti L, Annicchiarico P, Carroni AM, Fornasier F, Romani M (2004) Combining drought tolerance and responsiveness to summer moisture availability in cocksfoot (Dactylis glomerata L.) germplasm grown in Mediterranean environments. Australian Journal of Agricultural Research 55, 1197–1204. doi:10.1071/AR04067
Reed KFM (1996) Improving the adaptation of perennial ryegrass, tall fescue, phalaris and cocksfoot for Australia. New Zealand Journal of Agricultural Research 39, 457–464.
Reed KFM, Lee CK, Jahufer MZZ, Anderson MW (2004b) Herbage cultivar description: Fraydo tall fescue (Festuca arundinacea Schreb. Australian Journal of Experimental Agriculture 44, 955–957.
Reed KFM, Nie ZN, Miller SM, Hackney B, Boschma SP, Mitchell M, Albertsen TO, Moore GA, Clark SG, Craig AD, Kearney G, Li GD, Dear BS (2008) Field evaluation of perennial grasses and herbs in southern Australia. 1. Establishment and herbage production. Australian Journal of Experimental Agriculture 48: 409-423.
Volaire F, Norton M (2006) Summer dormancy in perennial temperate grasses. Annals of Botany 98, 927–933.

9 Appendices

9.1 Project protocols

Perennial Grass Improvement for Low - Medium Rainfall Environments

Project Protocol

Carol Harris[1], Steve Clark[2] and Geoff Moore[3]

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3. Department of Agriculture Western Australia, Baron-Hay Court South Perth WA 6151

The CRC for Plant Based Management of Dryland Salinity supported by Meat and Livestock Australia has initiated temperate and tropical grass breeding programs in New South Wales, Victoria and Western Australia. This project will develop cultivars that improve the reliability of temperate grasses in the 400-700 mm rainfall zone with an emphasis on summer activity in tall fescue and herbage quality in cocksfoot. It will also identify and develop sub-tropical grasses suitable for Mediterranean and temperate regions.

More than 400 accessions of tall fescue, cocksfoot and sub-tropical grass species are being screened and evaluated at field sites in New South Wales, Victoria and Western Australia. This document details the measurement protocol for site description, data collection and procedures used at the 3 field sites. This protocol was developed by members of the project technical committee using the publications listed in the references section, as well as, building on past experience from various pasture evaluation projects.

While this protocol document is specific to the perennial grass improvement project it would be as useful as a general reference for future pasture improvement work.

General

<u>Meteorological data</u>

- Long term data for each site should be obtained from the closest Bureau of Meteorology weather station.
- Measure rainfall using an automatic rain gauge on site. Set-up logger to record rainfall every 30 min so as to measure rainfall intensity over time as well as amount of rainfall. Data to be presented as monthly totals.
- Optional: Measure air temperature using an automatic data logger. Set-up logger to record temperature every 30 min so as to determine daily minimum and maximum temperatures. Data to be presented as monthly averages.
- Optional: Compare weather data collected from site with rain gauges located on co-operators properties and with closet Bureau of Meteorology weather station.
- Evaporation data to be accessed from closet Bureau of Meteorology weather station.
- Optional: Soil water profiles to be calculated using on site rain and temperature data and the BOM evaporation data.

<u>Site details</u>

- Record site latitude, longitude and altitude
- Classify soil using Australian Soil Classification (Isbell 1996).
- Record details of land use history (years of pasture, cropping history, animal enterprises) and fertiliser history (amount and types)
- Sample soil at site prior to establishment of trials and thereafter once a year in autumn to determine soil fertility. Samples to be analysed for parameters listed below

Soil Parameter	Sampling Depth
pH ($CaCl_2$)	0-10 & 10-20 cm
CEC	0-10 & 10-20 cm
Cations	0-10 & 10-20 cm
P (Bray & Colwell)	0-10 cm
S (KCl_{40})	0-10 cm
OC	0-10 & 10-20 cm
EC	0-10 & 10-20 cm

Photographic records

- Photograph general site views and general shots of the trials 4 times a year (i.e. at the change of season) or when there are noticeable changes.
- Take close up photographs of grass lines that are of particular interest (i.e. worst/best/disease infection etc) 4 times a year (i.e. at the change of season).
- Close up photographs should be labelled with treatment name, replicate number and date.

Management – Temperate species

- Trials to be grazed after yield assessments (except when recording phenological development). Trials to be crash grazed with sheep down to a minimum of 800 kg DM/ha. After grazing if required trial area will be evened out using a sickle bar mower or wiper snipper.
- Animal ethics approval must be obtained for grazing management.
- The trials will receive 50 kg N/ha in the form of Urea twice a year (spring & autumn) and an annual topdressing of single superphosphate (P: 8.8% & S: 11%) or equivalent at 150 kg/ha in autumn.
- Grass weeds in the trial area will be controlled by hand weeding and broadleaf weeds will be controlled by using suitable herbicide such as Kamba M (340 g/L MCPA and 80 g/L dicamba).

Management – Tropical Species

- Trials to be mown to a height of 8-10 cm (bunch grasses) and 5-7 cm (stoloniferous grasses) after yield assessments. Or trials to be crash grazed with sheep down to a similar height. After grazing if required trial area will be evened out using a mower or wipper snipper.
- The trials will receive an annual topdressing of single superphosphate (P: 8.8% & S: 11%) or equivalent at 150 kg/ha in early autumn.
- The trials will receive 20-40 units N/ha in the form of Urea in autumn and either Urea or Sulphate of ammonia twice a year (late winter to early spring and then again in mid-spring depending on seasonal conditions). A third application may be warranted over summer if there is significant rainfall event (e.g. >50 mm over 3 days).
- Grass weeds in the trial area will be controlled by hand weeding and opportunistic mowing, while broadleaf weeds like capeweed and winter growing annual species will be controlled by using a suitable herbicide such as 2-4D or Kamba M.

Temperate grass nurseries

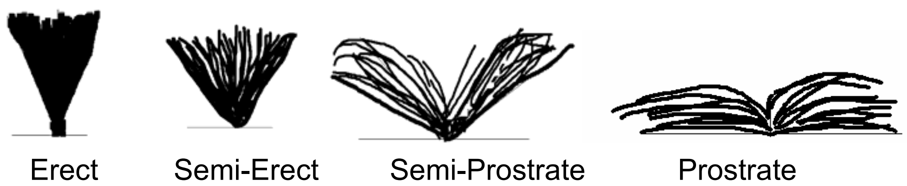
Seasonal growth (yield)

- To be measured at a minimum 4 times a year at the change of season but ideally every 6 weeks (i.e. 8 times a year).
- Before rating commences the plots should be generally assessed so that the best and worst plants can be decided upon.
- Plant rows to be visually scored for herbage mass using a scale of 0 to 9 where 0=nil yield, 1=low herbage mass to 9=high herbage mass.

- To ensure accuracy of the scores a calibration should be conducted at each yield assessment.
- Calibrate visual score of herbage mass by taking a minimum of 12 pasture cuts in the buffer rows, taking 4 cuts in each of the low, medium and high range of the herbage mass. The number of calibration cuts will need to be increased if there is a wide range of variability in herbage mass.
- The 12 calibration points should be selected and marked prior to scoring the plant rows but not cut until after the scoring has been finished. These calibration points can be referred to throughout the scoring process for consistency.
- The calibration cut will consist of a complete plant row; cuts will be placed in labelled paper bags, returned to the lab, dried and weighed.
- Note that a score of 9 on one occasion is not necessarily the same as a score of 9 on another occasion.
- Field plans without identifiers should be used so that the scoring is not biased with knowledge of the identity of a treatment.

<u>Growth habit</u>

- To be measured in autumn in year of sowing and spring in 2nd year after planting.
- Observations made visually as an estimate of the angle formed by an imaginary line through the region of greatest leaf density and the vertical. 4 levels of measurement, erect, semi-erect, semi prostrate and prostrate as shown below.



<u>Phenological development</u>

- To be measured over spring/summer in the 2nd and 3rd year after planting. Observations will need to be made at least once a week over this period.
- At each observation record the average stage of flowering for a maximum of 5 tillers per plant (giving a total of 20 tillers of each line per replicate), score for vegetative growth, and flowers in boot, emerging heads, flowers open and anthesis. It would be also useful to record signs of ergot infection in the seed heads at this time – use a scale similar to that for rust (see below under disease). Seed heads to be removed once anthesis has been reached except for in 2 reps (see seed yield potential below).
- From the individual plant data a mean date for the various stages of phenological development for each line can be obtained.

<u>Seed yield potential</u>

- In 2 reps phenological development should be monitored to seed maturity. Just before seed fall all seed heads for each line should be harvested, bulked together and collected into paper bags.
- At the lab seed heads should be threshed, seed collected and weighed to give an estimation of seed yield potential for each line.
- In addition the 1000 seed weights for each line can be measured.

Persistence
- Plant survival to be measured in autumn and spring each year
- A plant count of the number of sown plants surviving is to be made for each line and each rep (i.e. the number of plants out of 4 surviving in each replicate). This will give an average survival percentage rate for each line.

Leaf texture (tall fescue)
- To be measured in autumn and spring of each year.
- Each row of plants will scored for soft or harsh texture by feeling the leaves. Plants to be scored using a scale of 1 to 3, where 1=soft leaf texture, 2=medium (average) texture and 3=harsh or coarse leaf texture.

Leaf size (leaf width)
- To be measured in autumn and spring of each year.
- Each row of plants to be scored for leaf size using a scale of 1 to 4, where 1=very fine leaf (turf type), 2=fine, 3=medium (average) and 4=broad.
- Optional: Leaf samples can be taken from 2 reps to calibrate scores for greater accuracy. Forty leaves per line per rep will be harvested at the leaf base and leaf width will be measured at the broadest part of the leaf (in mm) to give an objective measure of mean leaf width for each line.

Disease
- Plants to be scored for tolerance to disease (namely rust) at a minimum 4 times a year at the change of season.
- Plants to be scored using a scale of 1 to 5, where 1=nil incidence of rust, 2=<25% of the plants showing signs of rust, 3=25 to 50% of plants showing signs of rust, 4=50 to 75% of plants showing signs of rust and 5=>75% of plants showing signs of rust.

Endophyte status (tall fescue)
- Approximately 30% of all treatment will be selected for determination of endophyte status. In total 80 plants will be sampled.
- The endophyte status of selected lines is to be determined in the 2nd or 3rd year after planting.
- From each plane collect up to 10 tillers per plant making sure tiller is cut at or just below ground level. Once cut tillers should be placed in a plastic bag with some moist paper towel and stored in an esky with ice bricks.
- Samples should be dispatched on overnight courier as soon as possible after collection to laboratory for analysis.
- Endophyte presence will be determined using Tissue Print Immuno Blot method?

Nutritive value
- Approximately 30-50% of all treatments will be chosen for nutritive value determination based on the assessment of yield, growth habit, tiller density and flowering time.
- In spring to early summer plants identified for sampling will have approximately 15g of fresh leaf and stem (free of seed head) material collected. Assuming approximately 70% moisture content this will provide 4.5 g of dried sample for analysis.
- At the time of sampling plants will be visually scored for leaf & stem percent and green & dead leaf percent. Ten samples will be taken and manually sorted for leaf, stem, green leaf and
  dead leaf to calibrate the scores.
- Samples will be placed in paper bags in a portable freezer and freeze dried on return to the laboratory.
- Samples will be analysed for digestibility, crude protein, neutral detergent fibre and water soluble carbohydrates.

Tropical grass nurseries

Bunch Grass nursery

Seedling Vigour

- A score of herbage mass of the seedling rows is to be conducted 12 weeks after planting/sowing.
- Rows are to be scored using a scale of 0 to 9, where 0=nil, 1=low herbage mass and 9=highest herbage mass. (please note calibrations cuts are not taken and the trial is not mown or grazed unless there is exceptional growth).

Seasonal growth (yield)

- To be measured at a minimum 4 times a year at the change of season but ideally about 6 times. The frequency will vary with the seasonal conditions. Biomass is not measured if the growth above cutting height is <250 kg DM/ha.
- Plant rows to be visually scored for herbage mass using a scale of 0 to 9 where 0=nil yield, 1=very low herbage mass to 9=highest herbage mass, use 0.5 increments. (A score of 9 should be 2x the biomass of a plot with a score of 4.5).
- To ensure accuracy of the scores a calibration should be conducted at each yield assessment. It is desirable to have an R2 > 0.8, while R2 >0.7 is acceptable (if R2 is less than 0.6 need to re-calibrate).
- Calibrate visual score of herbage mass by taking a minimum of 12 pasture cuts of a 1.0 m of plant row, avoiding the ends. Ideally take 4 cuts in each of the low, medium and high range of the herbage mass. The calibration cut are to be placed in labelled paper bags, returned to the lab, dried and weighed.
- The 12 calibration points can be selected and marked prior to scoring the plant rows but not cut until after the scoring has been finished. These calibration points can be referred to throughout the scoring process for consistency.
- Scores are converted to g DM per m of row (not kg DM/ha).

Growth habit: Rhodes Grass row trial

- To be measured in early December in year of sowing and autumn and spring in the 2nd year after planting.
- Observations made estimate the stoloniferous growth versus leafy growth from the crown. Scale is 1= all leafy growth from the crown with no stolons to 3 =All stoloniferous growth with no leafy growth from the crown (can use 0.2 to 0.5 increments).

Phenological development

- To be measured over spring/summer in the 1st, 2nd and 3rd year after planting. Observations are made every time the biomass is assessed.
- At each observation record the average number (or range) of seed heads per plant. (More intensive measurements are warranted for promising accessions.)

Persistence

- Plant survival to be measured in several times each year. The aim is to closely follow persistence over summer and also over winter when plants are most likely to be lost.
- A count of the number of sown plants surviving is to be made for each line and each rep (i.e. the number of plants out of 6 surviving in each replicate). This will give an average survival percentage rate for each line. When recording the data, the plants within a plot can be listed from no. 1 to no. 6.

Leaf size (Leaf width)
- To be measured in autumn and spring of each year on promising accessions only.
- Each row of plants to be scored for leaf size using a scale of 1 to 4, where 1=very fine leaf, 2=fine, 3=medium (average) and 4=broad. In addition in Reps 4 and 5, 20 leaves per line per rep will be harvested at the leaf base and the leaf width will be measured at the broadest part of the leaf (in mm) to give an objective measure of mean leaf width for each line. Stems are rated as 1=fine stems to 3 = coarse stems.

Disease
- Plants to be scored for tolerance to disease (e.g. rust) opportunistically when disease is affecting some or all of the lines.
- Plants to be scored using a scale of 1 to 5, where 1=nil incidence of rust, 2=<25% of the plants showing signs of rust, 3=25 to 50% of plants showing signs of rust, 4=50 to 75% of plants showing signs of rust and 5=>75% of plants showing signs of rust.

Feed quality (Nutritive value)
- Samples for nutritive value on selected, promising lines and commercial controls are to be collected at 3 times during the 2nd and 3rd years; i.e autumn growth, early spring and possibly late spring.
- After grass samples (100g fresh DM) have been cut and placed in plastic bags they should be stored in an esky with ice bricks.
- At the lab samples should be dried at 60oC. If time permits samples should be sorted into green and dead components before drying – if not sorting can be done after drying
- Once samples have been sorted they can be ground using a 1mm sieve. Approx 10g of ground material is required per sample for analysis. (depends on lab selected and pricing).
- Sample should be analysed for digestibility, crude protein and metabolisable energy.

Temperate grass drill row trials

Establishment
- Plant counts approximately 4 to 8 weeks after sowing
- The number of plants in a 10 x 10 cm quadrat is to be counted. This is to be repeated 4 times (i.e. 4 quadrats per row).
- Data to be expressed as plants per metre row

Seedling Vigour
- A score of herbage mass of the seedling rows is to be conducted 12 weeks after sowing.
- Rows are to be scored using a scale of 0 to 9, where 0=nil, 1=low herbage mass and 9=high herbage mass.
- Where plant population allows 4 plants per row will be harvest for detailed shoot and root measurements. Measurements will include tillers per plant, shoot height, root length, shoot & root dry matter.

Phenological development
- As for nurseries
- Select 20 tillers per row for measurement

Persistence
- To be measured in autumn and spring of each year.
- A visual score of the percentage of each row occupied by tall fescue plants. Scored using a scale of 1 to 4, where 1=<25%, 2=25 to 50%, 3=50 to 75% and 4=>75%.

Note: Seasonal Yield, Growth habit, Leaf texture (tall fescue), Leaf size (leaf width), Disease, Nutritive value and Endophyte status measurements as per those for nursery trials.

References

Anon. 1993. Experimental Protocols: grazing management sites (Meat Research Corporation: Sydney).

Anon. 1996. Tall fescue improvement for winter growth, seedling vigour and productivity. Final Report DAV095 (Meat Research Corporation: Sydney).

Campbell N.A., and Arnold G.W. 1973. The visual assessment of pasture yield. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13**, 236-267.

Cayley J.W.D., and Bird P.R. 1996. Techniques for measuring pastures. *Agriculture Victoria, Technical Report series No 191.*

Isbell R.F. 1996. The Australian Soil Classification. CSIRO Australia.

Lodge G.M. 1998. Themes and experimental protocols for sustainable grazing systems. LWRRDC Occasional paper No 13/98.

9.2 Scoping study

CRC FOR
PLANT ~ BASED
MANAGEMENT
OF DRYLAND
SALINITY

Perennial pastures for the recharge areas of southern Australia

S. J. Bennett, J. Ayres, B. S. Dear, M. Ewing, C. Harris, S. Hughes, M. Mitchell, G. Moore, Z. Nie, K. Reed, G. A. Sandral, J. Slattery, R. Snowball.

CRC for Plant-based Management of Dryland Salinity, 2002.
SCOPING DOCUMENT NO. 1

List of recommendations

Perennial grasses

1. *Develop cultivars of perennial grasses that are drought tolerant and persist in acid, low fertility soils and, in particular*:
- *Expand the cocksfoot breeding programme into low and medium rainfall environments*
- *Develop tall fescue varieties with increased summer growth using non-toxic endophytes*
2. *Develop perennial grass cultivars and species that show some summer activity, including*:
- *Select phalaris cultivars with high summer activity and drought tolerance*
- *Evaluate sub-tropical perennial grasses for low to medium rainfall areas*
3. *Improve seed set and harvestability of native grasses prior to commercialisation*

Perennial legumes

1. *Develop lucerne varieties suitable for more acidic soils*
2. *Develop lucerne cultivars with tolerance to manganese and aluminium*
3. *Select rhizobia with high nodule occupancy in lucerne, and which persist in acid soils*
4. *Develop new Lotus corniculatus (birdsfoot trefoil) varieties suited to areas receiving 400-750 mm annual rainfall with better persistence over summer and better drought and grazing tolerance*
5. *Evaluate other Lotus species for recharge control in southern Australia, especially L. glaber for high rainfall water-logged soils, and L. maroccanus for lower rainfall areas*
6. *Fast-track Dorycnium species for low rainfall areas including*:
- *D. hirsutum for dryland conditions in low rainfall areas on soils with low fertility*, *and*
- *D. rectum for permanent pastures in damp to wet areas*
7. *Evaluate other perennial legumes including*:
- *Hedysarum coronarium, a short-lived perennial species for calcareous soils, and*
- *Onobrychis viciifolia, which has a similar niche to lucerne, but in lower rainfall areas*
8. *Identify and collect native perennial legumes for the low to medium rainfall areas*

Native and exotic non-leguminous herbs

1. *Evaluate exotic herbs for the recharge zones of southern Australia, including*:
- *Chicory (Cichorium intybus) in areas with neutral to acidic soils*
- *Sheeps burnet (Sanguisorba minor), tolerant of mildly saline and infertile soils, with a preference for alkaline soils; and*
- *The plantain family (Plantago sp.) especially P. lanceolata*
2. *Evaluate native herbs for the recharge zones of southern Australia, including the genus Ptilotus*.

Background

The removal of perennial deep rooted species from the landscape is now widely associated with increased deep drainage resulting in rising water tables and increased flushing of salt into low lying areas or streams. Farming systems currently rely heavily on shallow rooted annual crops and pastures that are relatively ineffective at drying the profile and preventing deep drainage. There is limited current use of perennials in farming systems and then, when used, they are confined mainly to non-cropping areas. The challenge is to vastly increase the role and importance of perennial plants in farming systems.

Of available plant types, perennial pastures offer the best opportunities for rapid and large scale adoption, because the fodder they produce has the potential to be used effectively and profitably in existing or slightly modified livestock systems. In contrast, perennial crops including trees will generally require the establishment of completely new industries with associated infrastructure.

With this in mind we have reviewed the role and potential of perennial pastures to eliminate or reduce recharge on a substantial scale. The study covers exotic and native herbaceous perennial pastures (legumes, grasses and forbs) and evaluates their potential, if known to:

- Extract sufficient water to minimise recharge;
- Adapt to the prevailing soil and climatic constraints of the target zone (e.g. acidity, transient waterlogging etc), and
- Fit into and be more profitable than current or likely farming systems (particularly livestock utilisation).

The geographical area covered by the activities of the CRC for Plant-based Management of Dryland Salinity includes a diverse range of climates and soils. Annual rainfall varies from 300 mm to more than 800 mm, with a strongly mediterranean rainfall pattern through to summer dominant rainfall areas. Soils range from deep coarse textured soils to cracking clays with the pH varying from highly acid to alkaline. This range of agro-ecological zones provides a major challenge to the program, but also means that species with no or limited potential in one environment may be well adapted for use in others. Not only are different species of perennials likely to be important in different situations, but the functional role of the perennials will vary.

Lucerne is the most widely sown perennial in cropping areas, with exotic perennial grasses playing a small but growing role in eastern Australia. Expansion of the area under lucerne is restricted by a number of factors, including soil acidity, waterlogging, risk of bloat and susceptibility to set stocking (Dear *et al.* 2002). Native perennial grass pastures are widespread in the higher rainfall recharge areas of eastern Australia but these are often badly degraded and poorly managed, and are failing to prevent recharge.

Recharge control

The ability of perennial pastures to reduce recharge has become clear with recent experimental studies. A number of researchers have shown that changing from annual pastures with an average rooting depth of 50-70 cm to lucerne rooting to 2 m increases the maximum dry soil buffer from about 90 cm to 180 cm. On deep sands, serradella (*O. compressus*) has been reported with rooting depths of up to 195 cm and *Medicago tornata* to 130 cm (Hamblin & Hamblin 1985), but there are few other reports of annual species reaching these depths. However, on deep sands some annual species may be reducing deep drainage, and there may be a continuing role for them on these soil types. In many cropping soils lucerne can root to 3 m, and in these cases the dry soil buffer can reach 270 cm. Dry soil buffers of this magnitude can reduce deep drainage to nil in all but the wettest years in the 500 to 650 mm rainfall zone. Similarly perennial grasses can also create a substantial soil water deficit (Lolicato 2000; Ridley *et al.* 1997). Work in the NSW wheatbelt found that from a one-year pasture phase within a crop rotation, perennial grasses could create a deficit of between 140 and 162 mm. The maximum soil water deficit created by a number of perennial species is presented in table 1 in order of increasing deficit.

There is only limited data on the ability of native grasses to extract soil water. The information available (see table 1) suggests that native grasses such as Austrodanthonia are less effective at extracting water to depth compared to introduced temperate species (Sandral *et al.* unpublished data). However when persistence is taken into account, native grasses are likely to be superior due to better long-term persistence and less reliance on high inputs.

Table 1. Maximum dry soil buffer created by annual and perennial pasture and crop plants

Species	Location	Dry soil buffer (cm)	Reference
Annual crop	Rutherglen	84	Ridley *et al.* 2001
Annual pasture	Junee	89	Sandral, Dear, Virgona (unpub data)
Annual crop	Tatura	91	Whitfield 2001
Annual pasture	Tatura	100	Whitfield 2001
Austrodanthonia	Junee	140	Sandral, Dear, Virgona (unpub data)
Consol lovegrass	Junee	146	Sandral, Dear, Virgona (unpub data)
Cocksfoot	Junee	155	Sandral, Dear, Virgona (unpub data)
Lucerne	Junee	157	Sandral, Dear, Virgona (unpub data)
Phalaris	Junee	162	Sandral, Dear, Virgona (unpub data)
Cocksfoot	Tatura	170	Whitfield 2001
Birdsfoot treefoil	Tatura	200	Lolicato 2000
Phalaris	Tatura	210	Lolicato 2000
Lucerne to 2m	Rutherglen	228	Ridley *et al.* 2001
Lucerne to 2 m	Tatura	230	Lolicato 2000
Lucerne to 3m	Rutherglen	306	Ridley *et al*. 2001

Target Environments in southern Australia

An important prerequisite to defining gaps in current breeding activities and determining potential new research projects is to identify the areas that are contributing to the recharge of groundwater and local watercourses. As the areas affected by recharge vary in each region, a summary table is shown below (Table 2) where the priority areas are listed on a per state basis.

Table 2. Summary of target zones for recharge control on a per region basis

Target environment	**Rainfall (mm)**	**Soil type**	**Description**	**Area (ha)[1]**
Southern NSW				
1. Steep undulating slopes	> 800		Mainly non-arable	1.79m ha
2. Steep slopes, fractured rock	500-800	Shallow	Mainly non-arable hilltops and upper slopes	2.01m ha
3. Upper to mid-slopes	500-800	Low-fertility soils	Non-arable to direct drilling. High proportion native vegetation	1.3m ha
4. Mid slopes	500-800	Granite or shale duplex acid soils	Arable. Poor to moderately drained soils, sub-soils less acid	1.2m ha
5. Mid slopes	500-800	Granite or shale acid duplex soils	Arable, poor to moderately drained	1.8m ha
6. Low slopes	450-700	Red to red-brown earths, neutral-acid pH	Arable and cropping. Sub-soils more neutral	3.98m ha
Northern NSW				

Target environment	Rainfall (mm)	Soil type	Description	Area (ha)[1]
1. Upper slopes	550-900	Shallow soils	Mostly non-arable, forested areas, hilltops or upper slopes	2.54m ha
2. Mid slopes	550-900	Some acid soils	Mostly non-arable. Poor to moderately drained	1.06m ha
3. Low slopes	550-900	Red-brown earths, non-acidic	Mainly arable. Watertable > 5m	1.6m ha
4. Low slopes	550-900	Brown & black vertisols	Arable, some flooding. Watertable < 2m	3.89m ha
Victoria				
1. North-east Victoria	500-2500	Red duplex, earths, friable earths	Acidic soils, permenant pasture, some cropping	1.98m ha
2. North-central Victoria	320-1160	Red duplex, red clays, calcareous	Neutral, broad acre	2.6m ha
3. Golden-Broken	400-1800	Duplex, shallow stony, friable earth	Neutral to mildly acidic, mixed farming, some irrigation	2.4m ha
4. SW Victoria - (a)	600-700	Tablelands & slopes	Mainly arable, acidic loams	0.6m ha
5. SW Victoria - (b)	600-800	Basalt plains & rises	Mainly arable, acidic clay loams, waterlogging	1.0m ha
6. SW Victoria - (c)	550-850	Sediments	Mainly arable, acidic/ alkaline sandy loams	0.9m ha
South Australia				
1. Murray Basin	275-550	Mallee dune-swale system	Large areas of dryland salinity (upper SE)	3.6m ha
2. Eyre Peninsula	385-550	dune-swale landform, calcareous sands & acidic soils	Mainly arable, well drained. Variable soil types, mainly dune-swale landform, calcareous sands (north), to more acidic in the south	2.9m ha
3. Kangaroo Island	620	Neutral-acidic sandy-loams	Prone to waterlogging	0.4m ha
4. Mid-North	400-460	Red-brown earths; variable pH	Significant areas of non-arable land	1.1m ha
5. Yorke Peninsula	400	Neutral-alkaline sandy loams	Mainly arable, heavily cropped	0.6m ha
6. Mt Lofty Ranges	550	Shallow stony soils	Large areas of non-arable hills and rises	0.44m ha
Western Australia				

Target environment	Rainfall (mm)	Soil type	Description	Area (ha)[1]
1. Zone of rejuvenated drainage (a)	400-600	Loamy-duplex and -gravel, shallow sandy duplex soils	Mainly cropping. Well-drained to moderately well drained (pH acidic)	0.9m ha
2. Zone of rejuvenated drainage (b)	400-600	Deep sandy duplex soils	Arable and pasture. Well drained to moderately well drained (pH acidic)	1.18m ha
3. South coast (a)	400-650	Shallow to deep sandy duplex soils	Arable and pasture. Moderately well drained to imperfectly drained (acidic)	1.49m ha
4. South coast (b)	400-650	Deep pale sands	Pasture with some cropping. Excessively drained (acidic)	0.4m ha
5. Zone of Ancient Drainage (a)	300-450	Shallow sandy and loamy duplex soils	Mainly cropping. Well-drained to moderately well drained (alkaline to acidic)	3.22m ha
6. Zone of Ancient Drainage (b)	300-450	Deep sands and loamy earths	Arable and pasture. Well drained (pH acid to highly acid)	1,762,000

[1]Areas given are estimates of recharge areas

Southern NSW is a predominantly cool season effective rainfall environment, and the assumption has been made that in areas receiving less than 450 mm annual rainfall, recharge is negligible. Recharge from this region feeds into the Murrumbidgee, Murray, and Lachlan River catchments, which ultimately feed into the Murray Darling Basin. Northern NSW is a predominantly summer rainfall environment. Recharge from this region feeds into the MacIntyre, Gwydir and Namoi River catchments, which ultimately feed into the Murray Darling Basin. Dryland salinity in South Australia occurs in six catchments namely, the Murray Basin, Eyre Peninsula, Kangaroo Island, Mid-North, Yorke Peninsula and the Mt Lofty Ranges. Rainfall and soil types vary markedly - both across and within catchments. Recharge systems also vary and include the well-documented regional flow system of the Murray Basin to local flow systems found on Kangaroo Island, Yorke Peninsula and the Mt Lofty Ranges. Priority areas for recharge control are the low to medium rainfall regions with neutral to alkaline, sandy soils. In Victoria the regions most affected by saline groundwater intrusions are the South West, North Central and Goulburn-Broken regions. Predictive modelling of saline groundwater intrusions indicate that south west Victoria will become the largest area of Victoria affected by dryland salinity by 2020, and is estimated at 0.7 - 1.4m ha. The worst affected catchment is predicted to be the Glenelg-Hopkins (National Land & Water Australia, 2000). In Western Australia the situation is different to the eastern states as recharge areas remain as separate entities and do not ultimately feed into a single catchment. There are three main zones at risk of salinisation; the zone of rejuvenated drainage (central wheatbelt), the south coast and the zone of ancient drainage (eastern wheatbelt), and within these the main soil types have been prioritised.

Current perennial recharge breeding activities

In conjunction with Table 2 above of the target environments of southern Australia for recharge control, it is important to determine current breeding activities, what cultivars are available for which environments, and where the major gaps exist for which there are no perennial species currently available. This information is summarised in Table 3 below.

Table 3. Summary of current perennial legume and grass breeding activities for recharge areas, and identification of gaps in the target areas.

Breeding activities	Current knowledge	Gaps
Perennial legumes		
Lucerne	Cultivars available for neutral to alkaline soils, resistance available for common pests and diseases	Water-logging tolerance, salinity tolerance and cultivars for acidic soils
Birdsfoot trefoil	Cultivars available for high rainfall areas of southern Australia. Tolerant of water-logging and acid soils	Medium to low rainfall areas, better persistence under drought conditions
White clover	Successful in areas with more than 800mm annual rainfall	Medium to low rainfall areas (below 800mm/ yr)
Sulla	Breeding almost limited to mediterranean Europe. Good drought tolerance in alkaline areas	Neutral to acid soils, Tolerance to heavy grazing, prostrate types.
Perennial grasses	*Management is an issue in all grasses: weed control, soil fertility, grazing tolerance. Need species for medium to low rainfall areas with better drought and acidity tolerance and increased persistence*	
Perennial ryegrass	Suitable for high rainfall, fertile areas - dairy areas of Australia	Drought tolerance, benefits of ‘safe’ endophyte, increase into medium rainfall areas
Tall Fescue	Long growing season. Some tolerance to waterlogging and soil acidity	Benefit of ‘safe’ endophyte, increased drought and acidity tolerance
Cocksfoot	Reliable on acidic sandy hill country of low fertility	Enhanced performance in low-medium rainfall including wheatbelt
Tall wheat grass	Good summer activity. Developed for discharge regions, some salt tolerance	Better cool season activity
Phalaris	Deep-rooted, therefore dries out soil profile. Drought tolerant	Sensitive to heavy stocking, contains undesirable alkaloids, intolerant of acid soils
Native grasses	Number of elite lines selected for medium - high rainfall environments	Species/ ecotypes for medium to low rainfall environments. Improved seed yield and ease of harvesting required.

The risk of pests and diseases

Lucerne and other perennial pasture species provide a "green bridge" for the survival of pests and diseases over the dry summer period, and are a major reservoir for their spread to nearby crops, especially early in the growing season. The "green bridge" is particularly important for the carry over of pests, like aphids, and pathogens such as rusts and luteoviruses that have no means of survival except in living plant material, i.e. they have no diapause stage, no dormant resting spores, are not seed-borne, etc.

With regard to virus diseases, the big difference from the annual pasture situation is a high level presence of luteoviruses within the pasture at the very start of the growing season. Luteoviruses include bean western yellows virus (BWYV) and barley leaf rust virus (BLRV), their aphid vectors, and other viruses such as alfalfa mosaic virus (AMV). These high infection incidences provide a potential potent early reservoir for their spread to nearby crops and annual pastures, starting off early epidemics and thereby predisposing them to high final infection incidences and subsequent substantial yield losses. In contrast, within annual pastures, infection starts at a very low level early in the season, not reaching similar high levels until much later in the growing period. Thus infected annual pastures do not constitute a potent infection source for spread to crops at the critical initial phase of their growth.

Insecticide applications, especially pyrethroids, work well at suppressing the spread of luteoviruses as they are persistently aphid-borne, and so will be effective in suppressing their spread in lucerne stands. Insecticides can also provide some control of non-persistent aphid-borne, seed-borne viruses, such as AMV, within pastures, but are not as effective as with luteovruses. Sowing new pastures with healthy seed stocks of perennial plants avoids introducing seed-borne virus diseases in the first place and healthy seed programs need to be encouraged for lucerne. Spraying out heavily diseased perennial pastures with herbicide may sometimes be justified as a last resort, especially if they are old and have had a number of years to accumulate multiple infections.

There are plenty of older papers from overseas on the effect of AMV in reducing foliage growth of lucerne and the productivity of stands. In Australia, if we extrapolate to lucerne and other perennial species from the published medic data with AMV, infection reduces; herbage and seed production, plant density, nitrogen fixation, and the ability of infected plants to compete with plants of other species (e.g. capeweed), resulting in poorly productive stands with reduced legume contents. Virus infection also increases the concentration of deleterious oestrogenic compounds in the plant.

The importance and limitations of lucerne

Lucerne is a deep-rooted herbaceous perennial legume that is capable of substantially lowering watertables (Ridley *et al.* 1998) and reducing acidifcation rates (Bellotti *et al.* 1998; Passioura & Ridley 1998) in southern Australia, and thus has an important role in preventing dryland salinity. A major review of the success of lucerne to date, lucerne breeding programme objectives and current limitations to its expansion has been published by Humphries and Auricht (2001) and will not be repeated in this document. A summary, only, of the current limitations of lucerne and the suggested recommendations given in the paper are detailed below.

The expansion of lucerne into greater areas of southern Australia, and in particular into Western Australia, is limited by a number of important factors. These include a lack of tolerance to:

- Acid soils, and particularly a lack of tolerance to aluminium and manganese (Mugwira & Haque 1993), poor rhizobial performance (Howieson *et al.* 1992) and low nutrient availability (Baligar *et al.* 1993);

- Waterlogging, where the mechanism and variation has yet to be determined;
- Drought, where water use efficiency is an important consideration;
- Salinity, particularly tolerance of mature plants rather than germinating seedlings;
- Pests and diseases, especially multi-disease and pest resistance; and
- Grazing. Most grazing tolerant varieties have been developed from low yielding *M. sativa* ssp. *falcata*.

The competitive ability of the nitrogen-fixing rhizobia is also a problem as they are not competitive against the less efficient indigenous rhizobia (Phillips *et al.* 1985).

In all cases there is the opportunity to develop cultivars of lucerne that show greater tolerance than is currently available. In Western Australia, availability of more acid tolerant lucerne varieties would allow for a large expansion of the area currently sown to lucerne.

It is also recognised that lucerne is not grown in all the areas where it is currently suited. An educational programme is badly needed to provide support in areas where lucerne uptake has been slow to non-existant.

Potential for new perennial grasses

For the successful adoption and use of perennial grasses in recharge environments there is a need to improve adaptation. Cultivars are required that are drought tolerant and will persist in acid, low fertility soils to increase water use and reduce erosion in these environments. Current cultivars have failed to persist under these conditions, due to a lack of appropriate genetics and inappropriate management. Management issues include weed control, soil fertility and control of grazing. With a few exceptions, such as Phalaris and consul lovegrass, grass cultivar development in Australia has concentrated on high rainfall, fertile conditions. Cultivars bred in and for favourable environments such as New Zealand/Australian dairy areas have little value in medium/low rainfall regions.

Priority perennial species have been identified that are persistent, tolerant of high exchangeable soil aluminium levels, highly acid soils, waterlogged soils, low rainfall, heavy shade, short growing seasons and prolonged drought. Indicative genera include *Agropyron, Austrodanthonia, Bothriochloa, Bromus, Dactylis, Dicanthium, Digitaria, Elymus, Eragrostis, Festuca, Hordeum, Lolium, Lothopyrum, Microlaena, Panicum, Paspalidium, Phalaris, Poa, Setaria, Stipa and Themeda.*

Of the important commercial species, the two C3 grasses with the most summer activity are tall wheatgrass (*Lothopyron ponticum*) and tall fescue (*Festuca arundinacea*). Tall fescue is more tolerant of waterlogging than cocksfoot, and more tolerant of acidity than Phalaris (*Phalaris aquatica)*, plus has a long growing season, particularly in summer rainfall regions. Tall fescue infected with a non-toxin producing endophyte may well provide significant benefits in terms of seedling vigour, tillering, water use efficiency and drought tolerance, thereby significantly increasing the zone for which this grass may be relied on for both production and persistence. Tall wheatgrass yields well relative to tall fescue in summer in regions where summer rainfall is limited (Smith *et al.* 1994), but its use, to date, has been mainly confined to discharge environments, Research into its management and use is required (Smith 1996). However, its ability to grow in summer suggests that it should be included in studies in a range of environments.

Hamilton (NRE) is responsible for the genetic resource centre for perennial grasses in Australia, both exotic and native species. They will provide support for important introduced species of *Dactylis glomerata*, *Festuca arundinacea*, *Phalaris* sp. and *Lolium* sp., as well as minor species and native germplasm.

Perennial grass initiatives

1.Expansion of cocksfoot to the low and medium rainfall environments

To achieve genetic improvement in cocksfoot, a planned breeding project is overdue and should take precedence over further evaluation of accessions. Breeding promises an excellent chance of success because a number of diverse accessions have recently been identified as having promise in SE Australia. NRE has extensive experience in cocksfoot evaluation, plus the development of other perennial grass cultivars, and thus is in a good position to design and manage a cocksfoot-breeding program within a relatively short timeframe. In collaboration with researchers from the CRC-PMDS potential cultivars can be assessed and developed across southern Australia.

The aim of the programme would be to develop and evaluate, by 2008, broadly adapted synthetic cultivars of cocksfoot that will improve persistence and yield relative to standard varieties of cocksfoot when grown in the low rainfall, acid soil cropping districts of southern Australia. There are two breeding objectives:

a) An intermediate type. This would have increased water use and yield, obtained through summer activity, but with out losing persistence. It would be suited to the 400 to 600 mm annual rainfall zone, and

b) A low rainfall type. Scope exists to identify highly winter-active accessions from low rainfall (350 mm) acid soil areas where persistence maybe expected in districts with a 5-6 month growing season.

Secondary objectives of both these breeding programmes would include seed yield, disease resistance and nutritive value. However, disease incidence in cocksfoot is rare in the low to moderate rainfall areas. Sources of resistance to these have been clearly demonstrated (Clarke and Eagling 1994).

2. Increasing summer growth of tall fescue using non-toxic endophytes

The practical value of tall fescue pasture has been greatly boosted by the recent advent of a high winter-producing mediterranean type with summer dormancy which increases persistence (cv. *Fraydo*). The use of such material in mixtures with summer active tall fescue provides a nutritious summer active pasture with good year round carrying capacity.

The use of non-toxic or ‘safe’ endophytes incorporated into cultivars of tall fescue and perennial ryegrass have been shown to improve plant water relations, tillering, pest resistance, nutrient efficiency, mobility of toxic Al in roots, competitive ability, persistence and drought tolerance (Hoveland, 2000). In Australia only non-endophyte cultivars of tall fescue have been promoted - until now. The use of the new ‘safe endophyte’ has the potential to extend the zone of adaptation of tall fescue into lower rainfall, and perhaps less fertile areas, through increasing summer growth in disctricts where late season rainfall is limited.

To date, research into grass-endophyte relations has taken place almost exclusively overseas, and has been targeted at improving the stress tolerance of turf grasses. Variation in the toxic potential of endophytes in Australia has been recorded (Reed *et al.* 2000), but the development of select grass-endophyte associations for Australian livestock systems has not as yet occurred. Selecting fungal genotypes that have low/zero toxin production can eliminate the negative impact of endophyte toxin production on livestock.

The aim of the project would be to sceen tall fescue ‘safe’ endophye combinations at a range of environments around southern Australia. Commercial cooperation will be sought to obtain safe-endophyte-infected seed lines for a set of representative cultivars with contrasting growth rhythms.

Endophyte detection capability will be upgraded so that the evaluation of tall fescue accessions will not inadvertently spread unsafe endophyte. Promising lines will be identified and entered into a more advanced screening including water use measurement.

3. Selection of phalaris for high summer activity and drought tolerance

Phalaris is a semi-summer dormant, winter active species, that is deep rooted, drought tolerant and high yielding. It is therefore an effective plant to dry out the soil profile. However, it is sensitive to heavy stocking, contains undesirable alkaloids, and is intolerant of acid soils. CSIRO is currently conducting a phalaris-breeding programme focussed on persistence and winter vigour. The objectives of the CRC for Plant-based Management of Dryland Salinity are persistence, acid tolerance and summer growth. These differ from those of CSIRO, and therefore there is an opportunity to collaborate with CSIRO in a phalaris improvement programme.

A number of lines have been identified that have some of the desirable characters, such as acid tolerance, persistence, low summer dormancy and high summer regrowth, high productivity and salt tolerance, which can be incorporated in a breeding programme with evaluation being conducted at a variety of contrasting sites across southern Australia.

4. Selection of alternative grasses

Elite material of *Stipa semibarbata* and *Elymus scaber* is available for screening from the native and low-input grasses network (NLIGN) project and Department of Primary Industries, Water and Environment (DPIWE) Tasmania. Lines identified with high productivity from the NLIGN project include *Austrodanthonia fulva*, *A. richardsonii*, *Microleana stipoides* and *Themeda australis*. Other species that have been identified as requiring further evaluation include *Secale montanum* and *Bromus* species. Native grasses require improvement and research into both seed production and establishment if their cultivation on a broad acre basis is to be economic.

Themeda australia (kangaroo grass) is the most summer-active native grass species identified, to date. It is distributed widely across high rainfall areas of southeast Australia, and is currently limited by its susceptibility to heavy grazing and low seed production. A collection is required to obtain material from a wide range of ecotypes to conserve its rapidly diminishing genetic diversity. The collection will facilitate further studies on the potential development and use of the species as a broadacre grass for seeding recharge lands.

Secale montanum was one of the most promising grasses identified by CSIRO from their studies on the ecology, grazing and animal production of a wide range of native and exotic alternative perennial grasses carried out in NSW in the 1960s and 1970s. This perennial grass is particularly suited to the highlands but has shown promise on sandy soils in WA and SA (Oram 1996). The large seed size of *Secale montanum* also makes it a potential on-farm feed grain.

A number of *Bromus* accessions have been identified as promising from the following species *Bromus bibertsonii, Bromus mango, Bromus inermis, Bromus stamineus, Bromus valdivianus, Bromus macranthos, Bromus coloratus, Bromus carinatus.* These species have yielded well in Tasmania and better than native species in areas with some summer rainfall and relatively high soil fertility. They should now be considered for screening for potential use in mainland regions, and may have some value in NSW in particular.

5. Selection of sub-tropical grasses for areas with some summer rainfall or perched water tables.

There is need to expand the work being done on the sub-tropical grasses to include a wider range of environments, including some of the lower rainfall areas of the wheatbelt, especially those where the water table is not far below the surface. There is also the potential for some more scientific studies to determine the exact environmental requirements of each species in relation to the WA climate. This is particularly true of soil pH preferences, and salt tolerance. More information is required on rooting depth and water use, especially during the summer months and following summer rainfall events. Species currently under evaluation are shown in Table 4, along with their proposed environmental niche. There may also be other species available that are better suited to regions of the wheatbelt with a lower rainfall than the West Midlands.

Table 4. List of species currently under evaluation in the West Midlands, WA, and their potential use in the landscape.

Species/ soil moisture		Dry	Winte r wet	Winter flooded	Salt tolerance
Rhodes grass	*Chloris gayana*	*	*		*
Green panic	*Panicum maximum* var. *trichoglume*	*			
Setaria	*Setaria sphacelata*	*	**	*	
Blue panic/giant panic	*Panicum antidotale*		**	*	
Elephant grass	*Pennisetum purpureum*	*	**		
Kikuyu	*Pennisetum clandestinum*	*	**	**	
Para grass	*Brachiaria mutica*			***	*
Paspalum	*Paspalum dilatatum*		**	**	

* - satisfactory to *** - very satisfactory

Rotational grazing is necessary to maintain quality and palatability in sub-tropical species (Wiley 2001). Areas in which further research is urgently required include:

- Establishment - They are hard to establish and need total weed control;
- Nitrogen requirement - This is high, but can be overcome by sowing with a companion annual legume; and
- Barber's pole worm. This can be a problem in wet areas. Other worms may also be a problem.

Queensland DPI and NSW Agriculture have developed all of the current varieties of sub-tropical grasses that are available to date. The climates and soil types of these states are very different to those found in the wheatbelt of WA and therefore it is questionable whether the varieties that are being trialed in WA are actually well-suited to the conditions in the state. Further breeding and selection of the most promising species in WA may yield further improvements in their performance and persistance.

7. Using grass species to increase water use

There are a number of management options that need to be considered regarding the use of C3 and C4 grasses that have been identified as having desirable characteristics. C4 and C3 grasses with outstanding summer activity may have correspondingly low cool season vigour and in temperate Australia cool season yield is a crucial determinant of carrying capacity. The concept of a mixture of grasses is the obvious way to overcome this limitation. Mixtures can be used in a number of ways, such as:

- Sow as a mixture,
- Sow in a two-stage process: sow the summer-active species in spring then oversow the cool season species in the following autumn
- Sow the contrasting species in alternative rows
- Use the two species in separate areas as monocultures for use in a sequential grazing system

There is a need to evaluate the potential of sowing the C4 and C3 grasses as mixtures, to determine their water use over the whole year and the dry soil buffer they can provide.

Potential for exotic new perennial legumes

There is clearly a role for alternative perennial legumes that are well adapted to local soils, climate and farming systems. Lucerne is poorly adapted to acid and waterlogged soils, plus as the only major perennial legume available in mediterranean areas of southern Australia is an ecological hazard, in terms of disease and pest infestations. This section outlines the best options for developing new commercial perennial legumes well adapted to the growing conditions and farming systems in southern Australia.

Table 5. Perennial legume species currently under evaluation, with potential environmental niche, and notable characteristics.

Species	Environmental niche	Notable characteristics
Lotus		
L. corniculatus (birds foot trefoil)	400-750mm high rainfall zones	High genetic diversity, water logging tolerant. Contains condensed tannins
L. creticus/ L. cytisoides	Coarse-textured soils	Drought tolerant, some salt tolerance, good persistence, tap-root
L. glaber (narrow leaf trefoil)	Winter-waterlogged, black and grey clay soils of Murray Darling Basin	Reasonable flooding tolerance
L. maroccanus	Lower rainfall areas (400- 550 mm) with loamy to sandy soils	Earlier flowering, more determinant, higher seed production and greater seedling vigour than other perennial *Lotus* species
L. uliginosus *(big trefoil)*	Higher rainfall, waterlogged sites of coastal NSW	Produces tap root, stolons and rhizomes, tolerant of Al, Mn, acid soils and waterlogging. Sensitive to salinity. Potential for crossing with *L. corniculatus* to increase tolerance to acidity of latter
Dorycnium		
D. hirsutum (hairy canary clover)	Dryland conditions on soils with low fertility	Good persistence and summer production, drought and insect tolerant, good tap root
D. rectum (canary clover)	Permanent pasture areas in damp to wet areas	Good production on damp to wet areas, less woody than *D. hirsutum*
Onobrychis		
O. viccifolia (sainfoin)	Similar niche to Lucerne, well-drained medium to fine textured	Good insect control, non-bloating (condensed tannins). Erect habit, green manuring option, non shattering aerial seeding

Species	Environmental niche	Notable characteristics
	alkaline soils in low rainfall areas	
Trifolium		
T. hybridum (alsike clover)	High rainfall areas of western Victoria	Waterlogging tolerance, some drought tolerant. Aerial seedling. Tolerance to high alkalinity and acidity
Hedysarum		
H. coronarium (sulla)	Medium to fine textured calcareous soils	Genetically very diverse. Good drought tolerance with branching tap root, vigorous autumn production. Contains condensed tannins. Non-bloating, insect resistance, arial seeding, non-shattering

For many of the species being evaluated, there are no commercial varieties available in the world and the species are not presently used for sown pastures. On one hand, this means the material has not had an extended period of cultivation and plant improvement like lucerne, but there is also great potential for rapid improvement, as the genetic diversity available within lines is often large. For instance, early vigour can vary by a factor of five within lines of *Dorycnium hirsutum*. A list of species currently being evaluated, along with their potential environmental niche is given in Table 5 above.

The genetic resource centres at both SARDI (Adelaide) and DAWA (Perth) are responisible for much of the initial evaluation of these alternative perennial legumes. They are an integral part of any breeding programme providing seed collection, storage, evauation and bulking. Each GRC has its own mandate for species they will support. The SARDI GRC will support *Astragalus*, *Hedysarum*, *Lotus*, *Medicago*, *Melilotus*, *Onobrychis* and native and exotic species adapted to alkaline and saline soils. Currently over 6,000 accessions of 52 genera and 236 species of perennial legumes exist in the Adelaide GRC. The WADA GRC (Perth) will support *Coronilla*, *Dorycnium*, *Galega*, *Sutherlandia*, *Trifolium* and native and exotic species adapted to acid and saline soils.

A number of other species are also worthy of further evaluation, but at this stage little is known about their potential in southern Australia. These include:

- *Anthyllis vulneraria* - Temperate ecotypes from Europe did not survive Australian summer, but reported to be large variation. Currently under review by AQIS.
- *Astragalus cicer* - Winter dormant, summer active, requiring summer rainfall. Drought and defoliation tolerant, but low tolerance to acid soils. It is non-bloating, but causes a photosensitization response while being grazed (Marten *et al.* 1990).
- *Astragalus adsurgens* - Little research to date, but noted to have long, thick tap-root (Lumpkin *et al.* 1993), and to be cold and drought resistant. Seedling establishment slow, but rapid growth once established. Good seed production.
- *Dorycnium pentaphyllum* - Forage quality superior to *D. hirsutum* (Forde *et al.* 1989), but not as drought tolerant. Seedling vigour and growth in first year very poor and needs to be addressed. However, production in second year was equal to *D. hirsutum* (Wills *et al.* 1999).
- *Galega orientalis* - High yielding, drought tolerant species, growing on neutral to acid soils. A tap-rooted species, which can spread vegetatively by underground stolons. A number of cultivars available overseas. Rhizobial constraints to be overcome before further evaluation.

- *Hedysarum carnosum* - High yielding persistent species, tolerant of both arid and saline environments, but not necessarily water-logged soils. Tolerance to different soil types is unknown. *H.carnosum* is currently a prohibited import into Australia.
- *Hedysarum fruticosum* - Rhizomatous long-lived perennial. Found on sandy soils with neutral pH. Cold and drought tolerant, and also possibly some salt tolerance. Rhizobia constraints still to be overcome. AQIS status unassessed.
- *Lathyrus sylvestris* - Rhizomatous species. Drought, and salt tolerant, and pest resistant. Low winter activity so better suited to areas with summer rainfall. Highly productive under suitable conditions. Uncertainty about toxicity to ruminants (Foster 1990), a problem in many other species of genus.
- *Medicago arborea* - Leafy woody shrub with forage quality similar to Lucerne. Suited to infertile calcareous soils with annual rainfall above 250 mm. Highly susceptible to aphids, although some variation is present (de Koning *et al.* 2000). Needs controlled grazing.
- Other perennial *Medicago* -A number of other perennial *Medicago* have been suggested to have desirable genes for incorporation into Lucerne, such as drought tolerance (Cocks 2001), salt tolerance (Stasilyunas 1978) and aluminium tolerance in *M. sativa* ssp. *caerulea*, and abiotic stresses (Campbell *et al.* 1997) and potato leafhopper tolerance (Campbell *et al.* 1999) in *M. ruthenica*.
- *Melilotus alba* - Has annual and biennial types with fodder quality and digestability equal to red clover and Lucerne (Peacock *et al.* 1976). It is suited to alkaline soils, and can tolerate both wet and dry conditions. Also reported to show salt tolerance. Problems in this species include high coumarin content, and weediness risk. Low coumarin types available.
- *Melilotus officinalis* - Biennial species that is earlier flowering and better seed set than *M. alba*, but less productive. It is suited to alkaline soils, and can tolerate both wet and dry conditions. Also reported to show salt tolerance. Problems in this species include high coumarin content, but low coumarin types available.
- Other perennial *Melilotus* species that offer potential to the wheatbelt region, particularly on saline soils include *M. elegans*, *M. sauveolens* and *M. wolgicus*. These species have large taps roots and good summer production. *M. elegans* has good all round production, though can become woody over time. Coumarin levels are currently under investigation at the University of Adelaide.

Rhizobia research goes hand in hand with the development of legume pastures. Working *Rhizobium* collections exist at the Centre for Rhizobium studies, Murdoch University, SARDI Adelaide and NRE-Rutherglen where each unit has facilities for both short and long-term storage of *Rhizobium* germplasm. Germplasm collections are on-going with targeted Australian and overseas collections made continuously.

Perennial legume initiatives

1. Development of Lotus corniculatus

L. corniculatus (Birdsfoot or Broadleaf trefoil) is the most widely distributed species of perennial lotus and the most genetically variable. Despite the significant genetic variation in *L. corniculatus* the current commercial varieties come from a limited genetic background (Steiner and Poklemba 1994), which may partly explain why domesticated cultivars are restricted in their adaptation compared with wild types.

The huge genetic diversity present in *L. corniculatus* is currently being evaluated at SARDI, where significant variation has been identified in growth habit (prostrate vs erect), dry matter production (highly winter active to winter dormant), flowering time and pattern, and seed set. From this material, potential exists to develop new cultivars suited to areas receiving 550 mm to 750 mm annual rainfall permanent pasture zones, and 400-650 mm high rainfall cropping zones. However, there are a number of current limitations to the use of the genus *Lotus* as a whole, which need to be addressed before any varieties progress to commercial seed production, and developed cultivars are widely adopted.

These limitations include:

- A requirement for greater persistence over summer, coupled with increased rooting depth
- A need for a more determinant flowering period
- A need for reduced pod shattering
- Better rhizobial symbionts made available, and
- Better drought and grazing tolerance.

Positive attributes of *L. corniculatus* include:

- More tolerant of waterlogging (Barta 1987) and acid soils (Baligar *et al.* 1988) than Lucerne
- Contains condensed tannins which are known to 1) reduce protein degradation in the rumen and therefore through increased absorption of essential amino acids increase live weight gains, wool growth and milk production (Luque *et al.* 2000), 2) eliminate bloat (Li *et al.* 1997), and 3) inhibit infective gut worm larvae of sheep.

2. Potential of Lotus species for recharge control in Australian landscapes

A number of other species of perennial *Lotus* are being evaluated at SARDI for their potential in recharge control in southern Australia. These include, *L. creticus*, *L. cytisoides*, *L. glaber*, *L. maroccanus* and *L. uliginosus*. There has been less agronomic evaluation of these species than *L. corniculatus*, and therefore further evaluation is required before their full potential can be realised. The notable characteristics of each species and their potential environmental niche are given in Table 5.

Of particular importance at this stage are *L. glaber* and *L. maroccanus,* which have significant potential for commercial application in the high rainfall permanent pasture zones (600-750 mm) and the cropping systems (400-550 mm) respectively. To maximise their soil water use, it is suggested that selection is required for improved persistence over summer and rooting depth. As in all the species of *Lotus*, there is a need to select for determinant flowering and reduced pod shattering.

3. Fast tracking D. hirsutum and D. rectum for low rainfall areas

a) Dorycnium hirsutum (Hairy canary clover)
Hairy canary clover is a low-growing sub-shrub found on well drained, medium to coarse-textured soils in the Mediterranean Basin. Vegetative growth begins in late winter from the lower stems and the base of the plant, slows down during flowering (early summer) and resumes in autumn. The species is adapted to a range of soils with pH from mildly acid to alkaline (Allen and Allen 1981), but is susceptible to root rot in waterlogged soils.

There have been no commercial cultivars released, although the species is under commercial development in New Zealand (Wills *et al*. 1999) and has also been evaluated in Tasmania for several years (E.Hall, *pers. comm.*). It is showing promise in preliminary field evaluation in Western Australia.

There is a large diversity in seedling vigour, plant growth habit and flowering, both within lines and between lines. As a result, there is considerable scope for plant improvement through straightforward selection of elite plants within a population. Selection commenced at Medina RS (WA) in 2001/02 in collaboration with Eric Hall (DPIWE Tasmania), but would be enhanced by a full or part-time plant breeder.

It has a number of positive attributes for development that include:

- Ability to persist in dryland conditions on low fertility soils

- Tolerance of drought and severe frosts (Wills *et al.* 1989)
- Good insect tolerance
- Well-developed tap-root, and once established can grow in companion with other species, and
- Good summer production.

However, there are also a number of limitations to its development that need to be addressed. These include:

- A need for a contracted flowering period and reduced pod shatter
- Better seedling vigour and establishment. Establishment under a cereal cover crop is currently being investigated, and
- Selection for lower levels of condensed tannins, and increased digestibility.

Because there has been little agronomic evaluation of *D. hirsutum*, there are a number of questions that need to be answered before its full potential can be realised. These include:

- The ability of the rhizobia to persist in the field
- The range of soils and climates where it may have potential
- The degree of tolerance to acid soils, and
- The best way to utilise this species in a farming system. For instance, it may be best suited as a permanent pasture, because of its slow establishment.

b) Dorycnium rectum (Canary clover)

Canary clover is an erect, glabrous sub-shrub, which grows to a height of about 2m if ungrazed, preferring damp areas. There are no commercial varieties, but it has been evaluated in Tasmania for several years (E. Hall, *pers. comm.*). This species is showing promise in field trials in Western Australia. Second year growth was exceptional for an accession introduced from Portugal, which was less woody and more suitable for grazing and cutting than other accessions evaluated.

There is good potential for plant improvement through straightforward screening and plant selection as there is considerable diversity within and between lines. However, there is an urgent need to obtain more germplasm, as there are less than eight accessions currently in Australia, however it has recently been placed on the prohibited entry by AQIS.

It has a number of positive attributes for development, which include:

- Highly productive in damp to wet areas, and
- Under evaluation had better herbage production than *D. hirsutum* and *D. pentaphyllum* at all stages of the year.

However there are some limitations which need to be addressed including:

- High level of condensed tannins recorded
- Level of seedling vigour. This is moderate, and could be improved through plant selection
- Does not produce seeds until the second year, and
- There is a need to select for a contracted flowering period and reduced pod shatter.

The lack of previous agronomic evaluation of this species means that there are some questions that need to be answered, such as

- Persistence of rhizobia in the field
- Feed quality and concentration of condensed tannins, and
- Degree of waterlogging tolerance.

4. Evaluation of alternative perennial legumes

As well as the species listed above, there are a number of other species included in Table 5 that also require intensive evaluation for their potential in the recharge zones of southern Australia. Examples of these are:

- *Hedysarum coronarium* - A short-lived perennial species that thrives on neutral to highly calcareous soils. It has a deep branching tap-root, and therefore considerable drought tolerance. It is noted for its vigorous autumn and spring production, particularly in the second year after early rains (4 t/ha in autumn and 22 t/ha in spring in South Australia. It has excellent feed quality and contains low levels of condensed tannins that confer non-bloating and insect resistance. However it is semi-dormant in summer and current varieties do not tolerate heavy grazing. A RIRDC & GRDC project is currently underway to select soft-seeded, productive, grazing tolerant, prostrate types through NAPLIP in Western Austrlia, Queensland and South Australia.

- *Onobrychis viccifolia* - A non-bloating perennial adapted to well-drained neutral to alkaline soils. It is persistent under low rainfall conditions (330 mm) and has good insect resistance. It is equal in production to Lucerne and may provide an alternative to Lucerne for dry areas. However, it is more suited to cutting than grazing due to its erect growth habit. Prior to any new improvement programme it is necessary to investigate its potential benefits using current cultivars.

With all the alternative legume species listed above there is a need to establish the range of soils and climates where they have potential, the persistence of rhizobia in the soil, and their tolerance to diseases such as rhizoctonia.

The potential of native perennial legumes

Traditionally, commercial pasture species in southern Australia have been imported from the Mediterranean Basin, the basis being that such species are well adapted to both extreme climatic conditions and can withstand grazing pressure. However, Australia has a very rich native diversity of species, the majority of which have been previously over-looked in terms of their value for agriculture and the environment. There is therefore the potential for the development of native perennial species that are already well adapted to the climatic and edaphic conditions of southern Australian farming systems.

Germplasm holdings of native species are maintained in numerous locations across the country. Many large collections are maintained in commonwealth and state government departments and private collections. However the majority of germplasm conserved *ex situ* are tree and shrub species. Herbaceous and understorey species are poorly represented.

Organisations which offer assistance in the sourcing and utilisation of native germplasm include Florabank (http://www.florabank.org.au/), The Australian Network for Plant Conservation Inc. (ANPC) (http://www.anbg.gov.au/anpc/), FloraBase (CALM) (http://www.calm.wa.gov.au/) and Environment Australia (ERIN) (http://www.erin.gov.au/). These organisations bring together a diverse range of individuals, communities, local, state and commonwealth government agencies and industry groups who are actively working on the conservation of native species. They aim to improve the availability and quality of native seed and plant material for revegetation and conservation purposes in Australia. They are a good source of information networks and provide support, advice and assistance to interested parties, including researchers, collectors, seedbank managers and distributors of native seed and plant material. Florabank in particular has commissioned a number of surveys which outline current collections and distribution of native seed. Florabank objectives are to enhance existing networks between seedbanks and plant collections and should be a useful starting point in accessing existing native germplasm collections.

Native perennial legume initiatives

1. Identification of species for the low to medium rainfall regions

In contrast to the work on native perennial grasses, the search for and the potential of native perennial legumes (and associated rhizobia) as an alternative to commercial legumes in dryland farming systems is largely unknown. However, native perennial legumes are both diverse and widespread in temperate Australia.

Table 6. Native perennial legumes of the low to medium rainfall cropping regions of Victoria, Western Australia, South Australia and New South Wales.

Genera	Perennial species
Glycine	*Glycine clandestina* (twining glycine); *Glycine canescens* (silky glycine)
Kennedia	*Kennedia prostrata* (scarlet runner), *Kennedia eximia, Kennedia proprepens*
Cullen	*Cullen tenax* (tough scurf pea); *Cullen cinereum* (hoary scurf pea); *Cullen australasicum* (native scurf pea); *Cullen pallidum* (woolly scurf pea); *Cullen patens* (spreading scurf pea); *Cullen discolour* (scurf pea)
Swainsona	*Swainsona pyrophila* (yellow swainson pea); *Swainsona swainsonioides* (downy swainson pea); *Swainsona procumbens* (broughton pea); *Swainsona microphylla* (small leafed swainson pea); *Swainsona reticulata* (kneed swainson pea); *Swainsona purpurea* (purple swainson pea); *Swainsona phacoides* (dwarf swainson pea); *Swainsona sericeae* (silky swainson pea); *Swainsona affinis; Swainsona beasleyana; Swainsona canescens; Swainsona colutoides; Swainsona elegans; Swainsona elegantoides; Swainsona gracilis; Swainsona kingii; Swainsona microcalyx; Swainsona oliveri; Swainsona oroboides; Swainsona paradoxa; Swainsona paucifoliolata; Swainsona perlonga; Swainsona pterostylis; Swainsona rostellata; Swainsona tenuis*
Lotus	*Lotus australis* (Austral trefoil); *Lotus cruentus* (red bird's foot trefoil)
Glycyrrhiza	*Glycyrrhiza acanthocarpa* (native liquorice)

There is an urgent need to identify those perennial species that have the potential to be successful in the low to medium rainfall (<300-500mm) cropping regions of southern Australia as an alternative to lucerne. Lucerne has limitations in acid soils and in climates where rainfall is low and ambient summer temperatures are high. Targeted collections of genera from the drier areas are likely to yield species of value, although few are likely to be as widely adapted as lucerne.

Perennial species will be collected from these regions, evaluated and prioritised for recharge/ discharge and farming system applications. In addition, essential knowledge on their distribution and ecology, soil microbial and chemical conditions that reflect their native habitat are also required.

A review of current literature has identified a number of legume genera in the low to medium rainfall environments which may have potential to match the water-using and nitrogen fixing capacities of lucerne. Perennial species of the genera *Glycine, Kennedia, Cullen (Psoralea), Swainsona, Lotus* and *Glycyrrhiza* are being considered (see Table 6). However, their suitability, adaptation to the acidic soils of Western Australia, and grazing potential is unknown. Material for evaluation will be sought from both new and existing collections.

The toxicity of many species of native perennial legumes is an important consideration. Variation in levels of toxicity may be observed within species, and there may be the opportunity for breeding and selection for lower toxicity levels. However collaboration with both biochemists and nutritionists will be important in any evaluation of native legume species.

2. Collection and evaluation of native perennial legumes and associated rhizobia
Germplasm for native legumes is limited, and most has been collected from the medium to high rainfall zones (>500mm) of Victoria. Collection and evaluation of perennial legumes from the medium to low rainfall zones (500-300mm) of Victoria, NSW and WA is urgently required.

Little is known about the species that will be collected, or about their associated rhizobia. The native perennial legume research project will identify the distribution of native perennial legumes in the low to medium rainfall zones and consider the introduction of this genetic material into other regions of Australia under differing environmental conditions. The ecology and ecophysiology of each species will be evaluated, and it is possible, through selection and the use of adapted rhizobia, that some legumes may be of value under widespread agricultural conditions.

Rhizobial research will be conducted concurrently with this project. Rhizobial collections will be made in conjunction with native legume collections, and will be isolated and matched prior to any field evaluation of targeted species. Research is currently in progress determining the competition of native and exotic rhizobia on each other, and on the nodulation of exotic annual and perennial legumes, and native legume species.

The potential of native and exotic non-leguminous herbs
The Mediterranean Basin is very rich in forage species, many of which are little known in terms of their agronomic potential, especially in the eastern mediterranean, and to a lesser extent in north Africa (Le Houerou, 2001). There may therefore be a number of species that have the potential to be of use in recharge areas, but more research is required to develop a list of species which are perennial, summer active and deep rooted, and have some record of agronomic trials.

Even less knowledge is available about the agronomic potential of native non-legume herbaceous species, particularly in a paddock rather than an open grazing situation. The diversity of species in the semi-arid regions of Australia is also very diverse, although a large number of species are either poisonous to cattle and sheep or display spiny characteristics on either the stems, leaves or fruits. However, with breeding it may be possible to remove some of these constraints.

Native and exotic herb initiatives

1. Evaluation of exotic herbs for the recharge zones of southern Australia

The species listed below are those which are a little bit more common and therefore have limited information about their agronomic potential, however it must be kept in mind that the information provided in the text is often not under Australian conditions.

*a) Chicory (*Cichorium intybus*)*

This species is a tall, stiff non-spiny perennial with tough green stems and bright blue dandelion like flowers. Stems have widely spreading branches, 30-120 cm high. It is a very variable species, and is grown as a grassland herb in ley mixtures in much of Europe (de Rougemont 1989). A couple of cultivars have been developed in the US and Europe.

The positive attributes of this species include:

- Tolerance to very low pH, down to 4.5, although plant health and yield are optimised at levels between 5.5 and 6.5 (Paine 2001)
- It has a deep tap-root and is quite drought tolerant
- It is a summer active crop, dormant in winter, but with a rapid response to warm temperatures in spring (Lancashire and Brock 1983)
- It produces high yields of good quality feed in spring, summer and autumn (Clarke *et al.* 1990), feed quality in summer being superior to that of traditional ryegrass/ white clover pasture (Niezen *et al.* 1993). In New Zealand yields average 15-18 t DM/ha (Matthews *et al.* 1990)
- It has protein levels of between 20% and 30% and digestibility levels of greater than 90% (Paine, 2001), and
- It has a low concentration of condensed tanins that reduces the number of anthelmintic treatments required (Hoskins *et al.* 1999).

However, there are a number of limitations that need to be addressed. These include:

- A large proportion of herbage production is stems, up to 90%, and careful grazing management is required to control this
- Plant density decreases over the season by about 35%, particularly in late spring/ early summer. This decrease is not affected by grazing intensity, and is generally offset by an increase in the size of the remaining plants (Li *et al.* 1997)
- Trampling may increase plant death but further studies are required, and
- Grazing in late autumn reduces plant survival over winter as a result of reduced carbohydrate storage in the roots (Li *et al.* 1997).

b) Sanguisorba minor (Sheeps burnet/ Salad burnet/ Small burnet)

This is another species that has been used in a minor role in mixed pastures in both New Zealand and North America. It is reported as having good palatability to livestock, especially in late winter and spring (Wasser, 1982), therefore suggesting that it is not summer active, although no definitive information is available to support this. It is tolerant of mildly saline and relatively infertile soils, preferring loamy soils with moderate alkalinity. It is not tolerant of waterlogged conditions. It is also susceptible to overgrazing, and therefore must be managed.

These reports suggest that it would not be particularly suitable to the recharge areas of southern Australia. However, Press (1993) describes it as a rhizomatous perennial with a basal rosette and leafy flowering stems, common in dry grasslands. Without further research its potential in alkaline areas of southern Australia cannot be determined.

*c) The plantain family (*Plantago *sp.)*

The plantain family contains about 270 species, of mainly annual but some perennial species. There are five species native to WA and four species which have naturalised. These include the perennials *Plantago cretica* (Cretan plantain), *P. lanceolata* (ribwort plantain) and *P. major* (great plantain). *P. cretica* is only found around Toodyay, the other two species occur from Perth to Albany and are common on disturbed areas.

Ribwort Plantain (*Plantago lanceolata*) is a perennial, up to 120cm high, that produces several rosettes of hairless or downy leaves. A couple of varieties have been developed in the UK and are currently being tested in New Zealand (Paine, 2001; Stewart, 1996). A commercial variety from New Zealand is also available in New South Wales. It is attracting attention because it contains high levels of mineral nutrients, reasonable nutrient levels and high digestibility resulting in excellent lamb production. It is more tolerant of low P and K soils than Chicory, although it does not possess the deep tap-root. However it is deeper rooting than most grasses and is both heat and drought tolerant. It is also resistant to many common pests and diseases. In a mixed pasture it has the potential to displace broadleaf weeds, but is not thought to be able to out-compete the legume and grass species. Its most likely use is suggested to be as a component of mixed swards, particularly in pastures where grass growth is less vigorous, and therefore in low fertility dryland pastures.

There is a similar species to *P. lanceolata*, *P. altissma*, that is larger in all parts with hairless leaves that occurs in grassy places in east-central Europe and the Balkans. There are a number of other perennial species of plantain including *P. coronopus*, *P. media* and *P. major* that may be worthy of further evaluation.

There are almost certainly other genera and species that have not been listed in this text. However a search of the literature provided information only on the species listed above and very scarce information on others. Other papers list species of regions such as north Africa, but give no information on the palatability of those species. For example le Houerou (2001) lists large number of species, both woody and herbaceous that occur in the semi-arid regions of north Africa. However, only one species *Gymnoarpos decander* has any reference to palatability, with a mention that it is heavily grazed. A paper by Grzegorczyk and Alberski (1999), on native pastures in Poland, lists a number of non-leguminous forbs that are palatable to livestock and contain more sodium and potassium than the grasses in the pasture. These species include: *Taraxacum officinale* (common dandelion), *Achillea millefolium* (yarrow), and *Alchemilla vulgaris* (lady's mantle). These species are all common weeds of pastures in Europe, and have previously been introduced to Australia. Therefore, despite their potential palatability, extreme care should be taken before further introductions to Australia are even considered.

2. *Evaluation of native herbs for the recharge zones of southern Australia*

The few species described below are those that have currently undergone limited evaluation. However, given the diversity of the Australian flora, there are likely to be numerous other species worthy of investigation.

a) Prince of Wales feather mulla mulla/ Green mulla mulla (Ptilotus polystachyus)

P. polystachyus is a short-lived perennial, summer active, deep-rooted species of *Ptilotus* found throughout the dryer areas of the wheatbelt in WA. The genus is composed of about 100 species, of which the majority are perennial.

Preliminary research on *P. polystachyus* suggests that it has:

- Good potential for the dryer areas of the wheatbelt as it germinates in late spring, persisting as a prostrate rosette until the majority of agricultural crops have been harvested (late spring/ early summer) when it rapidly heads and flowers
- A preference for acid soils; and
- Protein levels in the leaves up to 22% (Mitchell and Wilcox 1994), although if this is stored as nitrates can have a negative effect on grazing animals (Pate *et al.* 1993).

Possible limitations that need to be addressed include:

- Difficulty in germinating seed (O'Connell 1995). Removal of the seed from the surrounding husks appears to remove germination inhibition (Pearse 2001). However this is a very lengthy, laborious process, and further research is required to determine more efficient methods of harvesting and threshing of seed
- It is unknown whether herbage production in the species can be increased by applications of P and/ or N, and
- Persistence. There are some reports that the species is annual (Mitchell and Wilcox 1994), and others that it is perennial. Its longevity appears to be season dependent, but further research is required.

b) Buck bush (Salsola kali and Felty bluebush (Maireana tomentosa)

These two perennial herbaceous species occur in the Pilbara region of WA. They provide low nutritive value feed in rangelands of the region, particularly in dry seasons when the presence of ephemeral forbs is severely restricted. Both species declined by up to 50% during the dry period between August and November, but after summer rains showed an increase of up to 5-fold in *S. kali* and between 7-9-fold in *M. tomentosa*. Both species responded to applications of P after summer rains (Islam *et al.* 1999), but did not react to applications of N. However, both species contain more than the 1% (dry weight basis) of N; the recommended minimum concentration by grazing animals (National Research Council, 1984).

Salsola kali is referred to in Islam *et al.* (1999) as a perennial forb. According to FloraBase (Calm, 1998) this species is a synonym of *Salsola tragus*, but *S. tragus* is an annual species. There are no other species of *Salsola* listed as occurring in WA.

c) Other perennial species worthy of further investigation.

A special report on some native Australian fodder plants (Year Book Australia, 1912), has been produced by the Australian Bureau of Statistics (Commonwealth of Australia, 2001), and although the original date of publication is now very old, there may be some interesting species in the list. Therefore, a summary table (Table 7) of that report is given below listing the perennial herbaceous species with some recorded palatability.

More information is required on all of these species to determine their potential as recharge species in southern Australia. From the information that is readily available it has been impossible to determine what their preferred soil types are, whether they are summer or winter active, rooting depth etc. Therefore before it is proposed to include any of these species for evaluation it is suggested that further literature searches are required.

Due to the limited amount of information available on any of the species described in this text, plus any other exotic or herbaceous forbs not listed here, the CRC has the potential to play a large part in developing non-leguminous herbaceous species for the recharge areas of southern Australia.

Table 7. Summary of native Australian fodder species (Adapted from Commonwealth of Australia report 2001).

Species	**Distribution**	**Available information**
Bursaria spinosa (native boxthorn	Throughout Australia	Very palatable, but thorny. Small shrub to small tree.
Claytonia balonnensis (Periculia)	SA, QLD and NSW	Succulent, palatable
Portulaca oleracea (Purslane/ pigweed)	Australia, except Tasmania	Succulent/ palatable
Malvastrum spicatum	SA, NSW, QLD	Sheep feed to squatters.
Sida corrugata	Australia except Tasmania	Good forage plant. Other species in genus also of value.
Sida rhombifolia (paddy Lucerne, Queensland hemp	QLD, NSW	Well-known fodder in warm regions, can become noxious weed in cooler areas
Gossypium sturtianum	Inland Australia	Adapts well to cultivation, especially hot dry areas.
Boerhaavia diffusa (Tar-vine)	Australia, except Tasmania	Long-tap root, drought resistant. Provides feed early in season. Can become a weed in warmer countries.
Bertya cunninghamii (Gooma)	Vic., NSW (inland)	Very palatable, other spp. in the genus poisonous, but not recorded in this sp.

Impacts of proposed initiatives

Magnitude of impacts

Where deep-rooted perennial species are used, recharge is reduced to between 0 and 3% of average annual rainfall. This compares to 6 to 11% under annual crops and pastures. These values have been calculated for the 400 to 750 mm zone in NSW. If species with a deep tap-root are selected, it can be assumed that water use across states and rainfall zones would be similar to Lucerne. However, further research is required to confirm this.

In respect of the perennial grasses, as new cultivars become available it is expected that the area of adaptation of perennial grasses will expand. Also as awareness of the need to reduce recharge increases, the area of land sown to perennial grasses will further expand. Therefore, it is conservatively estimated that by 2010, 600,000 ha will be sown annually, and should reduce recharge by 25%.

Spatial scale

In northern New South Wales, the priority area for recharge control is the northern upper catchment of the Murray Darling Basin (NSW northern tablelands/ north west slopes). It is proposed that birdsfoot trefoil is suited to this area and that the land sown to birdsfoot trefoil can be expanded to 2.5m ha by 2010.

In southern New South Wales the priority area for recharge is the mid-catchment region of the Murray Darling Basin (36m ha). It is estimated that 46% (16.5m ha) of this is unsuitable for Lucerne or Phalaris. Perennial Lotus have potential for the acid and waterlogged soils of this area (25% of the mid-catchment zone).

In Victoria the priority areas for recharge control are north-east/ north-central Victoria (6.98m ha) and south-west Victoria (2.6m ha). Both of these areas are under-utilised for lucerne, and therefore it is proposed that some of the alternative tap-rooted perennial legumes may be viable options, reducing recharge and increasing productivity in these areas.

In Western Australia the priority areas for recharge control are the Zone of Rejuvenated Drainage (3.1m ha) and the South coast (2.4m ha), both of which are at high risk of extensive dryland salinity and have local groundwater flow systems that respond to a change in land use. The Zone of Ancient Drainage (eastern wheatbelt) is a more difficult area to control recharge as the timeframe for salinisation is much longer and a high proportion of the recharge is episodic, associated with high rainfall events. In this zone, deep sands (1.5m ha) and duplex soils on the slopes (1.6m ha) are the two priorities for recharge control using herbaceous perennial plants. The total area in Western Australia is in excess of 7m ha where lucerne is less suited or alternatives to lucerne are required to ensure the new farming systems are robust. The initiatives proposed have the potential to fill some of the niches where Lucerne is currently unsuited, thereby increasing productivity and reducing recharge.

References

Allen, O.N. and Allen, E.K. (1981). 'The Leguminoseae. A Source Book of Characteristics, Uses and Nodulation'. The University of Wisconsin Press.

Baligar, V.C., Campbell, T.A. and Wright, R.J. (1993). Differential responses of alfalfa clones to aluminium-toxic acid soil. *Journal of Plant Nutrition*, **16**, 219-233.

Baligar, V.C. Wright, R.J. Fageria, N.K. Foy, C.D. (1988). Differential responses of forage legumes to aluminium. *Journal of Plant Nutrition, 11, 549-561.*

Barta, A.L (1987). Supply and partitioning of assimilates to roots of Medicago sativa L. and Lotus corniculatus L. under anoxia. *Plant, Cell and Environment, 10, 151-156.*

Bellotti, W., Auricht, G.C., Williams, R. and Hill, M.J. (1998). The evolving role of lucerne in Australia. In 'Proceedings of the 36th North American Alfalfa Improvement Conference'. (Ed. J. Bouton). P.62.

CALM (1998). 'FloraBase - Information on the Western Australian flora'. (Department of Conservation and Land Management. http://www.calm.wa.gov.au/science/florabase.html)

Campbell, T.A., Bao, G. and Xia, Z.L. (1997). Agronomic evaluation of *Medicago ruthenica* collected in Inner Mongolia. *Crop-Science* **37,** 599-60.

Campbell, T.A., Bao, G., Xia, Z.L. (1999). Completion of the agronomic evaluations of *Medicago ruthenica* ((L.) Ledebour) germplasm collected in Inner Mongolia. *Genetic-Resources-and-Crop-Evolution* **46,** 477-484.

Clarke, R.G. and Eagling, D.R. (1994) Effects of pathogens on perennial pasture grasses. *New Zealand Journal of Agricultural Research* **37**, 319-327.

Clark, D.A., Anderson, C.B., and Gao, H.W. (1990). Liveweight gain and intake of Fresian bulls grazing 'Grasslands Puna" chicory (*Cichorium intybus* L.) or pasture. *New Zealand Journal of Agricultural Research* **33**, 219-224.

Cocks, P.S. (2001). Ecology of herbaceous perennial legumes: a review of characteristics that may provide options for the control of salinity and waterlogging in dryland cropping systems. *Australian Journal of Agricultural Research* **52,** 137-152.

Commonwealth of Australia (2001). 'Environment. Special article - Some native Australian fodder plants.' (Australian Bureau of Statistics. Http://www.abs.gov.au/ausstats/).

Dear, B.S., Moore, G.A., and Hughes, S.J. (2002). The adaptation and potential contribution of temperate perennial legumes to the southern Australian wheatbelt. *Aust. J. Expt. Agric.* (In Press).

de Koning, C.T., Hughes, S.J., McLachlan, D. and Duncan, A.J. (2000). *Medicago arborea* - a leguminous fodder shrub for low rainfall farming systems. *Cahiers Options Mediterraneannes* **45**, 435-439.

De Rougemont, G.M. (1989). 'A field guide to the crops of Britain and Europe.' Willaim Collins Sons & Co., Ltd: London.

Forde, M.B., Hay, M.J.M. and Brock, J.L. (1989). Development and growth characteristics of temperate perennial forage legumes. *In* 'Persistence of forage legumes'. (Eds. G.C. Marten, A.G. Matches, R.F. Barnes, R.W. Brougham, R.J. Clements, G.W. Sheath). pp. 91-110. American Society of Agronomy Inc., Wisconsin, USA.

Foster, J.G. (1990). Flatpea (*Lathyrus sylvestris* L.): A new forage species? A comprehensive review. *Advances in Agronomy* **43,** 241-313.

Grzegorczyk, S. Alberski, J. (1999). The presence of forbs in meadow-pasture plant communities of the Olsztyn Lakeland. *Folia Universitatis Agriculturae Stetinensis, Agricultura, **75**, 103-106*

Hamblin, A.P. and Hamblin, J. (1985). Root characteristics of some temperate legume species and varieties on deep, free-draining entisols. *Australian Journal of Agricultural Research* **36,** 63-72.

Hoskin, S.O., Barry, T.N., Wilson, P.R., Charleston, W.A.G., and Hodgson, J. (1999). Effects of reducing anthelmintic input upon growth and faecal egg and larval counts in young farmed deer grazing chicory (*Cichorium intybus*) and perennial ryegrass (*Lolium perenne*)/ white clover (*Trifolium repens*) pasture. *Journal of Agricultural Science, Cambridge* **132**, 335-345.

Hoveland, C.S. (2000). Endophytes - research and impact. In 'Proc. 4th International *Neotyphodium*/Grass interactions Symposium' (Eds. V.H. Paul and P.D. Dapprich), Soest, Germany.

Howieson, J.G., Robson, A.D. and Abbot, L.K. (1992). Acid tolerant species of *Medicago* produce root exudates at low pH which induce the expression of modulation genes in *Rhizobium meliloti. Aust. J. Plant Physiol.*, **19**, 287-296.

Humphries, A.W. and Auricht, G.C. (2001). Breeding lucerne for Australia's southern dryland cropping environments. *Aust. J. Agric. Res*. **52**, 153-169.

Islam, M., Turner, D.W. and Adams, M.A. (1999). Phosphorus availability and the growth, mineral composition and nutrative value of ephemeral forbs and associated perennials from the Pibara, Western Australia. *Australian Journal of Experimental Agriculture* **39**, 149-159.

Lancashire, J.A. and Brock, J.L. (1983). Management of new cultivars for dryland. *Proceedings of the New Zealand Grassland Association* **44**, 61-73.

Le Houerou, H.N. (2001). Biogeography of the arid steppeland north of the Sahara. *Journal of arid environments* **48**, 103-128.

Li, G.D., Kemp, P.D. and Hodgson, J. (1997). Regrowth, morphology and persistence of 'Grasslands Puna' chicory (*Cichorium intybus* L.) in response to grazing frequency and intensity. *Grass and Forage Science* **52**, 33-41.

Lolicato, S.J. (2000). Soil water dynamics and growth of perennial pasture species for dryland salinity control. *Australian Journal of Experimental Agriculture* **40**, 37-45

Lumpkin, T.A., Konovsky, J.C., Larson, K.J. and McClary, D.C. (1993). Potential new speciality crops from Asia: Adzuki bean, edamame soybean and astragalus. In '*New Crops*' (ed. J. Janick and J. E. Simon), pp. 45-51. New York, Wiley.

Luque, A., Barry, T.N., McNabb, W.C., Kemp, P.D. and McDonald, M.F. (2000). The effect of grazing *Lotus corniculatus* during late summer-autumn on reproductive efficiency and wool production in ewes. [Journal article. Federal . Government Publication] *Australian Journal of Agricultural Research. [Collingwood, Victoria, Australia : CSIRO] 2000. v. 51 (3) p. 385-391.*

Marten, G.C. Jordan, R.M. and Ristau, E.A. (1990). Performance and adverse response of sheep during grazing of four legumes. *Crop Science* **30,** 860-866.

Matthews, P.N.P., Kemp, P.D., and Austin, G.M. (1990). The effect of grazing management on the growth and reproductive development of chicory. *Proceedings of Agronomy Society of New Zealand* **20**, 41-43.

Mitchell, A.A. and Wilcox, D.G. (1994). 'Arid shrubland plants of Western Australia.' University of Western Australia Press, Perth.

Mugwira, L.M. and Haque, I. (1993). Screening forage and browse legumes germplasm to nutrient stress. 1. Tolerance of *Medicago sativa* L. to aluminium and low phosphorus in soils and nutrient solutions. *Journal of Plant Nutrition*, **16**, 19-35.

National Research Council. (1984). Nutrient requirements of beef cattle. 6th Edition. National Academy of Sciences, Washington DC.

Niezen, J.H., Barry, T.N., Hodgson, J., Wilson, P.R., Ataja, A.M., Parker, W.J. and Holmes, C.W. (1993). Growth responses in red deer calves and hinds grazing red clover, chicory or perennial ryegrass/white clover swards during lactation. *Journal of Agricultural Science* 121, 255-263.

O'Connell, K. (1995). 'Ecology of *Ptilotus* species of the Upper Fortescue Valley, Pilbara, WA'. Curtin University of Technology, Perth.

Oram, R.N. (1996) *Secale montanum*- a wider role in Australasia? *New Zealand Journal of Agricultural Research* 39, 629-633.

Paine, L. (2001). 'Broadleaf perennials'. UW-Extension Columbia County. Http://www.uwex.edu/ces/cty/columbia/agriculture)

Passioura, J.B. and Ridley, A.M. (1998). Managing soil water and nitrogen to minimise land degradation. In 'Proceedings of the 9th Australian Agronomy Conference.' (Eds. D.L. Michalk and J.E. Prately). Pp. 99-107. Australian Society of Agronomy, Wagga Wagga.

Pate, J.S., Stewart, G.R. and Unkovich, M. (1993). 15N natural abundance of plant and soil components of a Banksia woodland ecosystem in relation to nitrate utilisation, life form, mycorrhizal status and N2-fixing abilities of component species. *Plant, cell and Environment* **16**, 365-373.

Peacock, F.M., Hodges, E.M., Greene, R.E.L., Kirk, W.G., Koger, M. and Crockett, J.R. (1976). Forage systems, beef production and economic evaluations, south central Florida. Agric. Res. Cent., Ona, Florida, USA. Bulletin-Agricultural-Experiment-Station, University-of-Florida. No.783.

Pearse, S. (2001). 'An investigation into the germination biology, dormancy mechanism and growth of Ptilotus polystachus (green mulla mulla)'. Hons Thesis. University of Western Australia.

Phillips, D.A., Bedmar, E.J., Qualset, C.O. and Teuber, L.R. (1985). Host legume control of Rhizobium function. In 'Nitrogen fixation and CO_2 metabolism.' Proceedings of the 14th Steenbeck Symposium, Madison, 1984. (Eds. P.W. Ludden and J.E. Burris) pp. 203-211. Elsevier Publishing Company, New York.

Press, B. (1993). 'Field guide to the wild flowers of Britain and Europe.' New Holland Ltd: London.

Reed, K.F.M., Leonforte, A., Cunningham, P.J., Walsh, J.R., Allen, D.I., Johnstone, G.R. and Kearney, G. (2000). Incidence of ryegrass endophyte (*Neotyphodium lolii*) and diversity of associated alkaloid concentrations among naturalised populations of perennial ryegrass. *Australian Journal of Agricultural Research* **51,** 569-578.

Ridley, A.M., White, R.E., Simpson, R.J. and Callinan, L. (1997). Water use and drainage under phalaris, cocksfoot and annual ryegrass pastures. *Australian Journal of Agricultural Research* **48**, 1011-1023

Ridley, A.M., Haines, P.J., Wilson, K.F., Ellington, A. (1998). Phase farming using lucerne in crop rotations. In 'Proceedings of the 9th Australian Agronomy Conference.' (Eds. D.L. Michalk and J.E. Pratley). Pp. 803-806. Australian Society of Agronomy, Wagga Wagga.

Ridley, A.M., Christy, B., Dunin, F.X., Haines, P.J., Wilson, K.F. and Ellington, A. (2001). Lucerne in crop rotations on the Riverine Plains. 1. The soil water balance. *Australian Journal of Agricultural Research. 2001*, **52**, 263-277.

Smith, K.F., Lee, C.K., Borg, P.T. and Flinn, P.C. (1994). Yield, nutritive value, and phenotypic variability of tall wheatgrass grown in a nonsaline environment. *Australian Journal of Experimental Agriculture* **34** 609-614.

Smith, K.F. (1996) Tall wheatgrass (*Thinopyrum ponticum* (Podp.) Z.W. Liu + R.R.C. Wang): a neglected resource in Australian pasture. *New Zealand Journal of Agricultural Research,* **39** 623-627.

Stasilyunas, O.A. (1978). Salt tolerance of tetraploid Medicago coerulea. Fiziologiya-i-Biokhimiya-Kul'turnykh-Rastenii. **10**, 1, 83-85.

Steiner, J.J. and Poklemba, C.J. (1994). *Lotus corniculatus* classification by seed globulin polypeptides and relationship to accession pedigrees and geographic origin. *Crop Science*, **34**, 255-264.

Stewart, A.V. (1996). Plantain (*Plantage lanceolata*) - a potential pasture species. *Proceedings of the New Zealand Grassland Association* **58**, 77-86.

Wasser, C.H. (1982). ‘Ecology and culture of selected species useful in revegetating disturbed lands in the west’. U.S. Fish & Wildlife Service.

Whitfield, D.M. (2001). Water content of a red-brown earth subjected to a range of agronomic vegetation options in south-eastern Australia. *Australian Journal of Agricultural Research* **52**, 587-592.

Wiley, T. (2001). Sub-tropical perennial grasses. Department of Agriculture Western Australia, Bulletin No. 4473.

Wills, B.J., Douglas, G.B., Foote, A.G. and Trainor, K.D. (1999). Germplasm characterisation and palatability of *Dorycnium* species under New Zealand dryland conditions. *Plant Genetic Resources Newsletter* **120,** 8-14.

Wills, B.J., Begg, J.S.C. and Foote, A.G. (1989). *Dorycnium* species - two new legumes with potential for dryland pasture rejuvenation and resource conservation in New Zealand. Proceedings of the New Zealand Grasslands Association **50,** 169-174.

9.3 Material Transfer Agreement

THIS MATERIAL TRANSFER AGREEMENT is hereby made and entered into as of on the day of

two thousand and eight by and between **FUTURE FARM INDUSTRIES CRC PTY LIMITED** ACN 125 594 765 an Australian corporation with its principal executive offices located at M081, The University of Western Australia, 35 Stirling Highway, Crawley, Western Australia, Australia, and

HERITAGE SEEDS PTY LTD * with its principal executive offices at *.

RECITALS:

WHEREAS Owner owns Material.

AND WHEREAS Recipient has asked Owner to provide a sample of Material to Recipient, and Owner has agreed to do so.

AND WHEREAS Owner may also disclose Confidential Information to Recipient.

AND WHEREAS Material and Confidential Information have an unique value to Owner, and may be the basis of applications for patents.

AND WHEREAS Owner will be prejudiced by any unauthorised use of Material, or any unauthorised use or disclosure of Confidential Information, may be precluded from being granted patents, and may suffer financial loss.

AGREEMENT

NOW, THEREFORE, in consideration of the premises set forth herein and the covenants and promises hereinafter set out, Discloser and Recipient, intending to be legally bound, hereby agree as follows:

ARTICLE 1. MEANINGS

1. In this Agreement, the following words have the following meanings:

Confidential Information means all information disclosed by Owner to Recipient including inventions; discoveries; facts; data; ideas; manner, method or process of manufacture; method or principle of construction; chemical composition or formulation; techniques; products; prototypes; processes; names; know how; routines; specifications; drawings; trade secrets; technology methods; computer programs; works in respect to which copyright subsists; circuit board layouts; and other knowledge;

Derivative means any material that is derived from or based upon Material, whether or not progeny, and whether modified, or unmodified;

Investigator means Heritage Seeds Research staff including the Research Manager, Allen Newman, Pasture Specialist David Hawkey, Regional Managers Adrian Driden and Daniel Brash, tropical research Scientist Leonard Song and Tropicals Research Technician Gregory Verness.

Material means pre-commercial cultivars of tall fescue, cocksfoot and *Panicum Maximum* developed to adapt to the low to medium rainfall environment of temperate Australia by FFI CRC Grass Breeding Project (P1 05) and associated agronomic information collected during the course of breeding the material;

New IP means such of the following as arise from Recipient's use or possession of Material or Confidential Information:

(a) a Derivative

(b) inventions; discoveries; facts; data; ideas; manner, method or process of manufacture; method or principle of construction; chemical composition or formulation; techniques; products; prototypes; processes; know how; routines; specifications; drawings; trade secrets; technology methods; works in respect to which copyright subsists; and other knowledge;

Purpose is to assist project participants to undertake performance evaluation and commercial suitability at agreed sites to determine performance compared to known commercial comparators.

ARTICLE 2. PROVISION OF MATERIAL

2.1 Owner will provide a sample of Material to Recipient.

2.2 Recipient must ensure that only the Investigator has access to Material.

ARTICLE 3. SAFETY

3.1 Recipient acknowledges that Material may be toxic, may contain infectious agents, or other substances that are hazardous or dangerous, or harmful on persons or property.

3.2 Recipient is responsible for Recipient's safe handling and storage of Material, in such as a way as ensures that Material will not cause any harm to any person, or to property.

3.3 Recipient warrants to Owner that given the nature and characteristics of Material, Recipient:

(a) is aware of all matters that concern the safe handing and storage of Material

(b) has all facilities that are required for the safe handing and storage of Material.

ARTICLE 4. USE OF MATERIAL

4.1 Recipient must use Material only for the Purpose, and must not use Material or Confidential Information for any other purpose.

4.2 Recipient must comply with any written directions from Owner in relation to the use of Material, whether given before or after this Agreement is entered into.

4.3 Recipient must not use Material for any commercial purpose.

4.4 Recipient must not lodge any patent application or any other application for the statutory protection of Material, without the prior written consent of Owner.

ARTICLE 5. CONFIDENTIAL INFORMATION

5.1 Owner may also disclose Confidential Information to Recipient.

5.2 Recipient must use Confidential Information only for the Purpose, and must not use Confidential Information for any other purpose.

5.4 Recipient must not lodge any patent application or any other application for the statutory protection of Confidential Information, without the prior written consent of Owner.

5.5 Recipient may communicate Confidential Information to such of its directors, officers, and employees as need to know Confidential Information for the Purpose. Recipient warrants that each such director, officer, or employee is bound to Recipient by obligations of confidentiality at least to the same extent as are imposed upon Recipient by this Agreement.

ARTICLE 6. CONFIDENTIALITY & TRANSFER OF POSSESSION

6.1 Recipient must keep Material and Confidential Information secret and confidential.

6.2 Recipient must not disclose to any person or make known in any manner any part of Material or Confidential Information.

6.3 Recipient must not provide Material, nor any sample of Material, nor any Derivative, to any person, nor in any other way part with possession of Material, nor any sample of Material, nor any Derivative, without Owner’s prior written consent.

6.4 Recipient must keep Material and Confidential Information in a secure place so as to ensure that unauthorised persons do not have access to Material or Confidential Information.

6.5 Recipient acknowledges that damages may be an inadequate remedy to Owner in the event of any breach of this Agreement occurring, and that only an injunction might be adequate to properly protect the interests of Owner.

ARTICLE 7. WRITTEN CONSENT

7.1 Owner may consent to Recipient parting with possession of Material, or making a disclosure or may relieve Recipient from complying with the whole or any part of this Agreement. Such a consent can only be in writing.

7.2 Owner may consent pursuant to Article 7.1 subject to conditions, including a condition that the person to whom Recipient proposes to provide Material or to disclose Confidential Information executes in favour of Owner an agreement upon the same terms as this Agreement.

ARTICLE 8. ENDING OF OBLIGATION OF CONFIDENTIALITY

8.1 Recipient shall be relieved from Recipient's obligations of confidentiality in this Agreement in respect to Material or any part of Confidential Information which:

(a) Recipient can show was in the possession of Recipient as at the date of the provision of Material, or disclosure; or

(b) Recipient can show is or becomes part of the public domain otherwise than by a breach of this Agreement; or

(c) Recipient can show was received in good faith from a person entitled to provide it to Recipient; or

(d) Recipient can show was independently developed by Recipient, by employees who did not have access to Material or Confidential Information.

8.2 If parts or elements or features of Material or Confidential Information are in the public domain, or otherwise fall within one of the categories mentioned in Article 8.1, but the combination of those parts or elements or features is unique, Recipient may not take the benefit of Article 8.1.

ARTICLE 9. OWNERSHIP & RIGHTS

9.1 Recipient acknowledges that this Agreement is not a contract for sale of goods.

9.2 Recipient acknowledges that

(a) Material

(b) all of Confidential Information, including any copyright that subsists in any part of Confidential Information,

shall at all times remain the absolute property of Owner.

9.3 Nothing in this Agreement confers upon Recipient any right or license to any part of Material or Confidential Information.

9.4 Within three months of the conclusion of this agreement pursuant to Article 13.1, the Recipient has an exclusive right to submit an Expression of Interest to the Owner to commercialise the Material.

9.5 The Owner undertakes to consider any Expression of Interest submitted pursuant to Article 9.4 in good faith and according to its objective to commercialise its research output in such a manner as to ensure that the maximum benefit accrues to Australia, including Australian industry, the Australian environment and the Australian economy generally.

ARTICLE 10. NEW IP

10.1 The New IP shall be owned by Owner.

10.2 Recipient shall promptly disclose the New IP to Owner.

10.3 Recipient shall observe, in relation to the New IP, all of the obligations in this Agreement as if the New IP was part of Confidential Information.

10.4 All of the provisions in this Agreement relating to Confidential Information shall apply equally to the New IP, and this Agreement shall be read as if Confidential Information included the New IP.

ARTICLE 11. PUBLICATIONS

11.1 Recipient must not publish any paper which in any way refers to Material, any Confidential Information, or the New IP, without the prior written consent of Owner.

11.2 Owner records that subject to its commercial interests in relation to Material and Confidential Information, and subject to Owner and its researchers being acknowledged in any paper, it may furnish its consent pursuant to Article 11.1.

ARTICLE 12. INFRINGEMENT

12. If Recipient shall learn or believe that:

(a) any unauthorised person has come into possession of any part of Material or Confidential Information; or

(b) any unauthorised person is doing anything in contravention of rights that attach to and arise from Material or Confidential Information,

Recipient must immediately report full particulars to Owner, and must provide to Owner all reasonable assistance and information it may request with respect to that information.

ARTICLE 13. DURATION OF CONFIDENTIALITY

13.1 The term of this agreement is two years.

13.2 The obligations upon Recipient in this Agreement end upon the expiration of that period. This does not affect the provisions of this Agreement relating to the ownership of New IP.

ARTICLE 14. RETURN OF MATERIAL & CONFIDENTIAL INFORMATION

14.1 Owner may at any time by notice in writing to Recipient require the return to it of Material or Confidential Information.

14.2 Within 7 days of receipt of such a notice Recipient must deliver to Owner Material and Confidential Information together with all copies of all Confidential Information in its possession:

(a) provided by Owner; or

(b) which Recipient has for any reason made.

14.3 Any part of Confidential Information which cannot conveniently be returned by Recipient to Owner shall be completely destroyed in such manner and at such time as directed by Owner, including by deletion from all computer records and electronic or magnetic storage devices.

14.4 Any part of Material which Owner does not require returned to it shall be destroyed in the manner required by any law or regulatory agency for the disposal of potentially biohazardous waste.

ARTICLE 15. NO ASSIGNMENT

15.1 This Agreement may not be assigned by any party.

ARTICLE 16. NO WARRANTIES

16.1 Owner makes no warranty nor any representation that Material or Confidential Information:

(a) is fit for any, or any particular purpose

(b) does not infringe the rights of any other person.

16.2 Neither party makes any warranty or representation in relation to:

(a) Material or Confidential Information

(b) the likelihood or otherwise of Recipient being granted any rights in relation to Material or Confidential Information

(c) the likelihood of the parties entering into any further agreement of any type.

ARTICLE 17. GOVERNING LAW

Each party may bring proceedings in any court of competent jurisdiction in the place where its principal executive offices are located.

SIGNATURES OF PARTIES

This Agreement shall be effective when signed by all parties, and its effective date is the latest of the dates set out below.

SIGNED on behalf of FUTURE FARM INDUSTRIES CRC LIMITED
BY

K. F. Goss
Print Name

____
Signature

7/7/08
date

SIGNED on behalf of HERITAGE SEEDS PTY LTD
BY

J. McDonald
Print Name

____
Signature

30/6/08
date