New discoveries in pasture research: current status & developments with temperate perennial pastures and shrubs in southern Australia

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Why bother with perennials? This question has often been asked in semi-arid regions such as Western Australia where pastures based on annual legume species have been so successful. This success has sometimes been taken to mean that perennials have no place. However perennial species have been, and still are, of major importance to grazing animals across Australia. When Europeans first arrived species such as Themeda australis dominated large areas and native perennials continue to do so, particularly in eastern Australia (45).

Perennial species, on theoretical grounds, offer advantages over annual species for many environments. Perennials can provide forage outside the main growing season which can be of better quality than dry fodder, lessen the variation in the forage supply, stabilise the botanical composition by limiting weed invasion, reduce the risk from soil erosion and transpire more water so helping to control the rise of water tables (43, 51, 69, 71). Total production from perennial pastures can also be greater, often double, in areas of favourable summer rainfall. The main deficiencies of perennial species are often the greater difficulties and cost in establishment, their variable persistence with common systems of grazing management and their difficult integration with cropping.

New developments with perennial pasture species are, unfortunately, few and far between, as is general for agricultural research, due to restricted funding. Despite this, some work is proceeding that offers promise. The first part of this paper reviews the major constraints on perennial species and how programs aim to overcome or lessen these constraints. Emphasis is on the current status of knowledge as much as any new directions. The second part considers limitations and improvements being made in native pastures, shrubs and the major temperate species currently in use. The geographical scope of the paper will be restricted to that part of southern Australia which receives a higher proportion of its annual effective rainfall in winter than in summer.

Potential production and constraints

What chance is there for improvement? Potential production from perennial species is limited in Australia by the major constraints of rainfall and temperature. In southern Australia low rainfall is mainly a problem in summer, while low temperatures, and possibly light, are the main constraints in winter. The constraints of water shortages in summer are exacerbated by the associated high temperatures. It is difficult to completely overcome these climatic constraints and to do so would probably require plants with a remarkably different physiology to those we currently use. Comparisons of a range of introduced species often show that they all have a similar potential for annual production (31, 63, 65), emphasising a common, underlying, physiology. Pasture research currently aims more to optimise production within the climate than to develop radically new strategies or to try and maintain as uniform a supply of forage during the year as is practical. This can be done by improving plant growth and, or survival during dry and, or cold seasons. Some alternative approaches are also being developed as shown by the use of the fodder shrub, Tagasaste, sown in the deep infertile sandy soils of Western Australia.

Differences between species do exist and can be exploited. These differences in responses to drought or temperature and in competitive ability against other species are often largely seen in the seasonal distribution of forage production. To fully utilise such differences it is necessary to maintain a high proportion of desirable species in the pasture. The botanical composition of a pasture depends partly on the competitive ability of each species and partly upon the management, including grazing management, of that pasture. Differences in animal production between pastures, within a region, are often due to differences in the seasonal supply of forage which can arise as much from changes in botanical composition as from species differences per se. These points will be expanded below.

Drought tolerance

Perennial species need some mechanism to allow them to survive the driest periods of the year, unlike annuals which can escape those seasons. In practice this usually means that perennial pasture plants need to survive the average dry season, while shrubs have to cope with the driest years. There has been considerable interest for many years in improving the drought tolerance of pasture species and this aim is continuing.

The first big advance in this direction was the use of phalaris which extended considerably the area sown to perennial grasses. Haifa white clover made some smaller gains for legumes, while lucerne has been of major importance in the drier areas. However perennial pasture species are still largely confined to regions where the annual rainfall exceeds 500-600 mm (400 mm for lucerne) in eastern Australia or the growing season is 8 months, or longer, in Western Australia (6). Even within those regions the productivity of a perennial based pasture is often no better than one based predominantly or exclusively on annual species. To further improve the dry season performance of pasture species selection programs for phalaris, perennial ryegrass and white clover continue to place emphasis upon drought tolerance.

The mechanisms whereby plants adjust to water stress have received close attention for many years (26, 27). However for the improvement of plant growth during dry seasons agronomic criteria, rather than physiological, are more useful. A recent comparison of the water relations of phalaris and perennial ryegrass, done in the field and controlled environments

(44), has shown few physiological differences between the two species. In fact, on criteria such as osmotic adjustment, phalaris appears to be less drought tolerant than published data for wheat (46). Phalaris achieves a greater degree of drought tolerance than perennial ryegrass by being a larger plant, where dry sheaths help to protect the leaf and tiller buds, by having a deep root system, and having buds that go dormant at high temperatures (5, 40, 58). Dormant buds provide a mechanism for drought escape. Phalaris, though, requires some water in the root zone to survive (39), and this limits its distribution to moderate rainfall environments. There is still a need to seek perennial, temperate, pasture grasses which can persist and be productive in the semi-arid cropping zone. This is especially so in eastern Australia where topography limits cropping, or where a longer term more stable pasture phase is required. None of the temperate pastures species currently in use seem able to survive dry seasons where the root zone is completely dry. Native species may be able to do this and if so could extend the range where perennial species are sown.

The importance of deep root systems for drought tolerance is clearly seen in the case of lucerne. Studies on the leaf water relations of lucerne (2) indicate that it has no great advantages over many other species, yet it can persists in a 400 mm rainfall environment. Lucerne has deeper roots than phalaris, and this is probably the main reason why it will grow in drier regions than will phalaris, though it is doubtful if lucerne, like phalaris, would survive if there was no water in the root zone. Lucerne is also able to readily shed leaves under water stress. The white clover improvement program at Glen Innes is studying the advantages of a tap and, or deeper root system for that species as a means of increasing its performance in what are currently marginal environments. Caucasian clover is more drought tolerant than white clover and it is considered that again this is due to a deeper root system. One of the obvious attributes of shrubs and fodder tress is their deeper root systems.

The improvement of plant growth during dry seasons has often been studied from the point of view of growth and water relations on dry soils, but to date this has not lead to any marked gains. With the benefits of hindsight this is probably realistic, as plants need a considerable amount of water to maintain cell turgor and to keep stomates open so that photosynthesis can proceed. To expect plants to grow when there isn't sufficient water to maintain normal cell function is unrealistic. Recent research (49) has suggested that in any case the performance of leaves, under dry conditions, is being regulated by root activity and not by the water relations of leaves. In this context the relevance of 'osmotic adjustment' is now being questioned as there is doubt if it is an active mechanism (48). Osmotic adjustment may only be a passive mechanism in many cases arising as a consequence of a reduction in growth. Research with perennial ryegrass has suggested that differences between genotypes in leaf water relations are of little use for the improvement of growth in dry seasons while regrowth after drought is (19, 53, 54, 55). The Victorian program to improve the drought tolerance of perennial ryegrass is based on using genotypes selected from dry climates, and those plants still growing after the last major drought.

Perennial species can also take some advantage from drought avoidance mechanisms that allow them to persist in drier climates than might be expected. Early flowering perennial ryegrass cultivars, e.g. cv. Kangaroo Valley, are able to persist in lower rainfall environments than other longer season cultivars as they have completed the main part of their growing cycle before the dry season starts. Survival of such ecotypes over dry summers can be further enhanced by avoiding overgrazing. Perennial ryegrass will also re-establish from self-sown seed after a drought better than other perennial grasses (10). An ability to re-establish should improve the usefulness of perennial species, but few can do so satisfactorily. Often plant densities obtained are lower than desirable.

The improvement of dry season performance of perennial pastures is now being based upon selecting plants that have agronomic traits such as deep roots, quick recovery from drought or persistence under grazing in dry climates. Progress will be slow because few resources are devoted to this work.

Winter production

Throughout much of Australia where perennial pastures are used growth rates are at a minimum in winter and this frequently sets the limit on stocking rates and animal production from those pastures. Recent research has aimed to identify the reasons why some grasses grow better in winter than others so that improved recommendations can be made and cultivars selected that are more productive in winter. Differences, in winter growth, between grass species and cultivars during winter are largely due to the timing of reproductive development (30). The earlier a plant initiates flowering, the greater is its growth rate over winter. Leaf growth is stimulated to twice normal rates (33), and this stimulus lasts until seed heads emerge. All grasses tested to date show this response. The temperature response curve for reproductive plants is much steeper than for vegetative plants. Use of this information can improve grass growth during winter and this is being done in the phalaris and perennial ryegrass improvement programmes. However this improved growth can be at the expense of nutritive value and animal performance if flowering coincides with lambing or calving.

The research outlined above has its major effect from mid-winter on. There is often still a gap in the forage supply from mid-autumn to mid-winter. The size of this gap depends upon the timing of opening rains. If these rains fall in autumn before temperatures are less than 10?C then good pasture growth results and early winter forage is available. However if the period of reliable rainfall does not start until temperatures are low, there is often a severe shortage of forage. Management may offer the best way to overcome this feed gap. Deferred grazing (73) is one option, though it has only been tested in annual pastures where benefits have been marginal, if at all (8). Another can be the strategic application of nitrogen fertiliser in autumn or even strategic irrigation, if a low cost irrigation method is available. Further research into management methods is needed to overcome this shortage of early winter feed.

Legume growth in winter is less than that from grasses when temperatures are less than 10?C. This is largely due to the relative inactivity of Rhizobia at those temperatures (20). Differences between species and cultivars exist, though, which allow the use of legumes to improve the forage supply in winter. Subterranean clover will grow better than white clover in winter. Winter-active lucernes are also available. Differences between legume cultivars in growth rates during winter may also relate to flowering patterns, but this has not been tested to date. Where winter temperatures exceed 10?C, legume growth in swards of moderate leaf area index may not be limited by temperatures (11, 29) but may be by the quantity of light received.

Grazing management

Grazing management is often considered, among Australian research personnel, a non-subject for all pastures with the exception of lucerne where it can't be ignored. This situation has arisen because of the many experiments done in the past in which no major effects were found.

However most of those experiments imposed a constant management scheme throughout the year, in contrast to the fact that plant growth is anything but constant. Also most of the experiments only lasted 3-4 years. After 3-4 years changes in botanical composition are just starting to occur which may subsequently have a large impact on animal production (4, 9 ,64).

Despite the anti-grazing management views, there is evidence that grazing management can be important. Continuous grazing of perennial pastures in winter can increase the proportion of annual grasses in the pasture (47) leading to less production per ha from perennial species over summer. Omitting grazing in autumn on the northern tablelands of N.S.W. significantly increased the proportion of white clover in the pasture (17). Heavy grazing during flowering can significantly reduce undesirable species and if combined with lax grazing at other times of the year the botanical composition of pastures can be shifted towards desirable components (36).

Variation between years in animal production has often depended upon the amount of green forage available over summer from perennial species (16, 34, 67, 76). Observations on pastures in central N.S.W. (32) also suggest that grazing management can be critical for botanical composition as annual grasses now dominate many pastures. Perennial species are a low proportion of the pasture and only dominate in ungrazed areas - this may indicate an incompatibility of many perennial pasture species with high continuous grazing pressures. There is a major need to learn more of how to manage our existing species and cultivars to maintain a desirable balance of species to optimise year round production. Research is in progress at several centres to better understand the effects of strategic grazing practices on pastures.

Weed control

Perennial pastures, especially the grasses, can reduce invasion by weeds (42, 51) and are frequently sown as an aid in weed control (43). The ingress of undesirable species into a pasture not only limits growth of desirable plants but can also cause other economic losses, through vegetable fault in wool and hides (74) and toxicities. The original Australian cultivar of phalaris has been of considerable benefit in suppressing weeds in higher fertility sites, often in combination with grazing strategies (41), and is still widely used for this purpose despite potential toxicity problems. The new cultivars of phalaris have not been as competitive and the current phalaris improvement program aims to seek cultivars that have more of the characteristics of the original Australian cultivar. Perennial ryegrass is only competitive against many weeds in areas of high rainfall and high fertility. The importance of weed control needs to be remembered when evaluating perennial pasture species. The best biological control of a weed is by an aggressive pasture and appropriate grazing management.

Current situation

Native pastures

Pastures dominated by native species still occur over large areas in eastern Australia and play a major part in grazing industries. In general native pastures are not as productive as improved pastures, and this may be largely due to the lack of legumes and low fertility (15). Areas that have been fertilised and to which legumes are added, can be highly productive (12). Such pastures are not strictly native, but they still can contain a significant proportion of productive native species. Native species often make their major contribution in out of season, e.g. summer, production. Native grasses however appear so susceptible to over grazing that in central N.S.W. they only form a minor part of improved pastures (32). However work on the Northern Tablelands of N.S.W. (35, 68) has shown that selections from high fertility heavily grazed sites, such as stock camps, can be as productive as introduced species and that these selections can be maintained in pastures. Programs have now begun to domesticate four perennial native grasses in N.S.W. (Danthonia linkii, Agropyron scabrum, Microlena stipoides, and Astrebla lappacea).

Mitchell grass (Astrebla lappacea) is a C_4 grass which is being domesticated to allow re-establishment of pastures after cropping in the marginal cropping areas around Walgett.

Fodder shrubs and trees

Most native trees and shrubs have relatively poor nutritional qualities and their regrowth rates after harvesting are slow (14). The value of such plants in livestock feeding programmes has been somewhat overrated. In contrast, introduced species such as tagasaste (Chamaecytisus palmensis) and leucaena (Leucaena leucocephala) may have a significant potential in suitable environments for producing large amounts of nutritious fodder (13). These species can make a significant contribution to the out of growing season fodder supply, particularly in problem environments.

There is a generally accepted relationship between effective rainfall and forage production of around 1 t of dry matter per ha per 100 mm of rainfall (75), but this is not normally achieved by annual pastures on the infertile deep sands of Western Australia. However tagasaste at 2,000 trees per ha, in rows 5 m apart, has increased the total production on such problem soils to the expected level (3.5 t from tagasaste and 1.5 t from annual species in the inter-row space for 500 mm of rain between May and October (72).

Tagasaste, established in deep infertile sands in south Western Australia has proved to be an economic addition to grazing systems (37). Direct grazing of tagasaste is used to replace grain feeding of sheep during the autumn feed gap, where tagasaste plus the dry inter-row pasture provides maintenance requirements. Also grazing tagasaste at joining can improve the reproductive performance of merino ewes (57), while grazing over summer can increase wool production (56).

There are some problems such as development of economic cutting machinery, occasional bark stripping and poor liveweight gain together with many management factors to be worked out with tagasaste. However, in Western Australia more than 10,000 ha of deep sands have been sown to tagasaste since 1986 and it seems this new strategy will be extensively tested in the next 5-10 years.

In addition to the strategic use of tagasaste for animal production in specific environments, perennial trees and shrubs have a role as shelter (animals, crops and soils) and in the control of recharge above potentially saline sites by acting as water pumps (21). The need for wind breaks is critical in many areas of Australia.

White clover

White clover (Trifolium repens) is probably the second most important legume in Australia after subterranean clover, but it has also been one of the most neglected in terms of research effort. In higher rainfall areas white clover can survive and be very productive (3), though as has been known for 50 years (28) proper grazing management is required to maintain it in the pasture. A reduction in summer rainfall over recent years in northern N.S.W. has also lead to a decline in the productivity of white clover (70). Current cultivars of white clover do have several deficiencies such as low seed set, poor drought tolerance, or poor grazing tolerance. A national program has now been started at Glen Innes in N.S.W. to select improved cultivars. The value of various traits, such as leaf and plant size, habit, root morphology, seed production, survival under grazing, will be examined in this program. The first releases from this program should be available for wide testing within a few years. Additional research into salt tolerance is being done in the Victorian irrigation areas.

Lucerne

Lucerne (Medicago sativa) is the one perennial pasture plant used in Australia for which there has been a large effort into both cultivar improvement and management. The lucerne breeding program was stimulated by the Introduction of aphids into Australia, though it emerged subsequently that in many areas resistance to fungal diseases had a bigger impact on yields than did aphid resistance. Another important development in this program has been the release of cultivars with a range of seasonal growth patterns to suit different climates. Cultivars such as Aurora now have a range of desirable traits to suit many needs and this has restored the place of lucerne as a major pasture species. A new development has been the program in Canberra to increase the sulphur protein content of leaves with the aim of increasing wool yields. It is understood at this stage that the level of protein being expressed is very low, but may reach economic levels with further development. Lucerne will also be among the first plants to have an expert system developed, which will encompass many aspects of cultivar selection and management. This system will aid the transmission of information to farmers and their advisers.

Other legumes

Red clover (Trifolium repens) is widely sown in pasture mixtures, though its persistence is often poor. Improvement of root and crown rot resistance of cv. Redquin is being investigated in N.S.W., but the release of a cultivar cannot be expected for some years (38).

Lotus (Lotus majo) is a species able to grow in low fertility and wet situations. The non-bloating trait of lotus is also of considerable interest. Limited research is being undertaken to improve the drought and frost tolerance of lotus.

Caucasian clover (Trifolium ambigum) is a deep rooted perennial legume that has a high tolerance of cold and drought. However it can take some years to establish, so limiting its prospects for pasture development. Caucasian clover will probably be used in areas where white clover fails, such as in areas of low rainfall and temperature. Seed of the cv. Monaro is now being produced in New Zealand.

Sainfoin (Onobrychis viciifolia) is a productive, non-bloating, drought tolerant legume which prefers well drained, alkaline soils. Management requirements are similar to those for lucerne. The S.A. cv. Othello is now available and has been tested in many parts of the country. Results to date suggest a more limited role for sainfoin than was originally envisaged. Sainfoin is susceptible to a range of diseases. In general lucerne is likely to be more productive.

Phalaris

A survey in central N.S.W. during spring 1988 (32), has shown that phalaris (Phalaris aquatica) is confined to the higher rainfall and more fertile soils, a pattern that often applies in other regions though the expectation is that phalaris has a wider role. Phalaris is often considered to be the most persistent of all temperate grasses commonly sown. However many advisers have questioned the ability of the newer cultivars to persist in regions where the original Australian cultivar still flourishes. New cultivars, eg. cv. Sirosa, seem to require more proctection from grazing when flowering in order to persist (23). Cv. Sirosa phalaris has died out in plots cut every 6 weeks over 4 years (31) whereas cv. Australian remained.

Phalaris is considered to be the most drought tolerant of the temperate grasses commonly sown (5, 60). However its limited distribution in dry areas of central N.S.W. and elsewhere suggests that its drought tolerance is not very great. This opinion is backed up by the data discussed previously under water relations. The programme of phalaris improvement fortunately continues, despite many attempts to kill it. The programme aims to select cultivars that have improvements in seed yield, winter activity, ease of establishment, ability to survive grazing under dry conditions together with a reduction in toxicity. Phalaris toxicity is now considered to be due to two conditions, a nervous and a cardiac disorder (7) and with current cultivars use of cobalt bullets can overcome most problems.

Perennial ryegrass

Perennial ryegrass (Lolium perenne) is the most widely sown grass in Australia. Its high nutritive value, ease of establishment and flexibility of use are reasons for its popularity. Perennial ryegrass cultivars, especially cv. Kangaroo Valley, are among the most productive of grasses in winter and can equal the forage yields of annual species (30) during that season.

A major deficiency of perennial ryegrass has been a poor drought tolerance, due in part to the small plant size and shallow roots of this species (44). In dry seasons plant mortality is high, allowing invasion of weeds as well as reducing productivity. Programs to improve drought tolerance continue to use ecotypes, such as UNE100, from around the mediterranean (66). However it is doubtful if perennial ryegrass will ever be as drought tolerant as Phalaris.

Diseases of perennial ryegrass such as crown rust can have a major effect on growth and acceptability to stock, especially in cv. Victorian. Fortunately sources of resistance are available among other commercial cultivars. Other diseases can effect ryegrass e.g. stem rust, net blotch, blind-seed and barley yellow dwarf, and efforts are being made to locate sources of resistance (65). However with many of these diseases the full extent of their effects are not known and this limits our ability to decide their importance.

Endophytes, fungii that live inside ryegrass and many other grasses, can have large implications for animal production. Endophytes can confer on the grass some resistance against pests, which aids establishment (65) and survival, and also stimulate growth (24), but they can cause staggers and increase lamb mortality (18) resulting in considerable losses in animal production. Arguments for and against endophytes in grasses are considerable and at this stage we need to defer final recommendations until we have more extensive information on the role of endophyte in Australian pastures.

Other grasses

Several other perennial grasses are used, notably cocksfoot (Dactylis glomerata) and tall fescue (Festuca arundinacea), but currently little work is done with their development. Cocksfoot is marginally less productive in growth and animal products than the other grasses, though it does persist better in some environments, such as light or acid soils, than even phalaris. Tall fescue is difficult to establish as seedling vigour is low, but once established it can be productive and persistent. Tall fescue will often survive droughts as well as phalaris. Many attempts have been made to produce hybrids from tall fescue and perennial ryegrass to combine the seedling vigour and high nutritive value of ryegrass with the persistence and yield of tall fescue, but none have been commercially successful. Breeders in other countries are combining ryegrass with a range of fescue species to see if that desirable plant can be achieved.

Several grass species are suited to specific soil types. Perennial veldtgrass (Ehrharta calycina), lovegrass (Eragrostis curvula), Tambookie grass (Hyparrhenia hirta), and Couch grass (Cynodon dactylon) are capable of growing on soils that are low in water and nutrient holding capacity (52). While their total production in relation to rainfall may be low they could be of use in controlling re-charge to groundwater supplies. Kikuyu (Pennisetum clandestinum) has become widely established in coastal areas. Selection has been used to develop varieties, such as cvv. Noonan and Crofts, that produce more seed and that are tolerant of diseases.

Concluding remarks

The aim of this review has been to examine the potential for forage production from perennial pastures and shrubs, concentrating upon new developments. As argued initially, the potential for production is set by the climate and most cultivars in use can produce similar yields given the right conditions. To improve pasture and animal production it is therefore necessary to be more subtle than simply seeking total yield increases. It is necessary to so modify production patterns with perennials that periods of normally low forage production can be improved or the variation in production between years can be reduced. Some advances have been made in understanding the basis of yield under dry and cold conditions and under the competitive environment of the typical mixed pastures. But our understanding of such processes is very limited and our predictive ability is much less than we would like. We certainly cannot approach our pastures with the understanding and refinements evident in New Zealand and British pastures (e.g. 22, 50, 59). Our ability to improve pasture productivity is further limited by the narrow economic margins per ha from livestock production. Future pasture improvement research should still emphasise legumes.

An increasing amount of interest is being directed towards the use of perennials as 'water pumps' to assist in the control of recharge to the groundwater. This is especially so in Western Australia (71), but is also relevant to the irrigation and dryland areas of eastern Australia (1). The replacement of the predominantly perennial native vegetation by annual species has contributed to rising water tables in many areas of southern Australia. A common consequence has been an increase in the level of salinity in the soil with deleterious effects on forage production. The greater potential water use per annum of perennial species (25) has contributed to renewed interest in their use.

Many of the pasture cultivars used are derived from overseas sources with only limited development in Australia. They are based on the most successful Introductions without any further refinements. Also often one cultivar is expected to suit a wide range of regions and management conditions. The only bred plants are phalaris and more recently lucerne. It is thus easy to appreciate why so many cultivars fail to satisfy our requirements. Considerable research needs to be done to properly develop cultivars that can fully exploit the wide range of environments and livestock systems in use in Australia. To do this we need publically funded research programs which could be reimbursed by royalties from seed sales as well as from traditional sources. Solid research into management coupled to plant improvement programs has always made progress of use to the farmer and there is no reason why it should not continue to do so for perennial pastures for many years to come.

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