The search for alternative temperate perennial pasture species for low to medium rainfall environments in Tasmania

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Abstract
In response to the need to find better adapted and more persistent perennial pasture plants for the dryland pastures in the cool-temperate low to medium rainfall (500-700 mm) regions, over 1000 accessions representing 24 species of perennial legumes and 64 species of perennial grasses, were introduced, characterised and evaluated for production and persistence under sheep grazing at sites throughout Tasmania. The work has identified four alternative legume species in Talish Clover (*Trifolium tumens*). Caucasian Clover (*T. ambiguum*), Stoloniferous Red Clover (*T. pratense var. stoloniferum*), Lucerne x Yellow Lucerne Hybrid (*Medicago sativa* x *M.sativa* subsp. *falcata*); and two grass species in Coloured Brome (*Bromus coloratus*) and Hispanic Cocksfoot (*Dactylis glomerata var hispanica*).

Keywords: persistence, perennial grass, perennial legume

Key messages

- The traditionally used species perennial ryegrass (*Lolium perenne*), summer active cocksfoot (*Dactylis glomerata*), fescue (*Festuca arundinacea*) and white clover (*Trifolium repens*) are not adapted to Tasmanian hill country environments
- This project has identified a number of species with superior drought tolerance and persistence over the traditional pasture species, which are well adapted to Tasmanian hill country environments
- Several of these species are new to agriculture and there are still challenges ahead for them to become mainstream species.

Introduction
Considerable potential exists on the dry steep hill country of Tasmania for the use of drought tolerant perennial pasture species, outside the range of traditionally sown pasture species. The need for alternative species was highlighted by the result of a pasture survey in the Midlands and Derwent Valley regions of Tasmania which showed ground cover contributed by commonly sown improved grass species (cocksfoot, *Dactylis glomerata* and perennial ryegrass *Lolium perenne*) to be frequently as low as 5% (Friend *et al.* 1997).

White clover (*Trifolium repens*) red clover (*T. pratense*), strawberry clover (*T. fragriferum*) and lucerne (*Medicago sativa*) are the four most widely used perennial legume species across the regions. In these environments all of these species have adaptational deficiencies limiting their persistence. *T. repens* is at its natural limit of climatic adaptation performing best in areas receiving more than 700 mm mean annual rainfall (Dear & Ewing 2008). *T. pratensis* has a low tolerance to moisture stress and will not survive long, dry summers. *T. fragiferum*, is more drought tolerant than *T. repens*, but is best adapted to wet or saline soils and will not survive extended dry periods (Dear *et al* 2003). The persistence and use of *M.sativa* is restricted by factors including water logging, acid soils and unfavourable grazing management.

Perennial ryegrass has remained popular largely due to the availability of relatively cheap seed, ease of establishment and management. However, under dryland conditions perennial ryegrass pastures have a number of limitations including poor persistence and low productivity during the summer months, creating land care issues and also a major feed gap. Perennial ryegrass is also highly susceptible to a number of pasture pests and has negative animal health issues due to the presence of endophytes. Phalaris (*Phalaris aquatica*) is well adapted to hill country, however, it also can have negative animal health issues and cocksfoot is not popular due to its strong clumping habit.

Dry summers and longer term droughts have been a regular feature of the dry regions of Tasmania resulting in poor productivity, lack of persistence and in many cases the complete failure of current species and cultivars. The objective of this study was to evaluate the persistence and production of a range of perennial pasture species collected from environments similar to the target area, with the long term goal of providing producers in the target environment with well adapted alternative pasture species. To this end, a project entitled “The Herbage Development Program”, initiated in 1992, by the Tasmanian Department of Primary Industries, Parks, Water and Environment

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(DPIPWE), aimed to find adapted species to fit into this environment. This program moved to the Tasmanian Institute of Agriculture (TIA) in 1996, where it continues to this day.

Methods

The work involving the search for new species has been conducted in essentially four stages/ components.

Initially, a series of ecogeographic surveys into regions identified the homoclimes of the target area. A number were clearly recognised but interest focused on those that were known to contain species of high pastoral value, namely in the Iberian Peninsula and the dry montane valleys of South-Central Argentina and Chile. A collecting mission to the former was undertaken in 1993 (Reid 1995) and accessions were obtained principally from areas within a 50 km radius of the towns of Burgos, Soria and Zamora. *D. glomerata* var. *hispanica* was the principal grass collected and *T. pratense* amongst the perennial legumes. Sites of collection were as varied as having an annual rainfall as low as 350 to 500 mm, summer temperatures often in excess of 40°C and winter temperatures as low as -15°C. Further accessions were obtained through various Australian and overseas genebanks including the Australian *Trifolium* Genetic Resource centre, the Margot Forde collection and the United States Department of Agriculture (USDA).

Table 1 Grass species screened during the project.

Scientific name	No of accessions screened	Scientific name	No of accessions screened
Agropyron cristatum	4	*Dactylis smithii*	4
Agropyron desertorum	4	*Dactylis woronowii*	1
Agropyron hybrid	2	*Digitaria argyrograpta*	2
Agropyron intermedium	4	*Digitaria eriantha*	1
Agropyron magellanicum	2	*Digitaria milanjianum*	1
Agropyron trichophorum	3	*Digitaria pentzii*	2
Arrhenatherum elatius	3	*Digitaria smutzii*	3
Bromus anatolicus	2	*Elymus lanceolatus*	1
Bromus anomalus	1	*Elymus patagonicus*	1
Bromus araucanus	2	*Elymus pubiflorum*	1
Bromus auleuticus	1	*Elymus trachycaulus*	1
Bromus biebersteinii	2	*Festuca arundinacea*	9
Bromus breviaristatus	1	*Festuca idahoensis*	13
Bromus carinatus	13	*Festuca longifolia*	1
Bromus catharticus	17	*Festuca nigrescens*	1
Bromus coloratus	2	*Festuca ovina*	81
Bromus inermis	3	*Festuca pallescens*	2
Bromus macranthos	2	*Festuca pratensis*	5
Bromus mango	4	*Festuca rubra*	3
Bromus marginatus	7	*Lolium perenne*	27
Bromus runssoroensis	1	*Phalaris aquatica*	2
Bromus setifolius	3	*Phalaris* hybrid	5
Bromus sitchensis	3	*Phleum pratense*	7
Bromus spp.	18	*Poa ampla*	8
Bromus stamineus	5	*Poa canbyi*	6
Bromus syriacus	5	*Poa glaucantha*	1
Bromus tomentellus	14	*Poa ligularis*	1
Bromus tomentosus	7	*Poa pratensis*	4
Bromus valdivianus	6	*Poa secunda*	1
D. glomerata ssp *glomerata*	92	*Psathyrostachys juncea*	1
D. glomerata ssp. *hispanica*	22	*Secale montanum*	4
Dactylis marina	2	*Thinopyron ponticum*	2

The second stage saw over 1000 accessions representing 64 species of perennial grasses (Table 1) and 24 species of perennial legumes (Table 2) screened as spaced plants at either DPIPWE's Mt Pleasant Laboratories field site, Launceston, Tasmania or its Cressy Research Farm, Cressy, Tasmania, for their potential use as pasture herbage plants in the target environment.

The third stage commenced in 1995. Following plant characterisation and phenotypic selection for desirable traits, 185 of the most promising lines representing 28 species of perennial grasses and 24 species of perennial legumes, including 10 commercial cultivars were selected for preliminary field evaluation and adaptation at three sites: Jericho (Central Midlands, cold winters, hot dry summers, clay loam soil), Hamilton (Derwent Valley, drought prone. north facing slopes, clay loam) and Swansea (East Coast, drought prone, occasional summer rain, heavy cracking clay soil). The lines were established in 5 m rows of spaced plants, planted 25 cm apart and 1 m between rows. Lines were not replicated.

At this stage, the evaluation process involved the determination of relative herbage production, seasonal distribution, nutritive value, palatability, and sensitivity to a range of stresses including frost, drought, grazing tolerance and susceptibility to pests and diseases, and long term persistence across a range of environments. The persistence of the accessions was measured by counting the surviving original plants (Table 3). All lines were grazed heavily by sheep after each herbage production assessment. The target environments selected for this screening work were considered “difficult” because of the combined effects that drought; cold and low to moderate soil fertility have on pasture production and persistence.

Finally, from the early performance of lines at three sites, 85 experimental lines representing 23 grass species were selected for advanced testing in replicated 10 x 1.5 m sward trials established in 1998 at five evaluation sites, and 15 legume species established at two evaluation sites in 2005, to compare the productivity and the persistence of these lines against commercial varieties. Herbage production was assessed by cutting 0.5 x 0.5 m quadrats from each plot and visually assessing them for botanical composition in the laboratory. The samples were dried at 100°C for 24 h and the herbage yields kg DM/ha calculated. The persistence of the accessions was measured using basal frequency assessments. These were made after the autumn break each year. Two square quadrats of steel mesh, each with 100 cells (each 0.1 x 0.1 m) were placed in fixed positions on the ground within each plot, at each assessment time. Cells containing a portion of a live plant crown of the sown species were counted and recorded; the combined total number of cells containing a live crown was used as an estimate basal frequency (Table 4).

The grass evaluation sites were situated at Cranbrook (East Coast, drought prone, low fertility, slightly saline, gravelly clay loam soil), Triabunna (East Coast, high fertility, summer rain, fine sandy clay loam), Jericho (Central Midlands, cold winters, and hot dry summers, clay loam), Ross (Northern Midlands, drought prone, sandy loam) and Cambridge (Coal River Valley, drought prone, fine sandy duplex soil). The legume sites were Jericho and Cressy (cold winters, dry summers, light well drained sandy soil).

Table 2 Species of perennial legumes screened during the project.

Species	No. of accessions	Species	No. of accessions
Astragalus chinensis	1	*T.burchellianum*	13
A.falcatus	1	*T.fragiferum* *	39
Coronilla varia *	48	*T.hybridum*	22
Dorycnium hirsutum	8	*T.medium*	21
Dorycnium pentaphyllum	17	*T.montanum*	12
Dorycnium rectum	3	*T.ochroleucum*	8
Hedysarum coronarium	16	*T.pannonicum*	9
Lotus corniculatus *	28	*T.physodes*	48
L.tenuis	1	*T.pratense* *	78
Medicago sativa *	4	*T.repens* *	98
M.sativa x falcata	6	*T.rubens*	3
Trifolium africanum	10	*T.tumens*	62
T.ambiguum *	31	*Vicia cracca*	19

* Including a control commercial cultivar.

Table 3 Plant survival at the Hamilton north facing slope site, after 4 and 5 years, expressed as a percentage of the original plants.

Species	Fourth year survival (%)	Fifth year survival (%)
Bromus stamineus (cv. Grasslands Gala)	0	0
Bromus uniloides (cv. Matua)	0	0
Dactylis glomerata ssp hispanica [a]	82	67
Dactylis glomerata “intermediate” [b]	34	11
Dactylis glomerata ssp glomerata [c]	13	2
Dactylis glomerata (cv. Porto)	32	0
Festuca arundinacea (cv. Demeter)	0	0
Festuca ovina	85	85
Lolium perenne (cv. Jackaroo)	0	0
Phalaris aqautica (cv. Australian)	100	20

[a] mean of 19 lines, including cv. Uplands and cv. Sendace's parents
[b] mean of 52 lines
[c] mean of 13 lines.

Outcomes

To date, the perennial herbage development program has resulted in the commercial release with Australian Plant Breeders Rights protection (PBR) of four grasses and five legumes. Two cultivars of Hispanic cocksfoot (*D.glomerata* ssp *hispanica*), Uplands and Sendace have shown the ability to survive extended dry periods in a low rainfall environment, surviving drought conditions in Tasmania's Derwent Valley where the mean annual rainfall (1995 to 2000) was 382 mm (Table 3). Perennial ryegrass has failed to persist at this site with rainfall below 500 mm/year. The cultivar Uplands is now widely sown by producers in the target area and also throughout Victoria and the highlands of New South Wales. The cultivar Megatas (*Dactylis glomerata*) was selected for its excellent seedling vigour and increased leafiness and vigour with a low crown. It is highly summer active, producing high protein, high energy forage all year round with a high level of digestibility and nutritive value. Megatas has little or no aftermath heading, a desirable trait, as summer rains result in the production a large bulk of leafy highly palatable feed. The cultivar Exceltas (*Bromus coloratus*) is a summer active perennial with the original germplasm coming from South-Central Chile. Exceltas out-yielded all perennial ryegrass cultivars in late spring/early summer in irrigated trials conducted by the DPIPWE at the Elliot Research Station, and in dryland trials conducted by the TIA at the Cressy Research Farm, Tasmania (Hall and Hurst 2012) (Table 5).

The legumes are now in the early stages of commercial seed being production. The *M. sativa* x *M. falcata* lucerne hybrid, cv. KI Creepa is summer active and highly stoloniferous, and has survived at all sites under the sheep grazing regimes. It is comparable in yield with the control cv. Prime but decidedly more persistent under grazing (Table 4). Caucasian clover cv. Kuratas is strongly rhizomatous and besides being selected for superior yield and persistence, has proven to be a good seed producer. Alsike clover cv. Hytas is more suited to the medium rainfall areas and often difficult soils, for example, both acid and water-logged. The Stoloniferous Red clover cv. Rubitas is also more suited to areas receiving in excess of 600 mm rainfall where it has proved to be persistent and long-lived. Talish clover (a species new to pastoral agriculture) has both a deep taproot which confers its excellent drought tolerance, and a growing points originating just below ground level, making it difficult for sheep to overgraze (Hall *et al*. 2013).

Other alternative species identified as worthy of further consideration include the legumes *Trifolium hybridum, T. ochroleucum*, *T. physodes*, *Lotus corniculatus* and *L. tenuis*, and the grasses *Bromus auleticus* and *Festuca ovina*.

Future work

As several of the developed varieties are new species to Australian agricultural pasture systems there are many challenges ahead for these species to become 'mainstream' as many farmers are reluctant to change from using 'traditional' species (Vanclay 2004). There is a need to demonstrate the benefits of growing these long lived perennial grasses and legume across the target environments. It is also important to develop agronomy

Table 4 Species average and maximum frequency data taken from a combined site analysis of perennial legume evaluation sites established in 2005.

Species	Number of lines	2007 Frequency (%)		2010 Frequency (%)	
		Mean	Highest	Mean	Highest
Lotus corniculatus *	4	32	66	14	31
Medicago sativa *	1	64	64	60	60
M. sativa x falcata	2	86	87	91	92
T. ambiguum *	6	34	50	31	55
T. fragiferum *	3	34	40	2	3
T. hybridum	2	12	20	0	0
T. physodes	10	21	47	14	33
T. pratense *	7	36	41	4	7
T. repens *	3	6	13	0	0
T. tumens	7	57	68	42	65
LSD (P=0.05)		12		10	

* including a control commercial cultivar

Table 5 Seasonal herbage production (kg DM/ha) of Exceltas *(B. coloratus)* versus 9 perennial ryegrass *(L. perenne)* cultivars in 2011 at Cressy, Tasmania.

Season Cultivar	Late Summer	Autumn	Winter	Spring	Early Summer	Total
Arrow	1229	1700	1346	1814	436	6525
Avalon	1069	1470	1344	2115	266	6264
Banquet II	1282	1905	1258	1995	685	7125
Bealey	1289	1674	1416	2593	1069	8041
Exceltas	983	1126	1818	3136	1420	8483
Expo	1170	1522	1361	2594	550	7197
Ohau	1220	1823	1250	2240	569	7102
Victoca	1202	1302	1323	3585	535	7947
Wintas	1002	1179	1061	1873	302	5417
Wintas II	835	1456	1300	2340	313	6244
LSD (P=0.05)	ns	380	236	777	289	458

and management strategies for the species, including maximising seed production, grazing management and compatibility with other species, for them to maximise their full potential benefits in perennial pasture systems. The development of comprehensive extension packages for seed growers and farmers is now a priority to give them the confidence to adopt these species. The benefits to animal production, the environment and the species role in combating climate change also need better quantification.

Conclusions

The superior drought tolerance and persistence of a number of alternative pasture species against the commonly sown cultivars and species tested, highlights the potential to develop new cultivars from this material. It highlights the importance the environment a species has come from in determining its adaptability when developing new cultivars. With the failure of a number of "traditional" species and cultivars, along with the increasing problem of land degradation in the low rainfall areas of Tasmania, the development of drought tolerant, well adapted alternatives must now be considered a high priority with long term persistence becoming the principal selection criteria. All of these new cultivars are exhibiting agronomic characteristics that are likely to be of value in other parts of the world with similar climates, for example, Southern South America, the Pacific North-West of the USA and New Zealand.

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