Improving the adaptation of perennial ryegrass, tall fescue, phalaris, and cocksfoot for Australia

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Abstract The main perennial pasture grasses sown in Australia are perennial ryegrass (Lolium perenne L.), phalaris (Phalaris aquatica L.), tall fescue (Festuca arundinacea L.), and cocksfoot (Dactylis glomerata L.). The area of adaptation, and the longevity and yield of these species are likely to improve considerably over the next decade as a result of the activities within the Australian Grass Improvement Program. Recent use of summer-dormant cultivars of phalaris has proved successful and novel summer-dormant cultivars of perennial ryegrass and tall fescue will soon be released to commerce. Of these four naturalised species, all but tall fescue have been commonly sown by farmers in Australia for 60–130 years. However, only phalaris has been subjected to detailed and sustained research. Breeders have provided a range of phalaris cultivars for early to late-season environments with improved seedling vigour, winter growth, and reduced anti-quality factors. They have also addressed edaphic limitations. Programmes are now in place to improve the other species. This review outlines the aspects of that work directed at improved adaptation to the Australian environment. A limited range of genetic resources has entered evaluation—for all four species. For perennial ryegrass, the collection of local ecotypes is well advanced. Breeding is in progress for all except cocksfoot, and is coordinated within national programmes characterised by nationwide progeny tests, and strategic support research. Significant efforts are being taken—particularly with perennial ryegrass—to strengthen new cultivars via selection for resistance to common pathogens. Progress in the development of biotechnological procedures is expected to facilitate further improvements to the adaptation of perennial grasses to adverse climates.

Keywords cultivars; perennial grasses; pasture; Mediterranean region; North Africa; ecotypes; drought tolerance; endophyte; winter growth; seedling vigour; summer dormancy; acid soils; aluminium; water-logging

INTRODUCTION
The main perennial pasture grasses sown in Australia are perennial ryegrass, phalaris, tall fescue, and cocksfoot. The climates vary greatly across the regions where each species has been used, but up until 20 years ago each species was virtually dependant on one cultivar—cv. Victorian perennial ryegrass, cv. Demeter tall fescue, cv. Australian phalaris, and cv. Currie cocksfoot. As recently as 10 years ago, the use of three of these grasses by farmers was predominantly with these original, generally adapted cultivars (Table 1).

The Australian cultivars have been described by Oram (1990). Up until the mid 1980s, the other cultivars which were used significantly included cv. Kangaroo Valley and cv. Tasdale perennial ryegrass, and cv. Australian phalaris—all Australian ecotypes. Cv. Seedmaster phalaris and cv. Porto cocksfoot were also used. It is clear that farmers’ assessment of the species’ usefulness must be limited by the narrow genetic base with which they have been supplied.

More recently the old cultivars of perennial ryegrass have been partly displaced in the market by seed of a range of proprietary cultivars, mainly imported. As at 1993/94, net imports were approximately 3000 t and the production of seed of
old cultivars was 1400 t (Australian Bureau of Statistics data summarised by Reed et al. 1995). The production of seed of proprietary cultivars is not reported.

Merit-testing of experimental varieties is now organised within a national protocol directed by a broadly based Australian Pasture Plant Evaluation Committee (APPEC Inc.) under the auspices of the Australian Grass Improvement Program.

Over the decades, seed of many alternative grasses such as *Phleum*, *Poa*, *Cynosurus*, *Anthoxanthum*, *Holcus*, *Secale*, and *Alopecurus* have been sown by farmers for pasture but are no longer used for that purpose. Several of these remain as common naturalised species in pasture. *Thinopyron* and *Bromus* continue to be cultivated while several other genera remain under evaluation.

Apart from their adaptability, part of the popularity of the main four introduced perennial grasses would appear to be their deep root system, relative to annuals (Garwood & Sinclair 1979) which helps to prolong the period of active growth by utilising subsoil moisture (e.g., Donald 1970), their herbage and seed yield potentials, their nutritive value, and ease of establishment.

Historic and recent developments in the management and improvement of the four main grasses, and some minor species, for Australasia, were comprehensively summarised for an Australian Grass Improvement Program workshop held at Hamilton, Victoria in 1993; the 20 papers—an important complement to this workshop—were published in a sequence commencing with Pearson (1994). They dealt with the breeding objectives, plant pathology, endophyte, nutritive value, and biotechnology support research and commercialisation of these species in Australasia. This paper attempts to outline the situations where the four grasses are grown and the developments which may expand the area of their adaptation.

### COMPLEMENTARY USE OF GRASS SPECIES

Before attempting to discuss the perennial grass species individually, it is appropriate to consider complementarity between species. Most Australian dairy farmers operate in heavily fertilised, high-rainfall areas with good drainage and rely almost exclusively on perennial ryegrass. Elsewhere there remain opportunities to match the most suitable grass to different parts of the farm, thereby not only recognising the soil’s suitability to hold various species, but also making best use of different soil types to extend the period over which quality pasture is available to livestock.

Tall fescue is commonly used where waterlogging is severe (G. N. Ward, Agriculture Victoria, Warrnambool, pers. comm.). Similarly phalaris should be considered, especially by wool growers wanting to raise rates of stocking and to increase the proportion of pasture growth that is utilised. On heavily stocked pastures, when a year of poor rainfall is encountered, the phalaris paddocks are an invaluable buffer and reduce the area of pasture that might need resowing (Reed 1974). There are opportunities for phalaris on the early-finishing, drier crest sites. There, unlike the situation with phalaris, the yield of perennial ryegrass declines relative to that recorded from the low-lying, later-finishing flats (Reed & Flinn 1993).

In a similar vein, there is a case for complementary use of early- and late-flowering cultivars of a grass in well-planned systems where contrasting growth patterns can be exploited, either in separate sowings (Neal-Smith & Wright 1969; Reed et al. 1980; Rodgers & Bailey 1981; Lowe et al. 1983), or in blends, in order to maintain high-quality pasture over time.

Grazing management also has a major influence on extending quality (Michel & Fulkerson 1985)

### Table 1 Species usage in Australia was dominated by one cultivar: Seed production and international trade for the main perennial grasses, 1983/84 (t).

<table>
<thead>
<tr>
<th>Perennial grass species</th>
<th>No. of cultivars cert’d</th>
<th>Main cultivar &amp; its % of the seed certified</th>
<th>Certified seed production</th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial ryegrass</td>
<td>5</td>
<td>Victorian, 95%</td>
<td>2998</td>
<td>66</td>
<td>1958</td>
</tr>
<tr>
<td>Tall fescue</td>
<td>1</td>
<td>Demeter, 100%</td>
<td>571</td>
<td>82</td>
<td>42</td>
</tr>
<tr>
<td>Phalaris</td>
<td>6</td>
<td>Sirosa, 69%</td>
<td>384</td>
<td>351</td>
<td>0</td>
</tr>
<tr>
<td>Cocksfoot</td>
<td>2</td>
<td>Currie, 68%</td>
<td>824</td>
<td>142</td>
<td>42</td>
</tr>
</tbody>
</table>
and needs planning in the context of complementarity. For example, if pasture quality is considered as the end of the season approaches, phalaris pasture should be utilised first; the quality of perennial ryegrass declines more slowly (Reed & Flinn 1993).

PERENNIAL RYEGRASS

Most agronomists prefer a growing season of greater than 8 months and/or an average annual rainfall of greater than 650 mm in order to maintain perennial ryegrass in southern Australia (e.g., Anon. 1995). Perennial ryegrass and tall fescue are often observed to be sensitive to low soil fertility—more often than is the situation with the other two species. The dairy farmer purchases most of the ryegrass seed but it remains an important option for meat and wool producers in the less than 650 mm rainfall zone where soil fertility and grazing management are critical for achieving longevity.

Perennial ryegrass is used commercially in Australia from Queensland to southern Tasmania—latitudes 21°44'S. The species is popular with farmers because it is well known and understood, and has a satisfactory feeding value. Beyond its long-term persistence zone it is therefore used virtually as an annual. This use occurs under irrigation in subtropical Australia (e.g., Lowe et al. 1996), and without irrigation in the central highlands of Victoria in localities with average annual rainfall as low as 470 mm. Seed cost and ease of establishment are major factors underlying the popularity of perennial ryegrass. It is popular in hot regions despite the fact that for persistence, tall fescue is more useful (Lowe et al. 1996).

Persistence, and the narrower issues of drought tolerance/drought avoidance are complex issues. Physiological studies remain a pressing need in order to improve our understanding of the relevant mechanisms. However, for the present, selection and testing in target environments with realistic management remain the most practical means of developing cultivars which can expand the area of adaptation.

In 1969 it was considered that the perennial ryegrass boundary was the 760 mm average annual rainfall isohyet—from Beerwah, Queensland, south around the coastal districts to the lower south east of South Australia and virtually all Tasmania (Moore 1969). In the more temperate states, Victoria and Tasmania, Moore extended the area out to about 700 mm. At the time he was writing, cv. Victorian was the major cultivar used throughout Australia. European and New Zealand varieties had been assessed in Victoria and subsequently discarded in the 1930s. New Zealand and USA (Oregon) cultivars were imported after the drought of 1967; these were also discarded afterwards—because of their failure to persist.

The utilisation of North African germplasm for improving drought tolerance (by avoidance) through summer dormancy must be considered potentially valuable. Although a range of intraspecific adaptive variation has been long recognised within the Mediterranean grasses (Hartley & Williams 1956), the North African types of summer-dormant perennial ryegrass have not yet developed into a commercial reality. Silsbury (1961) released an Algerian accession, cv. Medea. It was not maintained and was poorly promoted. Reed et al. (1980) recorded the increased cool-season yield of this type of ryegrass. Valley Seeds Pty Ltd subsequently crossed Medea with cv. Victorian and released cv. Brumby which has proved useful in regions with a pronounced Mediterranean climate (Table 2).

Research on the grass endophyte association is improving our understanding of moisture utilisation and may lead to improvements in the drought tolerance of perennial ryegrass and tall fescue (van Heeswijck & McDonald, 1992; Hume et al. 1993). Commercial cultivars of perennial ryegrass containing endophyte have exhibited satisfactory persistence relative to Algerian accessions free of endophyte (Reed et al. 1987).

TALL FESCUE

Mainly limited to the 650–750 mm rainfall, tall fescue is also sown in wetter districts where its superior tolerance to poor drainage (Buckner 1985) is appreciated. In the northern tablelands of New South Wales, it is the most suitable perennial because half the annual rainfall falls in summer. Tall fescue is more tolerant of hot climates than cocksfoot (Hoveland et al. 1970) and perennial ryegrass (Lowe & Bowdler 1995).

Robson (1967) found that North African tall fescue grew better at low temperatures than European cultivars because of its ability to make more photosynthate per unit area of leaf. Field trials sown at Canberra and Armidale (Neal-Smith & Wright 1969), in Western Australia (Rodgers &
Beresford 1970), Canberra (Schiller & Lazenby 1975), and Hamilton (Reed 1985) have clearly demonstrated that the autumn and winter yields of tall fescue can be greatly improved using Mediterranean ecotypes. Not having to withstand harsh winter conditions, such types often partition more photosynthate to the foliage (Robson & Jewiss 1968; Blacklow & McGuire 1971). In addition to making greater growth in winter, the herbage of such types may contain as much as 23% more soluble carbohydrate, particularly fructans (fructosans), than that in the commercial winter-dormant type of cultivar such as Alta (Blacklow & McGuire 1971). The evolution of fructan-rich grasses appears to have been favoured by dry environments (Hendry 1993).

The summer-dormant Mediterranean ecotypes however, often have low spring—summer growth. Early attempts to develop Mediterranean ecotypes (e.g., cv. Epic) emphasised their cool-season growth but did not emphasise their role in the marginal environment. Low seed yield reduced their value (P. Patten pers. comm.). Seed yield is a most important determinant for the sustained commercial success of any pasture cultivar.

As with perennial ryegrass, Mediterranean ecotypes of tall fescue are not currently available to the farmer; their eventual use in marginal environments typified by Balmoral in Victoria (550 mm rainfall) where soil moisture in summer is too low to permit growth, is expected to raise the reputation of the species (Table 2) and increase the area in which this species is currently considered suitable for profitable grazing.

Paired crossing of Mediterranean ecotypes with Northern European types has usually failed to produce fertile hybrids. Until success in this area is achieved, a current management trial at Hamilton suggests that farmers in mainstream fescue environments where some summer growth is experienced, may be able to increase the winter yield of fescue without forgoing late-season growth, by blending seed of the Mediterranean type with that of the existing commercial cultivars.

Tall fescue, whose summer activity makes it suitable to compete with the C4 grasses, has been more persistent and more productive (Lowe & Bowdler 1995), and at least as profitable as perennial ryegrass (resown annually) for milk production in south-eastern Queensland as determined in recent QDPI studies (Lowe et al. 1996).

**PHALARIS**

*Phalaris aquatica* is an outstanding species for drought tolerance (Axelsen & Morley 1968) and winter growth (Reed 1974). It can escape summer droughts of up to 5 months by surviving as underground axillary buds which maintain turgidity by drawing subsoil water from 1–2 m depths (McWilliam & Kramer 1968; Joffre et al. 1987 cited by Carlson et al. 1995).

As temperatures fall with the onset of autumn, phalaris quickly begins to grow, possibly by translocating carbohydrates from the basal tubers of the plant, with moisture drawn from the subsoil (Sankary et al. 1969). New and expanding leaves

| Table 2 Plant density and yield of dry matter (t/ha) of sown cultivars over 5 years at Balmoral, Victoria (P. Cunningham & M. Anderson, Agriculture Victoria, pers. comm.) |
|---|---|---|---|
| Species | Cultivar/ ecotype | Plant density 1991 (no./m²) | Plant density 1995 (no./m²) | Winter yield ('93+'94+'95) | 4-year cumul. yield |
| Perennial ryegrass | Mediterranean ecotype | 801 | 73 | 3.44 | 13.08 |
| Perennial ryegrass | Brumby | 753 | 31 | 3.42 | 14.05 |
| Perennial ryegrass | Flinders Island. ecotype | 701 | 20 | 2.98 | 13.40 |
| Perennial ryegrass | Kangaroo Valley | 486 | 16 | 3.64 | 12.03 |
| Perennial ryegrass | Ellett | 1,111 | 40 | 3.43 | 14.05 |
| Tall fescue | Mediterranean ecotype | 1,140 | 88 | 6.73 | 14.43 |
| Tall fescue | AU Triumph | 881 | 14 | 2.10 | 8.03 |
| Tall fescue | Demeter | 901 | 6 | 2.11 | 7.73 |
| Cocksfoot | Currie | 793 | 91 | 4.26 | 11.50 |
| Cocksfoot | Porto | 754 | 47 | 4.54 | 13.30 |
| Phalaris | Sirosa | 307 | 47 | 6.61 | 16.35 |
| Phalaris | Australian | 462 | 55 | 3.42 | 12.68 |
| LSD | $P = 0.05$ | | 16.6 | | 2.01 |
are high in fructosan, and are particularly palatable in winter-active accessions (Oram 1995).

With the commercialisation of winter-active types in the 1970s, CSIRO breeders have extended the area of adaptation of phalaris with cultivars Sirolan and Holdfast which flower 1–3 weeks earlier (Oram & Culvenor 1994). The capacity to demonstrate increased winter activity is greater in regions where radiation is greater than in, for example, Tasmania. Winter-active types and semi-dormant types have distinct growth habits; the winter-actives especially require rotational grazing in order to maximise yield and ensure persistence (Culvenor 1994). Cultivar Holdfast has further extended adaptation in that it has some tolerance to high exchangeable aluminium in soil; further selection work conducted on skeletal acid soil in northern Victoria may provide greater tolerance with the experimental variety “BP92” (Culvenor & Oram 1995).

Some quite early-flowering, highly winter-active types with summer-dormant buds such as ‘Perla’ (a United States cultivar—from a Moroccan accession) may expand the area of adaptation further into the wheat belt (Oram & Freebairn 1984). In the southern United States (Hoveland et al. 1970) and in Australia (Reed 1985), ‘Perla’ has demonstrated outstanding productivity in autumn–winter. CSIRO expect to release a highly winter-active cultivar, based on ‘Perla’, in 1998 (Oram & Culvenor 1994).

**COCKSFoot**

Mediterranean accessions of *D. glomerata*, although only released in the 1960s, (cv. Currie, ex Algeria) and 1980s (cv. Porto, ex Portugal), have taken most of the market in Australia. Previously, winter-dormant North European material was popular. The newer cultivars expanded considerably the area within which cocksfoot can be relied on to persist. Currie is approved for use in Victoria in districts with as low as 425 mm annual rainfall (Anon. 1995). Cocksfoot is often persistent on light-textured, low-moisture-holding hillsides. It is the most tolerant of the four species to high levels of aluminium in soil and so may be suited to some strongly acid environments (Scott & Fisher, 1989).

Cocksfoot has a noticeably lower feeding value for meat and milk production compared with perennial ryegrass (Milford & Minson 1966; Greenhalgh & Reid 1969). Thus although a common volunteer in high-rainfall districts such as West Gippsland in Victoria, its inclusion in seed mixtures in such areas—once favoured because of its late green “pick”—has decreased somewhat as later types of perennial ryegrass have been released and greater emphasis has been given to white clover (L. J. Hamilton pers. comm.).

As with Demeter tall fescue, the common cultivars of cocksfoot of Mediterranean origin (Currie & Porto) have proved highly adapted across widespread regions of Australia.

**FUTURE DIRECTIONS**

Pure North African selections and newer hybridisation projects now exist within the recently established National Perennial Ryegrass Improvement Program, and in addition, our collection of North African germplasm was considerably augmented by the collection from Tunisia (Chakroun et al. 1995), Morocco, and Sardinia undertaken by P. Cunningham, Agriculture Victoria, and W. Graves (USDA) in 1994. First-year characterisation information suggests that the North African accessions will expand the area for which the persistence of perennial ryegrass can be relied on (L. Song & M. Anderson pers. comm.). The same expedition also provided 92 populations of perennial grasses, including 20 of *P. aquatica* and 22 of *D. glomerata*, from Sardinia (P. J. Cunningham pers. comm.). As the first thorough collection of such material carried out on acid soils in the Mediterranean region, this now provides a genetic resource to improve tolerance to acid soil.

Seedling vigour and palatability are important selection criteria in current improvement work on tall fescue. Plant diseases lower the persistence, yield, and quality of grasses (Clark & Eagling 1994), but the impact of disease on tall fescue and cocksfoot has not been assessed in Australia. Plans have been laid to assess the crop loss and improve tall fescue by overcoming the limitations imposed by disease. Field tolerance of the Mediterranean ecotypes to crown rust compares most favourably with commercial cultivars (Snell et al. 1991). Villata & Clark (1995) have confirmed this difference in a detailed study under controlled conditions.

*Festuca-Lolium* hybridisation technology is continuing to develop (Spangenberg et al. 1994) and may extend the usefulness of these genera. The introduction of new linkage blocks in such intergeneric hybridisation offers potential to select
new genotypes which would respond more favourably to environmental stress. More recently, the role of genetic markers (or DNA probes) to locate these gene complexes, particularly the quantitative trait loci (QTL), has been reported in a number of plant species (Stuber 1989) and was also reported in perennial ryegrass (Hayward et al. 1994). With the availability of Polymerase Chain Reaction (PCR) technology, this procedure has been made easier so that more characters that relate to adaptation can be traced through the QTL. Fructan accumulation appears to be important for developing tolerance to adverse climate (Pontis 1989). Modification of fructan metabolism in transgenic plants will provide evidence of fructan’s role in the drought tolerance needed in future cultivars. Pilon-Smits et al. (1995) have made a case with tobacco.

In southern Australia, apart from areas below 450–500 mm average annual rainfall, or with extreme conditions such as deep sand, swamp, or low soil fertility, the main four introduced perennials for which we can access such a diverse genetic resource appear able to provide the base for a long-lasting pasture. It is appropriate to continue to evaluate other species of grass for use in Australian systems which are attempting to depasture the exotic cloven-hooved animals our present grazing industries depend on. In such studies it is imperative that we include the more novel types of perennial ryegrass, tall fescue, phalaris, and cocksfoot now becoming available.

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