Proc. Eleventh Ann. Conf. Grassld. Soc. NSW, 1966, pp. 28-33

NATIVE AND NATURALISED GRASSLANDS:

Development of native perennial grasses for grazing

W.H. (Bill) Johnston

N.S.W. Department of Land and Water Conservation, Wagga Wagga Research Centre, Wagga Wagga N.S.W. 2650.

Summary: This paper examines some of the ecological issues relating to the development of native perennial grasses for grazing. Grazing and pasture improvement cause wholesale changes in the botanical composition of native grasslands but the processes driving the changes are poorly understood. Changes in botanical composition result in a switch from summer to winter active species. This sets in motion a change in patterns of water use and nitrate demand which ultimately contributes to a number of land degradation problems. There is a pressing need to develop a wider range of resilient, summer active grasses to reverse land degradation trends, and it is argued that native grasses offer a number of adaptive advantages.

Over the past 10 to 15 years there has been an increasing level of interest and appreciation of the role of native grasses in grazed pastures in temperate areas of Australia. Contemporary research can be divided into three main themes:

- surveys of the status and composition of grasslands (*e.g.* Robinson and Dowling 1976; Munnich *et al.* 1991);
- changes in the botanical composition of mixed grasslands in response to grazing and pasture management, including the specific effects of sheep and cattle camps (*e.g.* Robinson and Dowling 1976; Lodge and Whalley 1985; Rogers and Whalley 1989); and
- domestication programs, which aim to develop viable cultivars of native perennial grasses for sowing in pastures (*e.g.* Lodge 1993; Johnston *et al.* 1995).

This paper outlines some of the ecological processes which occur in grazed pastures and considers their impact on the development of cultivars of native grasses for grazing purposes.

The status of native grasses in grazed pastures

Pasture surveys in southeastern Australia (Robinson and Dowling 1976; Kemp and Dowling 1991; Munnich *et al.* 1991; Benson 1994) have shown that native grasses are present over large areas; they make a considerable contribution to livestock production, even in high rainfall areas, and they occur widespread in sown pastures, especially as sown pastures degenerate. In the upper Murray area, Allan *et al.* (1995) found that introduced perennial grasses were most persistent on lower slopes, native perennial grasses were more prevalent on steeper slopes and hillsides while "degenerating" improved pasture occurred on low and medium slopes. A common observation in southern N.S.W. is that native cool season perennial grasses prefer shaded or protected aspects or situations (such as under trees), while warm season grasses prefer exposed sites and generally drier habitats. For some landscape classes, particularly hill lands, *in situ* native grasses offer the only viable option for continued livestock production and it is on these landscape classes that improved native perennial grasses will have their greatest application.

Land use statistics for N.S.W. show that throughout the Tablelands and near-slopes divisions the areas of sown pastures rarely exceed areas of unsown pastures except in the vicinity of major population centres such as Bathurst-Orange, Queanbeyan and Albury (Table 1). Further west, where the landscape is more suited to cultivation, the proportion of unsown pasture declines and the area of annual cropping in rotation with annual legumes and volunteer exotic annual grasses increases. For instance in the Corowa, Culcairn, Lockhart, Coolamon, and Temora Shires cropping and sown pasture combined account for 69.9, 81.6, 79.6, 75.8 and 76.8% of the total agricultural area of the shires. It is unlikely in these areas that perennial grasses will be widely sown except on retired land not suited to continued cropping.

Table 1. Land use statistics for the major statistical divisions in N.S.W. (Australian Bureau of Statistics 1988).

	Total area	Cropped area	Area of sown pasture	Area of natural pasture	Area of natural pasture
Statistical division (SD) or sub-division (SSD)	(ha)	(ha)	(ha)	(ha)	(%)
Northern Tablelands SSD	2189361	46290	691755	1451316	66.3
Northern Slopes SSD	2652268	581331	161175	1909762	72.0
Hunter SD	1438649	94540	182708	1161401	80.7
Central Macquarie SSD	2624432	493113	389018	1742301	66.4
Central Tablelands SSD	768452	39002	330614	398836	51.9
Bathurst - Orange SSD	96415	13597	44090	38728	40.2
Central Tablelands + Bathurst-Orange	864867	52599	374704	437564	50.6
Lachlan SSD	4064779	936702	778669	2349408	57.8
Southern Tablelands SSD	1802462	129631	870035	802796	44.5
Queanbeyan SSD	1422	168	1038	216	15.2
South Tablelands + Queanbeyan	1803884	129799	871073	803012	44.5
Central Murrumbidgee SSD	2211616	556268	801022	854326	38.6
Snowy SSD	677422	11448	208135	457839	67.6
Upper Murray SSD	993327	184242	373660	435425	43.8
Albury SSD	158140	31685	74046	52409	33.1
Upper Murray. + Albury	1151467	215927	447706	487834	42.4

The impact of grazing on grasslands

Pasture manipulation and management studies (*e.g.* Robinson and Dowling 1976; Robinson 1993), together with interpretations of floristic data based on grazed verses non-grazed sites and other information (*e.g.* Moore 1959; Benson 1991) provide some indication of how particular species and species groups have responded to grazing, fertiliser application and pasture improvement using annual legumes. The broad responses have been that the original tall-growing grasses have been replaced by short grasses, summer active species by winter growing species, perennials by annuals and native by introduced species.

The degree to which grasslands have changed depends largely on the intensity of the factors responsible for the change, and the time and the degree of recovery which may have occurred since the changes took place. For instance, areas which have been heavily fertilised, heavily grazed, and intensively pasture improved using subterranean clover least resemble the original grassland. The extreme of the switch has been that the tall, summer active perennial grasses have been displaced by short growing, introduced, winter active annual species (including broad leafed weeds), and today, large areas of the landscape are occupied by annual pastures containing only a low population of perennial plants. Areas which have been moderately pasture improved in the past may still contain a high proportion and diversity of native grasses but they rarely contain the same species as unimproved and ungrazed areas. Thus the species which are important in the pastures today, were rare in the original grassland, while species which were once prevalent have largely disappeared.

The result of the changes is that in place of the complex and patterned vegetation which was present before settlement, today's native or natural pastures consist of relatively simple mixtures of species (*i.e.* the overall species diversity (including shrubs and other species) has declined), and pastures have a similar botanical composition over a wide range of environments and soil types.

The ecotypes of grasses which remain in pastures today are there by default rather than by design and in the absence of deliberate selection and sowing of ecotypes known to posses superior traits, there is no reason to believe that they represent the best ecotypes for the particular situation. Broad based plant breeding and selection programs offer the only means of developing superior, adapted and persistent cultivars for sowing back into country most suited to native grass based pastures.

Agents of change

It is commonly believed that the changes which have occurred in native grasslands since European settlement are due simply to grazing and that the effect of grazing is due to defoliation and trampling (*e.g.* Donald 1970; Taylor and Whalley 1976). However, our knowledge of the processes of change is very limited. As well as being trampled and grazed, plants in grazed pastures are subject to a range of changed circumstances including changed light regimes, changed competitive relationships with other plants, changed patterns of water use, application of nutrients at near-toxic concentrations during urination and defecation, as well as differential and selective grazing. The general responses may be modified by other factors such as paddock size, grazing intensity, timing of grazing periods and rest periods, class of stock, fertiliser rate, frequency of application of fertiliser and so on. The situation is very complex and taken overall, grazing itself may be a minor factor in inducing change.

As well as being complex, the process of change is also dynamic. It may occur very quickly and in response to a particular set of circumstances. Cool season annual plants are favoured as invaders of tall-grass grasslands as pastures are opened up by burning and grazing because their life cycle is complementary rather than antagonistic to that of the perennial grasses and because they are shade tolerant. Patterns of germination, growth, flowering and seed set are important factors in their success. Because they grow earlier than warm season grasses, and use water rapidly in late spring, annual plants enjoy an out of phase competitive advantage which may result in a rapid loss of summer active species especially in a dry spring and summer and when the annual plants are growing vigorously. Rapid growth in spring by annuals restricts opportunities for seedling establishment by summer- growing perennials which have a high light requirement for germination and early growth. This effectively limits the period during which plants can reliably germinate and establish to the autumn which further encourages a shift away from summer active plants to cool season species. Factors which stimulate growth, such as fertiliser application and low stocking pressure increase the competitiveness of annual plants and reduces the persistence of summer growing perennials.

Although rainfall may vary markedly from year to year, and limiting soil conditions such as low fertility, and acidity can be ameliorated, resources available to a plant community are relatively fixed. Plants growing at the same time compete actively for the resources they need to sustain them and under a particular set of conditions, some plants compete better than others. For instance, where water supplies are restricted, plants which can survive long periods of water shortage, or plants which can grow and reproduce using only small quantities of water compete and reproduce better than plants which need a continuous and readily available source of moisture. Where water is plentiful, water saving plants are at a disadvantage compared with plants with a high water requirement and high growth potential. In grazed pastures there is a shift from native perennial grasses which require a steady and continuous supply of soil moisture, to more drought hardy species, and from grasses which achieve high rates of growth, to ecotypes which are lower growing and generally less productive especially in pastures which have been fertilised and semi-improved.

Some consequences

In looking at the ecological consequences of grazing on native grasslands, the question which needs to be considered is whether the "new" grassland is in better shape, and whether it is more productive and better adapted to being grazed than the original grassland. There is evidence from the northern and southern Tablelands that in some situations the grasslands which have evolved under grazing may be more productive than the original grasslands, and that several cool season species of native grasses which have become prominent in response to grazing (*Danthonia* and *Microlaena*) are more productive, nutritious and persistent than improved temperate grasses such as phalaris and cocksfoot growing under the same conditions. This is especially the case on less fertile soils and where fertiliser is applied at low rates, infrequently or not at all. It is also encouraging that many native grasses tolerate acid soil conditions to a greater extent than improved perennial grasses, and this may be a factor in tipping the balance against phalaris and cocksfoot, and in favour of native grasses on acid soils.

Natural vegetation is geared to using most of the resources (water, light, space and nutrients) available to it. Communities are diverse, and consist of layers of different species with different growth forms, and groups of species which grow at different times, or which draw their resources from different soil layers. This minimises competition and maintains stability. When components of the vegetation are lost, resources which are not fully utilised either go to waste or they become available to other species such as weeds.

The main consequences of losing summer active grasses from pastures is that soils have become drier in spring and wetter in autumn because water use has increased in spring and declined in summer. This means that the soils can hold less of the autumn rainfall and a greater amount of water drains away to water tables which leads to recharge. Less of the nitrate products of organic matter decay is also taken up because plants are not actively growing during the summer period of high nitrate availability. This leaves nitrate available to be leached which promotes soil acidification. The proportion of the soil surface not covered by vegetation also increases as pasture residues are grazed and break down which considerably increases the soil erosion potential in late summer and autumn. These problems are less evident in northern N.S.W. where summer active grasses are more prevalent, but in southern N.S.W. water tables are rising at a rate equivalent to about 11% of the annual rainfall of 500 mm; red brown earth soils are acidifying at a rate of around 250 kg lime/ha/year under annual vegetation, and soil erosion during summer and autumn is a major problem. Low soil pH is estimated to limit pasture and crop production over 13.5M ha of agricultural lands in eastern Australia (Coventry 1985).

Dryland salinity is emerging a major threat to agricultural production in southeastern Australia. Some 243,000 ha of once-productive lands in the Murray Darling Basin are saline (Murray-Darling Ministerial Council 1993, with updated estimates for Victoria provided by Allen 1994). The area of land affected is increasing at a rate of between 2 - 5% per year and over 1M ha is considered to be land at risk. Unlike problems of soil acidity and soil infertility which are treated by applying lime or fertiliser directly to the problem area, dryland salinity is landscape based and the source of the problem (recharge) is usually some distance from the saline site itself. Often the landholder with the salinity problem may need to depend on his neighbour to do something about the recharge.

Hilly landscapes, which are characterised by eroded, shallow, acid, infertile soils and which in the past have been pasture improved and have lost their cover of perennial grasses contribute disproportionally to problems of recharge while deeper more productive soils are at greater risk of becoming saline (Dyson 1993). On hill lands soil acidity is difficult and uneconomic to ameliorate and manage especially if they cannot be cultivated while perennial pastures are difficult to establish and improved temperate species are short-lived under grazing.

High costs of sowing and maintaining pastures, coupled with higher risks and lower returns mean that landholders are reluctant to invest in the extensive pasture improvement programs which are necessary if current trends in dryland salinity, soil acidification and loss of water quality are to be contained and reversed. The only viable options (aside from reafforestation) are to develop management guidelines which enhance the performance and persistence of the perennial grasses which remain on hill lands and to provide a range of superior commercially available cultivars of grasses which could be reliably sown and which would persist in low input grazing systems.

The role of legumes

Nitrogen is an essential component of protein, so in the absence of an effective means of converting atmospheric nitrogen into plant protein, pasture and animal production will always be limited. Legumes and their associated symbiotic bacteria are central components in cycling nitrogen within grazed pastures. However, legumes are also part of the problem in terms of persistence of native perennial grasses. Unfortunately, most legume research has focussed on improved and highly improved pasture situations and research has sought highly productive cultivars and management systems irrespective of their impact on grass persistence or land degradation. The role of legumes and their contribution to production under conditions of relatively low fertiliser input has been poorly researched. According to Dear and Virgona (1995) the role of legumes on production in low input situations hinges on three factors:

- the legume content needed to drive the required level of production both in terms of nitrogen needed by companion plants *and* in terms of the direct effect on animal production;
- the ability of the desired perennial components to tolerate that level of production; and,
- the level of additional input (fertiliser and perhaps management) needed to sustain the level of production desired.

Development of legumes for upland pastures, which are compatible with warm season perennial grasses, will most certainly require traditional ideas about fertiliser and yield performance to become secondary to issues such as legume persistence and the impact of legumes on the persistence of desirable grasses. This may mean that lower levels of nitrogen input may have to be accepted if a diverse perennial grass base is to be maintained.

What is needed

There is a pressing need to develop a wider range of summer growing perennial species which can be successfully sown back into degraded hill-land pastures, which are persistent under grazing, and which posses a capacity to respond productively to summer and autumn rainfall. Species of grasses which generally increase in abundance in response to grazing and pasture improvement, and ecotypes adapted to infertile, low pH soils and drier circumstances are likely to be most persistent. Persistence may be greater for species which are moderately palatable and ecotypes which are low growing and not necessarily highly productive. Adapted cultivars may also need to have a well developed capacity to maintain an adequate seed bank in the soil and to re-establish from seed following a catastrophic event such as a prolonged drought or intense fire.

There is also a pressing need to develop productive management guidelines for the most important grazed grassland types which occur in the southern temperate zone. These include tall cool season grasslands (*e.g. Poa* and *Stipa*), tall warm season grasslands (*Themeda*), short cool season grasslands (*Danthonia* and *Microlaena*) and short warm season grasslands (*Bothriochloa* and *Chloris*). Many grazed native grasslands which have not been subject to pasture improvement in the past still contain a mixture of warm and cool season species and these need also to be managed to maintain their diversity while still providing opportunities for productive grazing.

The LIGULE project (Low input grasses useful in limiting environments)

Australian native grasses offer adaptive advantages compared to non-indigenous species, however the agricultural potential of most species has not seriously been investigated. The LIGULE project aims to collect and evaluate a range of useful native grasses with the objective of identifying accessions which have potential to alleviate land degradation while sustaining production on hill lands. Research commenced in 1989 in collaboration with Meredith Mitchell from Agriculture Victoria's Rutherglen Research Institute and has since been expanded to include Craig Clifton from the Department of Conservation and Natural Resources, Centre for Land Protection Research at Bendigo Vic.

Thirty-three species were nominated as potentially useful based on information provided in Cunningham *et al.* (1981). Grasses which were likely to injure livestock, or those of low agronomic worth were excluded. A total of 807 Accessions were collected from 210 collection sites, located mainly in lower rainfall western N.S.W. and Victoria. These Accessions were planted out in nurseries at Wagga Wagga and Rutherglen and evaluated over a 2-year period.

The grasses were assessed for the following attributes about every 6 weeks:

- persistence (remaining numbers of live plants)
- vigour and responses to drought and frost
- plant size (height and diameter)
- morphology (growth habit, steminess, stem height), stage of growth and palatability
- insect and disease prevalence and damage

Accessions were grouped together based on the similarity of their performance over time using pattern analysis. A number of selection criteria were then applied which resulted in the nomination of 8 genera of grasses with superior attributes, and within these, a total of 20 accessions worthy of further evaluation.

The genera which were considered most likely to contain useful accessions were: *Bothriochloa, Chloris, Danthonia, Digitaria, Elymus, Enteropogon, Micro- laena*, and *Themeda*.

The 20 selected accessions have been established as spaced plants at 4 upland field sites near Cowra and Wagga Wagga N.S.W. and Rutherglen and Bendigo Vic. together with the following commercially available 'Control' cultivars: Consol lovegrass, Taranna wallaby grass, Porto cocksfoot and Sirosa phalaris.

The following measurements are being made each month:

- persistence and dry matter production
- herbage quality (digestibility and protein content)
- phenology, drought and frost responses, insect and disease prevalence and damage
- palatability at 1 site
- evapotranspiration at 1 site using ventilated chambers

Soil moisture status is being monitored to determine if accessions show marked differences in their ability to dry the soil profile and reduce deep drainage.

Concurrent with the 'core' research being conducted at the field sites, seed production and soil nutrient responses are also being investigated, and an intensive root growth study is also being conducted.

The research is expected to lead to the commercial release of a range of perennial native grass cultivars for use in grazed pastures on the uplands of the Murray-Darling Basin. In addition, it will provide some much needed data relating to the productive potential of species of native grasses which have not been researched in detail in the past. The concurrent moisture use and root growth studies will considerably boost our understanding of the role of native grasses in controlling recharge and other land degradation problems, while the seed production work will have a direct bearing on the prospects for early commercial release of material

Acknowledgments

The LIGULE project is jointly funded by the Meat Research Corporation, the Land and Water Resources Research and Development Corporation, N.S.W. Salt Action, the Victorian Salinity Bureau and the collaborating Agencies.

References

Allan, C., Millar, J. and Noble P. (1995). Perennial pastures in the upper Murray - a report on a landholder survey undertaken in North East Victoria. (Technical Report, Agriculture Victoria, Wodonga).

Allen, M.J. (1994). An assessment of secondary dryland salinity in Victoria. Technical Report No. 14; DCNR Centre for Land Protection Research Bendigo.

Benson, J. (1991). The effect of 200 years of European settlement on the vegetation and flora of New South Wales. *Cunninghamia* **2**: 343-370.

Benson, J.S. (1994). The native grasslands of the Monaro region: Southern Tablelands of N.S.W., *Cunninghamia* **3**: 609-650.

Coventry, D.R.. (1985). Changes in agricultural systems on acid soils in southern Australia. *Proceedings of 3rd Australian Agronomy Conference* 126-143.

Cunningham, G.M., Mulham, W.E., Milthorpe, P.L. and Leigh, J.H. (1981). "Plants of Western New South Wales" (Soil Conservation Service of N.S.W., Sydney.)

Dear, B.S. and Virgona, J.M. (1995). The role of legumes in low input perennial pasture systems of southern Australia. *Proceedings of the Second Australasian Perennial Grass Workshop*. Launceston Tasmania October 1995. pp. 225-239.

Donald, C.M. (1970). Temperate pasture species. In: "Australian Grasslands" (ed. R.Milton Moore) pp. 303-320 (Australian National University Press, Canberra).

Dyson, P.R.(1993). An overview of groundwater systems and the dryland salinity problem in Australia. *National Conference on Land Management for Dryland Salinity Control* Bendigo September 1993. (centre for Land Protection Research, Bendigo). pp. 78-80.

Johnston, W.H., Mitchell, M., Clifton, C., Waterhouse, D. and Koen T. (1995). The LIGULE project - an outline. *Proceedings of the Second Australasian Perennial Grass Workshop*. Launceston Tasmania October 1995. pp. 259-263.

Kemp, D.R. and Dowling P.M. (1991). Species distribution within improved pastures over central N.S.W. in relation to rainfall and altitude. *Australian Journal of Agricultural Research* **42**: 647-659.

Lodge, G.M. (1993). The domestication of the native grasses *Danthonia richardsonii* Cashmore and *Danthonia linkii* Kunth for agricultural use. 1. Selecting for inflorescence seed yield. *Australian Journal of Agricultural Research* **44**: 59-77.

Lodge, G.M. and Whalley, R.D.B. (1985). The manipulation of species composition of natural pastures by grazing management on the northern slopes of N.S.W.. *Australian Rangeland Journal* **7**: 6-16.

Moore, R.M. (1959). Ecological observations on plant communities grazed by sheep in Australia. *Biogeography and ecology in Australia (series Monographiae Biologicae)* **8**: 500-513.

Munnich, D.J., Simpson, P.C. and Nicol, H.I. (1991). A survey of native grasses in the Goulburn district and factors influencing their abundance. *Australian Rangeland Journal* **13**: 118-29.

Murray-Darling Ministerial Council (1993). "Dryland Salinity Management in the Murray-Darling Basin". (Ed. A. Beale) (Murray-Darling Basin Commission, Canberra.)

Robinson, J.B., Munnich, D.J., Simpson, P.C. and Orchard, P.W. (1993). Pasture associations and their relation to environment and agronomy in the Goulburn district. *Australian Journal of Botany* **41**: 627-636.

Robinson, G.G. and Dowling, P.M. (1976). Management of natural pastures on the northern Tablelands of New South Wales - a survey. *Australian Rangeland Journal* **1**: 70-74.

Rogers, R.W. and Whalley, R.D.B. (1989). Relationship between diaspore characteristics and distribution of grasses around sheep camps on the northern tablelands of New South Wales. *Australian Journal of Botany* **37**: 501-510.

Taylor, J.A. and Whalley, R.B.D. (1976). The philosophy of range management research in Australia. *Journal of the Australian Institute of Agricultural Science* **42**: 181-186.