Then, now and tomorrow of Australian pastures: Species selection for southern Australia

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Anthony Leddin grew up on a dairy farm in Yambuk in South west Victoria. He went on to study Agricultural science at Melbourne University where he discovered his passion in plant breeding. After volunteering for a year teaching agriculture in Samoa he came back to do a Masters in pasture breeding based at the Ag Department in Hamilton. After that he worked as a pasture agronomist at the Warrnambool CO-OP, a pasture research scientist with Heritage seeds, a seed production agronomist with Bayer and finally to his current role as Pasture breeder and Research manager with Valley Seeds for the last 14 years. He is passionate about plant breeding in Australia as he sees that our climate is unique in the world and it warrants specific varieties for specific needs.

Introduction

Australia has a rich history of breeding and development in temperate pasture species. From early European settlement, the demand for more productive pasture species has led to a change from the native grasses that were dominant in the landscape to introduced temperate and tropical pasture species for southern Australia. With the onset of climate change, there is an increased focus on the selection of pasture species that can maintain increased productivity under extreme environmental conditions. Farmers are inundated with new pasture varieties in the marketplace and it can be a difficult decision to choose the best species that matches their environment and their specific needs. To make this process more interesting for farmers, this paper will look at the history of the different pasture species that are used in temperate Australia, how they are currently used, and how they could change in the future to adapt to our variable environment. This story may help farmers improve their choices of what species work best for their needs on their farm. The knowledge of this story allows farmers to choose the best pastures species to suit the specific needs of their enterprise.

Native grasses

The main pasture species present in southern Australia prior to European settlement and the introduction of hard hooved livestock, consisted of the following:

- Weeping grass (*Microlena stipoidies*)
- Wallaby grass (*Rytidosperma caespitosum (syn. Austrodanthonia caespitosa)*
- Kangaroo grass (*Themeda triandra*).

Before the arrival of these European settlers, these grasses were grazed primarily by kangaroos. With aboriginal management, these grasses survived and thrived. However, when livestock were introduced in large numbers, these grasses decreased in persistence. This may have been due to the slower growth rates of these grasses with the added pressure of a higher stocking density. With the correct management, these species can survive in extreme environments. Some of the beneficial attributes for these species include:

- Greater tolerance to drought and persistence under dry conditions.
- Greater tolerance of lower-fertility soils.

With these characteristics in mind, there is a great opportunity to develop native grasses for the turf industry, as their slower growth rates would mean they would require less mowing. This may eventually lead to the development of more successful native grass cultivars for agriculture systems. Selection work to improve emergence vigour and seed production would create a more cost-effective product that would have a better chance of surviving when sown using conventional sowing equipment. Until this work happens, the best way to establish native grasses is through seedling recruitment of pre-existing native plants with timed grazing management. As most native grasses flower later than annual grass weeds, heavy grazing by stock in November followed by the paddock being closed up over summer allows native grasses to produce seed without the annual grass seed competition.

Perennial ryegrass

Perennial ryegrass was one of the first introduced pasture species in Australia with European settlement. In the 1800's seed or hay which contained seed arrived from England and was sown directly or indirectly by farmers. Those early perennial ryegrass plants had a growth pattern adapted to the environmental conditions of northern Europe with little forage production over the winter due to their colder condition and increased growth over the summer, not suited to southern Australia's temperate/Mediterranean environment. Over time and with natural selection, these plants have evolved to become ecotype cultivars such as Victorian ryegrass (released in 1936) and Kangaroo Valley (released in 1967). These plants are more adapted to the Australian environments that they evolved in with improved winter growth and greater persistence over drier summers.

Over time farmers demanded greater forage production from perennial ryegrass varieties and this led to the release of New Zealand (NZ) bred cultivars in the 1980's such as Ellett, an ecotype selection from dairy pastures in NZ that had a greater production under higher input systems and a later heading date. This was later improved again in the 1990's with even later heading perennial ryegrass varieties such as Impact, being developed from seeds collected from north-eastern Spain. Most of the late heading varieties seen in the Australian marketplace today are genetically based on this north-eastern Spanish material.

Another development in perennial ryegrass was the identification of endophyte (*Epichloë (syn. Neotyphodium)*) in the early 80's. This is a fungus that lives inside the perennial ryegrass plant in a symbiotic relationship with the grass, both benefiting from each other for survival. The grass shares nutrients with the endophyte and in return, the endophyte produces chemicals called alkaloids that help protect the ryegrass plant from stress such as insect attacks and grazing animals during false autumn breaks. It was found that some of these alkaloids such as Lolitrem B could cause ryegrass stagger in livestock or high levels of Ergovaline that could cause heat stress in livestock. This endophyte could be removed from the perennial ryegrass with heat treatments of seed but in areas where insect pressure was high, this was seen to decrease persistence. Work was carried out to identify novel endophytes that contained low or no levels of Lolitrem B and Ergovaline. The first successful novel endophyte, AR1, was released into the marketplace in 1999 and this has been followed by other successful types such as NEA2, Endo 5, and AR37. There will be more novel endophytes to be released in the future. As perennial ryegrass is a species used extensively around the world, it is the most likely species to see the future release of varieties bred using molecular techniques such as F1 hybrids and genetically modified organisms (GMO's).

Phalaris

Phalaris has been one of Australia's success stories for temperate grasses. Up until recently, it was the only grass that had its own long-term breeding program. Australia has been the leader in *Phalaris aquatica* variety development and it is well suited to the southern Australian environment with it being the most winter productive for forage growth out of all the temperate perennial grasses. The variety, Australian, was developed in the subtropical environment of Toowoomba in 1906. It was later found to be more adapted to predominately winter rainfall environments and this led to the release of the more winter active varieties such as Sirocco in 1967 and Sirosa in 1974. With a long-term breeding program, many weaknesses in the species could be bred for improvement. One of these was seed shattering which led to lower seed yields. In 1982, the variety Uneta was released which contained a gene that decreased the amount of seed shattering. This gene is present in many of the latest varieties to help improve seed yields and decrease the cost of seeds to farmers.

In the 1970's, alkaloids were identified in phalaris that caused phalaris staggers in sheep. This led to the development of Sirolan in 1976 and the more well known Holdfast in 1991. There are two types of toxicity in phalaris, those being phalaris staggers and sudden death. Phalaris staggers, can be decreased with selection for lower tryptamine alkaloids in plants. Sudden death is rarer than staggers, however, the causal agents for this are unknown.

Another trait selected for, in the breeding program, was grazing tolerance in the more winter active, upright varieties. This unique breeding method not only led to the creation of the grazing-tolerant Holdfast GT in 2008 but it still maintained high forage yields, a characteristic not usually seen in grazing-tolerant breeding programs.

At the same time Holdfast GT was released, Advanced AT was also released. This was a variety that was bred by crossing *Phalaris aquatica* with *Phalaris arundinacea*, a more summer-active and acid-tolerant species. This helped improve the acid soil tolerance of this *Phalaris aquatica* variety.

With the onset of climate change, phalaris has an important future in Australia. Future breeding will see the development of F1 hybrids in phalaris and the use of phalaris in other pasture industries such as dairy, where the persistence of perennial ryegrass is being decreased due to drier summers linked to climate change. However, in extreme drought, even phalaris has struggled to persist.

Cocksfoot

When it comes to drought tolerance, cocksfoot is the most persistent of the temperate perennial grasses. However, there is a diverse range of cocksfoot varieties that are currently available in the Australian marketplace, from those that are active in summer to those that are completely summer dormant. Therefore, not all cocksfoot varieties are drought tolerant. The Hispanica subspecies can go dormant in the summer and actively begin to grow again when the cooler temperatures of autumn occur. Even within the Hispanica types, there are different levels of summer dormancy, so the selection of the correct cocksfoot variety requires knowledge.

Currie was the first cocksfoot variety to be bred and released in Australia in 1958 after extensive seed collection in the Mediterranean region in 1937. Kasbah was bred and released in Australia in 1960 and is still known as the most persistent perennial grass species in Australia due to its high level of summer dormancy.

For a more summer-active variety of cocksfoot, Porto was bred and released in Tasmania in 1972 from a seed collection done in Portugal in 1954. It is still one of the most productive varieties of cocksfoot in Australia today. For a higher level of summer growth, the 1980's saw a release of NZ-bred varieties of cocksfoots such as Wana and Kara. There has not been much breeding done on cocksfoot due to the low sowing rates of the species, but this may change in the future with the need for more summer dormant varieties for drought regions where phalaris cannot persist.

Tall fescue

Tall fescue has been identified as an alternative to perennial ryegrass in locations where poor persistence occurs due to drier summers. There are two separate groups of tall fescues, the most common one being the summer active or continental type and the second group being the winter active or Mediterranean type. The main difference between the two groups is their growth pattern. The continental types grow mainly over the spring/summer/autumn period, and the Mediterranean types grow mainly over the autumn/winter/spring period. The Mediterranean types also can go summer dormant, although this is not a complete summer dormancy, so rain in the summer can activate them to grow again. Due to their alternative growth patterns, these different species are suited to different annual average rainfall environments. Continental types are suited to areas where summer moisture is dominant and the annual rainfall is 600mm. The Mediterranean types are suited to annual rainfall amounts of 400mm and areas that experience dry summers due to their summer dormancy.

Demeter was the first continental tall fescue bred in Australia and was released in the 1930s. The first Mediterranean tall fescue bred in Australia was Melik in 1971 from an Israel collection. A new generation of softer-leaved continental tall fescue varieties began in 1994 with the release of Advance from NZ. Following this was the development of

novel endophytes in tall fescue in 2003 with the release of Max P. What makes this endophyte different from the one in perennial ryegrass is that one of the chemicals it produces, loline, is translocated into the roots, giving possible protection against some root-feeding insects.

The future of Mediterranean tall fescue may be in partnership with phalaris as a safe species to graze in the autumn while phalaris toxicity may be an issue with a false autumn break. Tall fescue endophyte may also be important as more festulolium (ryegrass x fescue) is being created that can be inoculated with the fescue endophyte.

Sub clover

Sub clover would arguably be the most important pasture legume in Australia's history due to the way that it has changed cropping rotations and how it is adapted to our dry summers but can still be grazed at flowering and can reseed.

The first sub clovers were identified in Australia in 1887 and most likely indirectly introduced through hay. The first released variety of sub clover in Australia was the *subterraneum* subspecies, Mt Barker, in South Australia in 1907. With a greater demand for sub clovers that could tolerate waterlogged soils, there was the first release of a *yannicum* subspecies, Yarloop in Western Australia in 1947. Later, a higher-yielding subspecies of sub clover called *brachycalycinum* was identified and the cultivar, Clare, was released in 1949. Around this time in the 1940's, the first high estrogen sub clovers were identified (Dwalganup, Geraldton, Dinninup, Yarloop, Tallarook) and this led to the selection of low estrogen levels in all the later bred varieties. In the 1960's the disease clover scorch became a major issue in Australia and later varieties are selected for tolerance to this disease. One of the latest advancements in sub clover breeding in 2009 was the selection of redlegged earth mite tolerant varieties (Bindoon, Narrikup, and Rosabrook).

In selecting a sub clover variety, it is important to look at the subspecies that match the environment and grazing management, allowing the selection of the right flowering date that matches the annual rainfall. Hard seededness will become a more important trait in the future due to the increased variability that we are experiencing with autumn.

Lucerne

Lucerne trialling first occurred in Australia in the 1930's with CSIRO. Hunter River was the predominant lucerne variety sold in Australia up until the 1970's. This is a winter dormant type (5). In 1968 there was the release of an alternative creeping lucerne variety, "Cancreep" from CSIRO with a winter activity of 2-3. It was not until 1977 that there was an increase in aphid numbers in Australia that wiped out more than 60% of lucerne stands in Australia. This saw a major effort in breeding within lucerne. Combined with selection for increased resistance to insects and diseases there was an emphasis on winter activity. In the early 1980's Siriver was released with a winter activity of 9. One of the most popular varieties sold today is Aurora, released in 1983, with a winter activity of 6. Today, lucerne breeding programs in Australia focus on new traits such as tolerance to grazing, increased tolerance to acid soils, and tolerance to waterlogging with branch-rooted types. The main trait to consider when selecting a lucerne variety is its winter activity. Winter dormant types (3-6) are more suited to hay or grazing and will persist for more than 10 years. Winter active types (7-11) are suited to cropping rotations and rotational grazing and usually last around 5 years. It is critical not to rely on legumes to produce much dry matter (DM) yield over winter. Even highly winter-active types only produce around 30% of their annual DM yield over winter. Grasses can tolerate colder soil temperatures than legumes and will grow more in the winter than a legume because of this.

White clover

Up until the 1920s in Australia, the introduced varieties were predominantly Dutch and English white clover. Farmers were looking for a more winter-active white clover which led to the introduction of Ladino white clover from the USA in 1925 and NZ white clover (Huia) in 1930. It wasn't until 1936 that the local ecotype, Irrigation with a medium leaf size was selected and released in Australia. Haifa was released in 1971 after a collection in Israel in 1951 and is now the most widely used white clover in Australia. Future work must focus on drought tolerance and persistence in Australia, and this may come from hybrids with other species, e.g. *uniflorum* and *ambiguum*. When selecting a white clover variety, the larger the leaf the shorter the stolons that are formed but the higher the DM yield. It is also important to know that the tap root of white clover dies after 18 months and then the plant must survive from the roots formed from the stolons, so the more stolons, the better the chance of survival in a dry summer environment.

Strawberry clover

Strawberry clover was identified in Australia before 1900. The first successful cultivar, Palestine, was released in 1929 from seed collected in Israel. It is known for its improved drought tolerance over white clover, its higher level of salinity tolerance, and tolerance to waterlogging. There has been no cultivar released since Palestine but there are opportunities to produce more active winter lines for a grass seed mix.

Annual legumes

There are many different species of annual legumes to choose from. These are just a few that have been bred specifically for Australian farmers. In the mid 1980's, the first releases in this era were cv. Paradana balansa clover and cv. Persian kyambro clover (*T. resupinatum var. resupinatum*) for acid and neutral-alkaline waterlogged soils, respectively.

Biserrula cvv. Casbah and Mauro (2010), are a more hard-seeded, deeper rooted, and more persistent pasture legume than subterranean clover for ley farming systems in acid soils.

Gland clover (*T. glanduliferum Boiss*) (2002) cv. Prima, is an easy-to-harvest aerial seeding species resistant to red-legged earth mites and aphids. Its released to address the issue of soil erosion caused by the harvest of sub clover seed.

Eastern star clover (*T. dasyurum C. Presl*) (2007) cv. Agwest® Sothis was selected as an erect, aerial-seeding fodder legume for low tomedium rainfall areas. With delayed germination, it allows for the control of crop weeds following the break of the season by non-selective herbicides or cultivation before its germination.

Bladder clover (*T. spumosum L.*) (2012) cv. Agwest® Bartolo is a semi-erect, aerial-seeding alternative to subterranean clover that is able to set seed on hard-setting soils, where subterranean clover is unable to bury its burrs.

French serradella was bred as an alternative species to yellow serradella for deep, acidic, sandy soils with much greater ease of seed harvesting and processing, cvv. Cadiz, Margarita, Erica, and Eliza (2009).

Crimson clover is an erect, aerial-seeding legume suited to grazing and fodder production in short-term phase pastures—cvv. Caprera and Blaza (1998).

Arrowleaf clover is an aerial-seeding erect, deep-rooted legume that is suited to grazing and feeding production with late flowering for longer growth in the season: cvv. Arrotas and Cefalu (2012).

Berseem clover is a fodder legume suited to fertile, medium to heavy textured soils of mildly acidic to neutral pH cvv. Elite II and Memphis (2012).

Messina (*Melilotus siculus*), is a new annual pasture legume bred for saline soils prone to winter waterlogging.

When choosing an annual legume, match the traits of the variety with the system. The grass companion species in a mix with annual legumes should have similar emergence vigour, therefore, displaying compatibility.

Tropical forages

When you think of southern temperate pastures, tropical forages are not a species group that comes to mind. With the onset of climate change, there will be an increased opportunity to use tropical forages to manage a variable climate. A prime example of this was in the 2007 drought where kikuyu was the only species to survive at Hamilton in the sacrifice paddocks. Some grasses that have opportunities in southern Australia include Rhodes grass (*Chloris gayana*) that was introduced into Australia in 1901, green panic (*Panicum maximum*) that was first grown in Australia in 1930 and Kikuyu (*Cenchrus clandestinus*), introduced into Australia in the early twentieth century, becoming naturalised in Victoria in the 1940s. The holy grail in tropical breeding is to find a tropical legume that can compete with grasses, but this has been elusive to date.

Conclusion

Australia is the leader in the development of temperate pasture species for a Mediterranean environment. The foundations of this work should be attributed to the many people in the 1900s who had the vision to do seed collections overseas. These collections are close to the centre of origin for these species and allowed the material to be brought back to Australia to eventually breed the first of our pasture varieties. Modern techniques such as molecular breeding can build on these foundations to create varieties more rapidly adapted to our environment. However, breeding is just one piece of the puzzle. Agronomic practices such as grazing have just as much influence over the production and persistence of our pastures.

The clear message is that research and breeding of pastures in Australia must continue if we are to create the next generation of temperate and tropical pasture species that are adapted to a variable environment.