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The pasture and forage industry in the mediterranean bioclimates of Australia

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Summary - Farming systems in mediterranean bioclimate areas of Australian rely heavily on pasture and forage legumes. This paper describes the farming systems in place, challenges to these systems and future directions for the development of new cultivars. Commercial production of seed, the export industry and the sources of funding for cultivar development are discussed.

Key-words: Australia, pasture development, farming systems, legume

Résumé – *Les sistèmes colturels dans les zone bioclimatiques mediterranéennes de l'Australie se basent fortement sur les pàturages et les légumineuses fourragers. Cet étude décrit les systèmes colturels actuels, les poset en question aussi que les directives futures pour le dévelopement de nouvelles cultivars. La production commercial des semences, l'industrie d'exportation et le sources du financement pour le development des cultivars sont discutées.*

Mots-cles: *Australie, légumineuses fourragers, systèmes colturels*

Historical development

Australia has a very short agricultural history, starting with European settlement in 1788. Although the European farming practices used by the settlers were initially unsuccessful, a viable system had emerged by the 1900's based around crop pasture sequences using wheat and sheep (wool) production. One catalyst in the development of this successful farming system was the accidental introduction of subterranean clover that was able to self-regenerate in pasture crop rotations. Commercial sale of subterranean clover seed began in 1907 but little progress was made until the 1920's when the use of superphosphate fertilisers became common practice. By 1979, 12 million hectares of land were sown to subterranean clover cultivars (Rossiter 1979) and by 1997 an estimated 23.5 million hectares were sown to annual legumes (Sandral *et al.* 1997).

The areas of southern Australia which experience a mediterranean type climate include the south-west corner of Western Australia (12a and 9 in Figure 1), the southern portion of South Australia (12b and 9), Tasmania (8), Victoria (12b, 10b and 8) and southern New South Wales (8, 10b, 11b and 12b) (Gramshaw *et al.* 1989). Four main farming/grazing systems have evolved for mediterranean bioclimates using temperate pasture and forage legumes. These include ley, phased and forage farming systems and permanent pasture.

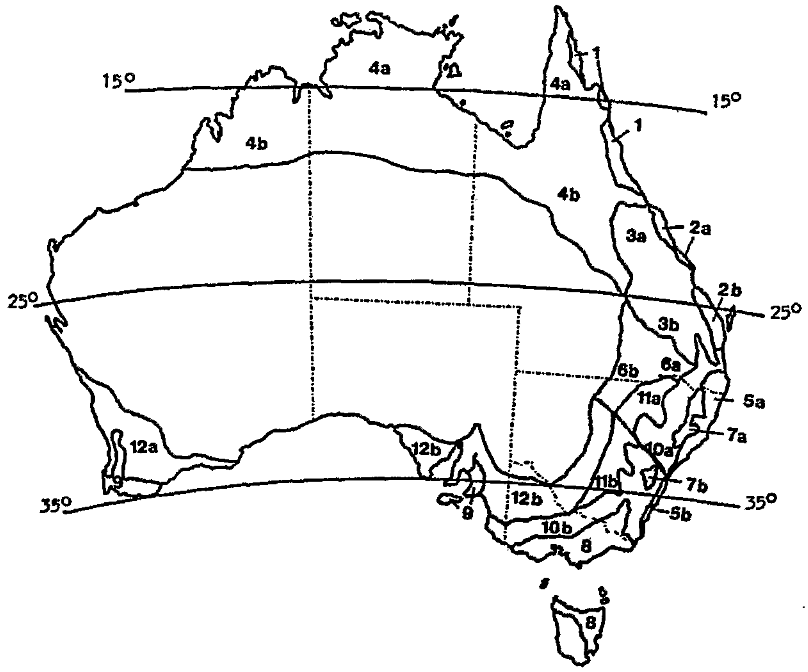

Figure 1. Bioclimatic zones of Australia adapted from Gramshaw *et al.* (1989). Zones 9 and 12 are strongly winter dominant, zones 7b, 8, 10b, 11b and 12b are winter dominant, zones 1, 5b, 10a and 11a are non-seasonal, zones 2, 3, 5a, 6 and 7a are summer dominant and zone 4 is strongly summer dominant.

The ley farming system

In the ley farming system, cereal crops are grown in rotation with pasture which usually includes a sown legume component that self-regenerates after the crop. This farming system is mostly practiced in zones 12a and 12b shown in Figure 1. As annual rainfall increases the length of the pasture ley tends to increase and the frequency of cropping is reduced.

The legume-based pasture provides fodder for sheep, acts as a disease break between the cereal crops and improves soil fertility through nitrogen fixation. The pasture is utilised for grazing throughout the year and supplemented with in-situ crop residues over the summer and some strategic feeding of grain, hay and silage. The stock carrying capacity of a farm is determined largely by autumn and winter-feed availability from pastures. Conservation of excess spring production in the form of hay or silage is mainly practiced in the high rainfall areas. When first developed, the use of annual legumes and superphosphate increased animal production three fold and increased cereal yields by 50 to 100% (Puckridge and French 1983).

The success of the ley farming system is dependent on the formation of a persistent seed bank, from which pasture regeneration occurs both between sequential pasture years and after one or two seasons of cropping. The sown legume must be able to mature and set seed before the end of the season, be fecund, have sufficient "between" season seed dormancy (hardseededness) to form a persistent seed bank and must be able to do all of this in the presence of grazing animals.

The development of pasture cultivars for Australian farming systems has been totally reliant on exotic genetic resources, as native legumes are generally not suited to agriculture. The ley farming system has largely been dependent on a few species including subterranean clover

(*Trifolium subterraneum* L.) and several medics (*Medicago* spp) (Cocks 1993). The cultivars of subterranean clover and the annual medic species developed by Australian plant improvement programs were initially based on naturalised ecotypes (for example the sub clover cultivars Seaton Park and Dalkeith and the medic cultivar Jemalong). More recently, material introduced from the Mediterranean regions (cultivars Denmark, Goulburn, Leura and York) and active hybridization (cultivars Nungarin, Riverina and Gosse) has been used to produce improved cultivars.

Subterranean clover is very successful in wetter regions (annual rainfall in excess of 450 mm) where soils are neutral to acid. However, inadequate levels of seed dormancy, and its lack of drought tolerance reduces its ability to persist in lower rainfall cropping systems (Taylor 1984). Annual medics are important in lower rainfall regions on light and heavy textured neutral to alkaline soils. Key species include *Medicago polymorpha*, *M. truncatula*, and *M. littoralis*. *Medicago murex* and *M. sphaerocarpos* can also be grown successfully on moderately acid soils (Howieson and Ewing 1986) although their commercial success in Australia has been limited. There are edaphic niches that subterranean clovers and annual medics do not fill. Examples include the acid and sandy duplex soils in areas that receive less than 350mm annual rainfall (Ewing *et al* 1992) and deep sandy soils with poor water holding capacity (Howieson and Loi 1993). The need to fill these niches and cater for evolving farming systems has forced Australian scientists to look beyond these species with current plant improvement programs. Such programs now include evaluation of species such as *Ornithopus compressus, Ornithopus sativus, Biserrula pelecinus, Trigonella balansae, Trifolium michelianum, Trifolium resupinatum, Trifolium glanduliferum* and *Trifolium vesiculosum.*

The phase farming system

Phase farming evolved concurrently with ley farming and is practiced mostly in zones 10b, 11b and the northeastern section of 12b (Figure 1). In this system farmers resow the pasture after each cropping sequence. In most cases the pastures are sown at a low rate as a polyculture, with the last crop in the sequence (a practice known as undersowing or cover-cropping). This system also allows the use of perennial species because a new perennial population can be established at the beginning of each extended period of pasture. Dryland lucerne (*Medicago sativa*) is an important component of farming systems in some areas of eastern Australia where there is a higher incidence of summer rainfall (Gramshaw *et al.* 1989). In zones such as 10b (Figure 1) lucerne or annual pasture legumes may also be sown with perennial grasses such as phalaris (*Phalaris aquatica*), cocksfoot (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*) or tall fescue (*Festuca arundinacea*).

A major advantage of the phase farming system is that the pasture phase provides an opportunity to use grazing and non-selective herbicides to control weedy species. To take advantage of these opportunities, many farmers using ley systems are beginning a transition to phase farming systems.

The phase system removes the requirement for very high levels of seed dormancy in the pasture cultivar, allowing many new species to be considered. The criteria for phase pastures include;

- Low cost of seed to allow high-density establishment at frequent intervals. In practice this has been interpreted as an ability to be harvested by conventional cereal harvesting equipment.
- Moderate levels of seed dormancy.

- Maturity time that allows seed set in poor seasons but late or indeterminate enough to exploit longer growing seasons.
- Mechanisms in seeds to avoid germination with summer rainfall.
- Ability to vigorously compete with volunteer species.
- Ability to fix nitrogen.
- Tolerance of pests and diseases.
- Compatibility with the use of non-selective herbicide (eg. Glyphosate) for weed control.

In the past, some annual legume cultivars of species such as subterranean clover and annual medics designed for the ley farming system have been used in the phase system. Aerial seeding pasture species that more closely meet the stated requirements of phase farming are only just emerging commercially. Examples include the French serradella (*Ornithopus sativus*) cultivar Cadiz, and crimson clover (*Trifolium incarnatum*) cultivar Caprera.

Forage farming systems

Forage legume break crops are sown as a single year forage between grain crops. This system differs to ley and phase farming in that no regeneration is required from the sown legume. Plants for this system are selected for their high dry matter production and late maturity as no seed set is required and nitrogen fixation needs to be maximised. Forage farming systems have only recently evolved due mainly to low returns from some pulse crops (eg. lupins) and the emergence of herbicide resistant crop weeds. Forage legumes have to some extent replaced lupins (*Lupinus angustifolius*) in the crop rotation as they provide a nitrogen benefit higher than that provided by lupins (Scott and Evans 1999) and the opportunity to control herbicide resistant weeds. Where herbicide resistant weeds need to be controlled, the forage legume is often sprayed with a non-selective herbicide in late spring before viable seed of the target weed is set. The residues are conserved as silage or hay.

Permanent pasture

Permanent pasture has always played a role in high rainfall areas as the topography makes these areas less suited to crop production. Dryland pastures in these areas still rely largely on annual subterranean clover and grasses such as ryegrass, phalaris and cocksfoot. In irrigated areas, white clover supplements subterranean clover. There are many cultivars available for the permanent pasture system, developed both in Australia and New Zealand. They are largely utilised in various rotational grazing systems and through fodder conservation of excess spring production.

New developments

In medium and low rainfall areas, the intensity of crop production is increasing on the most fertile soils. Animal production is being transferred to the poorer soils unsuited to cropping. Examples of such situations include waterlogged and mildly saline areas and infertile sandy soils, with low pH and low rainfall (Ewing 1999). The development of pasture legumes for these niches is a recent initiative by Australian Plant Improvement Programs. Balansa clover (*T. michelianum*) and persian clover (*T. resupinatum*) are two species adapted to waterlogged and mildly saline areas. Cultivars of these species have undergone rapid adoption due to their ability to increase livestock production substantially from these problem soils. Cultivars of yellow serradella (Charano, Santorini), French serradella (Cadiz), and *Biserrula pelecinus* (Casbah) have also recently been developed for use on the very infertile acid sandy soils.

Challenges to pasture based farming systems

The rate of change in Australian farming systems in mediterranean type climates has accelerated in recent years in response to a number of economic pressures and long term sustainability issues. The intensity, area and diversity of crops grown are increasing as the relative profitability moves away from livestock related products. There has been a trend to minimal (or even no) tillage of the soil in the cropping systems to allow earlier sowing, moisture conservation and reduce the risk of erosion and soil structure decline. The success of these systems relies on the use of selective herbicides to reduce weed competition. As a consequence, resistance to selective herbicides has developed in some weed species, including annual ryegrass (*Lolium rigidum*), wild oats (*Avena fatua*), barley grass (*Hordeum leporinum*) and wild radish (*Raphanus raphanistrum*) (Burnet *et al.* 1994, Hall *et al.* 1994, Broster *et al.* 1998, Hashem *et al.* 1998). This has resulted in an increased emphasis on the production of pasture species and cultivars suited to a phase or forage farming system which allows high cropping intensity (>50%) but also provides the fertility and weed control benefits of a ley pasture phase.

The poor buffering capacity, product removal and nitrogen leaching have resulted in acidification of an estimated 15 million hectares of Australian soils. The removal of native perennial vegetation and subsequent replacement with annual crops and pastures has disturbed the natural hydrological balance resulting in dryland salinity. These soil-degrading processes (acidification and salinity) are the result of the incomplete use of soil nitrogen and water by the annual plant based farming systems. Unused water leaches nitrate (an acidifying process) and then drains into the water table raising the water table and dissolved salts to the soil surface. Salt affected areas are first observed in the lower parts of the landscape and now a quarter of a million hectares of agricultural land in Western Australia alone has become too saline for agriculture (Malcom 1983). A further 1.8 million hectares of agricultural land has been damaged and 6 million hectares are threatened (Cocks and Bennett 1999). This has resulted in not only increased activity to develop waterlogged and saline tolerant plants such as balansa and persian clovers but also an increased emphasis on water use by deep rooted/long season annuals and perennial legumes.

As farming systems evolve, new needs and opportunities are created for pasture species (Ewing 1989). However, the development of new cultivars to fit these needs can take up to 10 years from recognition of a need. The process usually involves collection of suitable germplasm, breeding and selection programs, testing and finally commercialisation (Ewing 1989). To avoid the possibility that the development of new farming systems are constrained by the lack of suitable pasture plants, pasture scientists must be able to predict future trends and needs. This is accomplished by establishing formal and informal grower networks, bio-economic models such as MIDAS (Morrison *et al.* 1986) and an understanding of the impact of new technology at the grower level (Ewing 1989).

Current farming trends in Australia include (Ewing 1999):

- The development of all crop rotations, is currently being hampered by the development of herbicide resistant crop weeds.
- The introduction of crop/pasture rotations in high rainfall zones instead of permanent pasture.
- Increased frequency of cropping resulting in a shorter pasture phase.
- Increased length of the cropping phase threatening natural regeneration of pastures in ley farming systems.

- Soils unsuited to cropping (waterlogging prone, infertile etc) becoming increasingly important for pasture production as more arable lands are used for cropping.
- Wider use of perennials in response to soil acidification and salinity concerns.

Commercial production of pasture seed

Production of pasture seed is conducted entirely in the private sector and includes involvement of individual farmer growers, cooperatives of growers, seed processes and national seed production and marketing companies.

Until 1987, all pasture varieties were released to farmers without any restrictions on production or marketing. Following the introduction of Plant Breeders Rights (PBR) legislation it became possible for the developers of new cultivars to claim ownership and control commercialisation, which usually involved the licensing of private seed producers and the payment of a royalty to the breeders. New varieties that do not satisfy the requirements of the PBR legislation can still be made available to growers without restrictions on subsequent commercialisation.

Quality control of pasture seed is pursued through a certified seed scheme. Purity is determined by crop inspection during the growing season and seed inspections before sale. The seed must meet quality criteria including; high germinability, minimum presence of prohibited and proscribed weeds and cultivar purity. If passed, the seed lot is allocated a uniquely numbered government certified seed label. Cultivar purity can be difficult to determine unless cultivars have distinguishing morphological characters (for examples leaf markers). Where morphological differences do not occur purity is maintained by supervising seed production from seed of established initial purity. In this case seed can be produced for a limited number of generations.

Australian producers grow pastures for seed on approximately 72000 hectares with 25000-28000 tonnes produced annually. Of this production, public cultivars account for 19000-20000 tonnes of seed (certified) and proprietary cultivars 1400 tonnes of seed (Pickett Agricultural Services 1995). Most of the seed produced is sold on the domestic market.

Australia's Export industry

Agriculture is decreasing in importance to the Australian economy. In 1960 agriculture represented 12% of the gross domestic product, by 1995 this has fallen to only 2.5%. Pasture and forage seed production is only a very small component of agricultural exports, with an export value of between A$20 million and A$30 million in 1993/94 (Pickett Agricultural Services, 1995). Table 1 shows the species and quantities of seed exported from 1993 to 1998.

Table 1 Species and quantity (tonnes) of pasture seed exported from Australia.

Species	1993/94	1995/96	1997/98
Lucerne	2744	4043	3984
Barrel medic	241	132	96
Other annual medics	614	885	257
Subterranean clover	842	531	538
Strawberry clover	305	20	149
Other clovers	2038	358	1167
Other pasture legumes	55	38	1485
Total of all legumes	6839	6007	7682

(Source: The Seed Industry Association of Australia, 1999)

Australia holds only a 2-4% share of the world trade in pasture seed (Pickett Agricultural Services, 1995). The biggest buyers of Australian pasture seed in 1993 were Argentina (1189 tonnes), the United States of America (1169 tonnes), Spain (1155 tonnes) and Saudi Arabia (1051 tonnes).

Sources of funding for pasture cultivar development

Pasture breeding, selection and evaluation activities in Australia are dominated by the public sector. Private breeding does occur but is confined to a limited part of the species spectrum (annual ryegrass, lucerne). These cultivars are for the most part developed overseas and sold domestically with little testing for adaptation in Australia bioclimates.

Funding of public pasture improvement effort mainly involves investment by state governments (regional) and farmers. The farmers fund research through trust funds established to collect and distribute contributions made from the sale of their commodities (usually 0.5% of farm gate price matched by a contribution from the commonwealth (federal) government). The income from royalties in cultivar sales is also being redirected into research. Involvement by private research entities is limited by their ability to capture the full benefits of any research, despite the protection offered by PBR. The public research undertaken is nationally coordinated and has a regional focus.

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