Forage genetic resources — their national and international importance

R. REID
Department of Primary Industry & Fisheries, Kings Meadow, Tasmania, Australia

Abstract

Many areas in Australia have the potential for pasture improvement. In this paper, the history of pasture plant introduction to Australia is reviewed, and the contribution of exotic germplasm to improving pastures in the tropics is discussed. Methodology of germplasm collection is considered and it is concluded that there are still considerable opportunities for the introduction of novel and potentially valuable germplasm. The destruction of rangelands world wide makes it increasingly urgent that endangered forage germplasm is collected and conserved for the benefit of both Australia and countries overseas.

Introduction

Over about the last 60 years, some huge increases in animal production have been achieved in Australia, essentially by the amendment of soil nutrient deficiencies and the sowing of introduced pasture species.

This process started in the temperate zone, driven arguably by the success of sub-clover, and was later taken up in the tropics, associated with the rapid spread of Townsville stylo. As it became apparent that the early pasture cultivars were less widely adapted than originally claimed, the need to develop more variation within species or seek cultivars to meet specific requirements was recognised. To date, approximately 120 grass and 190 legume cultivars have been produced, and 4 nationally orientated forage germplasm genebanks have been established.

Correspondence: R. Reid, Department of Primary Industry and Fisheries, PO Box 46, Kings Meadow, Tasmania 7249, Australia

Setting the scene

Throughout Australia there are still many areas that have potential for pasture improvement, or are in some form of decline or degradation which could potentially be halted by the development of adapted cultivars. It is not within the scope of this paper to discuss every situation; nevertheless, I will present a few to illustrate the potential.

In the temperate areas, particularly in South Australia and Western Australia, there are approximately 2.5 Mha of deep sands where the existing pastures are non-productive and heavily weed-infested. Whilst *Ornithopus compressus* is a deep-rooted legume replacement for ill-adapted *Trifolium subterraneum* in the sands, there is currently a lack of grass options (perennial, biennial or annual) to increase productivity. The introduction of better suited grass species would have strong economic implications, and would also have conservation benefits such as increased water use, and good soil retention.

In New South Wales and Victoria, there are 4.6 Mha of cropping land that is rapidly acidifying, a process that can be halted or even reversed by the addition of a summer-active perennial grass. As yet, no such species has been found. All temperate areas have significant areas of pasture and cropping land under various levels of salinity, and there are limited cultivar options available for amelioration.

The tropical areas probably suffer less from overall land degradation, but there are significant areas of solodic soils in inland north and central Queensland where no legume species can be recommended with confidence. The clay soils of the brigalow region and the vertisols of northern and western Queensland still lack a proven legume option after 30 years of searching. *Desmanthus virgatus* is exhibiting a great deal of promise but is unlikely to be adapted to all situations. In south-east Queensland, although there has been some progress in finding suitable legumes tolerant of heavy grazing (*e.g. Arachis glabrata, Aeschynomene villosa* and *Vigna parkeri*), there is still a requirement for further cultivars to cover all soil types and grazing enterprises.

There are large areas in north and central Queensland where the native grass species are in rapid decline, brought on by a combination of drought and overgrazing. In the catchments of the large dams, such as the Upper Burdekin catchment, soil erosion is increasing rapidly and well adapted perennial grasses are required. Further, in the cropping areas of central Queensland, there is a role for short-lived, but highly productive, grasses and legumes for ley pastures.

Genetic resource programs

By the beginning of the twentieth century, temperate Australia was already relatively well endowed with both deliberately introduced and adventive pasture species (that is compared with the tropics). Building on this, a combination of state programs, in co-ordination with CSIRO, gradually evolved a plant introduction process that markedly increased the germplasm base. Thus, the Western Australians developed a *Trifolium* Genetic Resource Centre, the South Australians, a *Medicago* Genetic Resource Centre, and later, the CSIRO, a Tropical Pasture Genetic Resource Centre. Currently, the Margot Forde Forage Germplasm Centre in New Zealand curates the temperate perennial grasses and legumes for both New Zealand and Australia.

Since the late 1950s, collecting missions have been conducted, mainly to the Mediterranean region, with the purpose of introducing adapted forages for southern Australia. Although these missions have not as yet supplied germplasm to fill every requirement, they have resulted in the production of a series of cultivars, particularly from *Trifolium subterraneum, Ornithopus compressus* and the *Medicago* species. In contrast, acquisition of germplasm of other alternative pasture genera has been incidental and based very much on the available time and initiative of plant collectors (Auricht 1994).

The deliberate search for tropical forage germplasm did not get underway until the 1930s. By 1962, some 2000 tropical forage legume accessions had been introduced by CSIRO, but about half of these had been lost through deterioration of seed (Williams 1962). Most had been introduced through correspondence, but missions by Hartley to South America in 1947 and Miles to South Africa in 1952 provided a real stimulus to the process. Both missions provided material previously unknown to agriculture, for example *Lotononis bainesii* and *Macroptilium atropurpureum*; within a few years, forage cultivars were developed from these 2 species, which are still sown today. By 1984, the collection of tropical forage germplasm had grown to be the largest in the world, with a total of 16 000 viable accessions comprising 12 000 legumes and 4000 grasses.

Since then, further collecting, and networking with many of the international collections, has resulted in the Australian Tropical Forages Genetic Resource Centre (ATFGRC) now holding some 15 000 legumes and 10 000 grasses. As a resource for development of tropical forages, the ATFGRC collection is probably the most important in the world.

A measure of the success of this centre and its co-operating programs has been the number of cultivars released by the respective Herbage Plant Liaison Committees of Queensland, New South Wales and the Northern Territory, a total of 70 grasses and 58 legumes (6 temperate in origin). However, only a limited number are in widespread use and most of these are available for the medium and high rainfall environments.

It is somewhat more difficult to assess the impact of released cultivars on the pastoral industries of the tropics and subtropics relative to those in temperate regions. Some, such as Biloela buffel and Verano stylo, have gained quick acceptance and have proved to be well adapted over large geographical areas. Others, such as Tinaroo glycine, are widespread within a narrow geographical range. Some have been successful initially only to succumb to disease, *e.g.* Townsville stylo, or are characterised by fluctuating populations in pastures, *e.g.* Miles lotononis, or have proved to lack persistence under heavy grazing, *e.g.* siratro. Others, such as Dalrymple vigna, have simply not made the grade.

The situation with temperate perennial grasses is such that the principal genetic resource collections can probably provide adequate germplasm for most species originating in north-west Europe. Exchange protocols are in place and contacts maintained between Australian users and the major centres. There have been both organised and opportune collections of the 4 major species, *viz. Dactylis glomerata, Festuca arundinacea, Lolium perenne* and *Phalaris aquatica*, in the Mediterranean, North African and Near East regions, and it is likely that much of the genetic variation has now been captured. However, within the above regions, some specific areas still warrant detailed exploration, with the highest priority being Algeria (Reid 1994).

Alternative pasture species, including those from the genera *Bromus, Elytrigia, Hordeum* and *Thinopyrum,* are very poorly represented in Australasian collections, and little better represented in genebanks overseas. The few available accessions hardly represent the main habitats or the distribution range found in their area of origin. Consequently, ecological considerations can rarely be applied in selecting specific accessions for screening. The potential of a species can be assessed better when the collections available for evaluation represent the entire distribution range and the ecological niches where the species occur naturally. Unfortunately, this ecogeographical information is inadequate for the majority of the germplasm of interest (Reid *et al.* 1994).

Opportunities for further development

Opportunities for the development of both germplasm already held in genebanks and that still to be collected, are many and varied, and probably limited only by the wedding of well adapted germplasm to an imaginative idea. An example of this is the African *Trifolium* species. These have received little attention from plant evaluators in Australia, or overseas, with the exception of the development of Kenya white clover (*Trifolium semipilosum*). Twenty-nine introductions of 12 species were evaluated in the early 1960s at Samford, south-east Queensland (Mannetje 1964), and, as the annual species failed to regenerate, no further work was undertaken. However, this research did point to the value of 2 species as potential annual forage crops in the coastal subtropics. Chen *et al.* (1993) reported on the evaluation of a collection of African *Trifolium* species at Armidale, NSW, where all grew for one season only and failed to regenerate in subsequent years. Some species lacked appropriate rhizobia and further work was not recommended for the New England area. In the Ethiopian Highlands, a study of 34 *T. tembense* accessions native to the region showed a large amount of variation within the species. The relatively high yields with low levels of P application suggested that they are a potentially useful source of forage within the present farming systems in the region (Akundabweni 1985). Research in east Africa indicated that some perennial species, while possessing useful characteristics, were of low productivity and persistence (Bogdan 1956). For example, *T. cryptopodium* is a mat-forming species, common at altitudes between 2000 and 4000 m on most mountains in the region. It is described by Ibrahim (1989) as being highly palatable but of low forage production due to its small size. However, in a study by Kahurananga (1987) of 98 accessions of perennial African *Trifolium* species, *T. cryptopodium* not only had the highest dry matter production but also persisted under heavy grazing.

From this, it would seem that, from a global perspective, the potential for further development of the African *Trifolium* species has scarcely been recognised. The group is well represented in southern Africa from sea level in Cape Province to the highest altitudes in Lesotho. It is from here that the germplasm likely to be of value in Australia is found, as both climate and latitude have parallels. There is, however, some degree of urgency in the collection of this germplasm. Moss (1991) reported from Lesotho that *T. africanum* and *T. burchellianum* are considered to be most desirable constituents of the natural mountain pasture, but that, at some sites, continued overgrazing was taking its toll, and the species were no longer in evidence.

Invariably many "non-mainstream" species have been developed into cultivars because of the persistence and dedication demonstrated by individual researchers. Later, these species went on to become mainstream and this is well illustrated by the early championship of *Desmanthus virgatus* by R.L. Burt in the tropics and *Ornithopus compressus* by John Gladstones in the temperate zone.

Some adventive species are distributed widely and significant components of pasture systems, but have a narrow genetic base. Within some of these, there is considerable scope for improvement through focused collecting. For example, both *Paspalum dilatatum* and *Pennisetum clandestinum* are broadly adapted to the warm temperate and subtropical regions of Australia. Both species have undesirable characteristics, low quality at maturity, poor winter growth, ergot infection in the former, and poor seed production in the latter. As yet, there has been no systematic attempt to improve on these characteristics by widening the genepool, and then either through selection or breeding, producing cultivars that would have broad acceptance. *P. dilatatum* is known to be variable within Argentina and southern Brazil and a number of forms have been recognised. *P. clandestinum* is found on separated mountain systems in eastern Africa that have never been explored for pasture germplasm, which is somewhat surprising considering the global importance of the species.

A number of missed opportunities can be noted from personal experience. *Psoralea obtusifolia* is a ground-hugging perennial legume from the Kalahari region of southern Africa, where it is recognised as being an excellent, although somewhat rare, forage plant (Leistner 1967). Germplasm introduced to Australia in the early 1970s proved to be drought-tolerant, but produced little or no seed. This same germplasm, when introduced to a medium altitude site in Mexico with 300 mm annual rainfall, produced large quantities of seed, and was identified as a species worthy of further regional testing.

In northern Mexico, I collected a perennial *Stylosanthes* species growing on a vertisol in an area similar in climate to the western slopes of New South Wales. Grown initially in Townsville, it performed poorly in the tropical humid climate and, although seed was later produced in Charleville (F. Smith, personal communication), no further evaluation was undertaken.

There are many other species, much better known, that are yet to make an impact in the global scene. In particular, forage legumes that can withstand very heavy continuous grazing are in very short supply. In many developing countries, cheap seed is not an important selection criterion, and ability to propagate vegetatively is an advantage. Species such as *Desmodium heterophyllum* in the humid tropics, particularly on basaltic soils, *Arachis glabrata* in the humid subtropics, and *Trifolium ambiguum* at very high altitudes, such as the Himalayas and the Andes, have enormous potential, not the least through their capacity to conserve soil and prevent erosion.

Finally, I would like to mention an opportunity that has so far received little attention, with one notable exception. This concerns the development of cultivars specifically to address problems overseas. The exception is a program to develop cold-tolerant medics for those areas of the Mediterranean region that are too cold for the cultivars developed in Australia. Successful cultivars for this and other similar programs would be produced by the burgeoning Australian Seed Industry. Within the Autralasian Centres, there is almost certainly germplasm that can be developed to address identified overseas problem areas. Examples would include *Stylosanthes* for the African Sahel, *Digitaria* and *Urochloa* species for the Mexican subtropics, *Medicago* cultivars for the Tibetan and Mexican plateaux and a suite of annual legumes to grow in the south-east Asian rice paddy fallows.

The collecting process

With a few notable exceptions, most collecting missions have been of short duration, usually within the range of 3–8 weeks. In fact, it is probably true to say that most of the "easy" missions have been done and the reasons for this are obvious. The areas selected for collection are usually politically stable, there is ease of access by conventional vehicles, accommodation is available within reach of the collecting sites, permission to remove the germplasm has been readily granted, but, most importantly, the cost of the missions has not been excessive.

As our knowledge base widens and the pressures on plants increase, there is now a clear need to get "off the beaten track". Germplasm collectors will have to be prepared to walk into previously inaccessible areas, to camp where no accommodation exists and, quite simply, to rough it. These missions will not be cheap to mount as they will require not only longer stays in the target area but also specialised equipment, and in some cases, protective support. They will, however, in all likelihood, be linked to the other collecting agencies, such as conservation groups seeking to save species under threat.

The days when plant collecting required no more forethought than a holiday, and indeed fewer obligations, have now virtually gone. It has now become a virtual imperative that the collection process be undertaken by networks. This is not a new idea in that a number of successful collaborative germplasm acquisition projects have taken place. The 12-year project in the collection of *Arachis* in South America by personnel from

EMBRAPA, ICRISAT, USDA, IPGRI and the University of Corrientes, Argentina, serves as an excellent example (Simpson 1990).

An even more efficient collecting methodology is to base one or more persons within a prime target region. Supported from a multilateral-funded national staff base, working and training with national staff, this will give a greater degree of flexibility to the collection process. Being able to re-visit sites enables the collection of seed at optimum times, and, where necessary, acquisition of vegetative germplasm that can be grown back at the base. This ability to collect usually guarantees success (Sackville-Hamilon and Charlton 1995). A small-scale mission of this type was undertaken by an FAO-UNDP Forage Plant Development and Extension Project during the period 1975–1982. Unfortunately, much of the seed collected was inadequately stored and, although a rescue mission was undertaken by a consortium of Nordic Aid Agencies, very little material survived (IBPGR 1991).

There is a need for a comprehensive longer-term collection of forage germplasm in Kenya. This would provide opportunities to collect an enormous range of material from the seasonally wet-dry coastal region through to the highest peaks with their alpine/subalpine flora, also including the semi-desert area in the north of the country. An internationally funded project of this nature would offer a great deal to all participants but particularly to Kenya itself, which could reap the cash benefit from the development of its germplasm. The setting up of such a project would be complex and would take time, but when completed, it would go a long way to ensure that the germplasm would be both secure and widely disseminated to all potential end users. Similar projects should be considered for South Africa, southern Argentina and the Himalayan region, as a matter of urgency.

There are essentially 2 forms of collecting, namely, the exploratory and the focused. The former has been superseded as both geographic regions and individual species have become better known. It still, however, has value in those regions that are relatively poorly known botanically. Such areas would include the Horn of Africa, most of western China, central Asia, Sudan, Angola and Algeria. Most experienced collectors and germplasm curators would agree on which large regions still remain to be explored. The order of priority may differ depending on the perceived value of the germplasm or on the access to a particular region.

Focused collecting tends to be more diverse. Some missions will deal with 1 or 2 genera which are required for a particular purpose. Examples are drought-tolerant *Lolium perenne* in Spain or anthracnose-resistant *Stylosanthes* species in South America. Others will collect all variants in genera known to be used as pasture plants, and, in addition, species unknown to agriculture if they seem to be eaten by livestock and possess agronomicaly important environmental adaptations or morphological attributes. Priority regions for further collecting and target species are listed in Table 1.

International influences

At the 1992 Earth Summit in Rio de Janeiro, the Convention on Biological Diversity — ratified by more than 150 countries, including Australia — affirmed that 'States have sovereign rights over their own biological resources'. It also recognised that 'economic and social development, and poverty eradication are the first and over-riding priorities of developing countries'.

Herein lies the great dilemma for the forage genetic resource expert. The acquisition of germplasm is clearly going to become more difficult, if only because Governments see an opportunity to make money, while at the same time Third World agriculture will take longer, if ever, to receive the benefits.

It is even more important for the forage genetic resource fraternity to act decisively if they are to have any influence on the future collection and evaluation of germplasm. They are, indeed, obliged to inform the developing world through national and international agencies, where the great opportunities are to be found.

Although no comprehensive global assessment of the extent of grassland exists, the best estimates are from the Food and Agriculture Organisation (FAO 1994). About half the land area of the world can be classified as grazing land. The intensity of use of available grazing land varies significantly from one country to another. For example, 23 Mha of grass savanna in Indonesia are currently under-utilised, while almost all vegetation types accessible to livestock in India are heavily grazed or overgrazed.

Table 1a. Forage germplasm collecting opportunities considered to be of high priority in southern and north Africa.

District	Species	Comments	Australian target environments	Target environments overseas
Lesotho; O.F. State; Eastern Cape Province (subhumid)	*Trifolium africanum*	Very palatable; returns under rotational grazing	North and central slopes and tablelands of NSW	Mexican Plateau
	Trifolium burchellianum	Drought-tolerant		
	Panicum stapfianum	Heavy carrying capacity		
	Pennisetum sphacelatum	Remains green all year		
	Tetrachne dregei			
Lesotho (high altitude)	Perennial *Trifolium*	Acid soil-tolerant	Southern NSW Tablelands; Eastern Victoria	High Andes of Peru & Bolivia; Himalaya; southern China
	Bromus firmior	Very palatable		
	Fingerhuithia sesleriformis	Clay soils		
	Helictotrichon turgidum	Moist sites, evergreen		
	Pentaschistis galpinii	Tolerates heavy grazing		
	Secale africanum	Very rare, very palatable		
O.F. State; Eastern Cape Province (semi-arid)	*Digitaria eriantha*	Variable, valuable natural pasture	Darling Downs, Qld; NSW slopes	North-east Mexico; northern Argentina
	Fingerhuithia africana	Limestone, very palatable		
Western Cape (dry Med. climate)	*Chaetobromus dregeanus*	Very drought-tolerant Palatable, sandy soils	Sandy soils — southern WA and SA	Central Chile; northern Mexico; Morocco
Eastern Transvaal (low altitude)	*Brachiaria nigropedata*	Palatable, sandy soils	Central & southern Qld	American dry tropics
	Digitaria (complex)	All soils, very variable		
	Panicum deustum	Green in dry season		
	Urochloa oligotricha	Rhizomatous, palatable		
	Stylosanthes fruticosa	Drought-tolerant		
	Vigna spp.	Grazing-resistant types		
Angola (subhumid)	*Digitaria eriantha*	High quality	Central Qld	Central Brazil; medium altitude south-east Asia
	Digitaria milanjiana	Clay soils		
	Urochloa oligotricha	Very palatable		
	Vigna spp.	Rhizomatous		
Mozambique (subhumid)	*Digitaria gazensis*	Very palatable	North Qld & NT	American dry tropics
	Digitaria milanjiana	Drought-tolerant		
	Alysicarpus zeyheri	Seasonally waterlogged		
	Vigna monophylla	Drought-tolerant		
Algeria (mountains)	*Avena macrostachya*	Perennial	South-eastern Australia	Southern Chile; Argentina
	Dactylis glomerata	Cold & drought-tolerant		
	Festuca arundinacea	Cold & drought-tolerant		
	Lolium perenne	Cold & drought-tolerant		

Table 1b. Forage germplasm collecting opportunities considered to be of high priority in east Africa.

District	Species	Comments	Australian target environments	Target environments overseas
High mountains; Kenya; Tanzania; Ethiopia; Uganda	*Digitaria gazensis*	Seasonally waterlogged areas	Subtropical humid Qld and NSW	Humid Andes; south-east Brazil; south China
	Helictotrichon milanjianum			
	Pennisetum clandestinum	Moist soils, well grazed		
	Setaria sphacelata	Well known		
	Trifolium spp.	Very variable, well known		
	Vigna parkeri			
Semi-desert Kenya	*Dactyloctenium bogdanii*	Sandy soils, palatable	Inland northern Qld; semi-arid NT and WA	North-east Brazil; India
	Digitaria macroblephara	Vertisols		
	Sporobolus helvolus	Vertisols, very palatable		
	Sporobolus nervosus	Salty soils, palatable		
	Indigofera schimperi	Vertisols, very palatable		
	Alysicarpus ovalifolius	Sandy soils, loams		
Sudan (subhumid)	*Anthephora nigritana*	Clay soils	North Qld & NT	American semi-arid tropics
	Cenchrus setigerus			
	Chloris roxburghiana			
	Digitaria macroblephara			
	Digitaria nodosa			
	Alysicarpus ovalifolius			
	Indigofera schimperi			

Table 1c. Forage germplasm collecting opportunities considered to be of high priority in the Americas and south Asia.

Region	District	Species	Comments	Australian target environments	Target environments overseas
South America	Warm, humid parts of Argentina	*Agropyron scabrifolium*	Palatable good natural pasture	Central slopes NSW wherever currently adapted	South Africa; southern China
		Bromus unioloides	Very variable, very palatable		
		Paspalum dilatatum	Very palatable		
	Cold, humid parts of Argentina	*Bromus mango*	Summer-growing, very palatable	Cool temperate areas; Victoria; Tasmania	South-west Europe; Pacific coast USA
		Festuca gracillima	Rare, heavily grazed natural pasture		
		Poa ligularis	Variable, valuable natural pasture		
	North-east Brazil (semi-arid)	*Arachis* spp.	Many species unknown to agriculture	North Qld & NT	Sahelian Zone; semi-arid east Africa
		Aeschynomone spp.			
		Centrosema spp.			
		Macroptilium spp.			
		Stylosanthes spp.			
	Mediterranean Chile	*Bromus stamineus*	Good natural sheep pasture	Victoria; Tasmania	South-west Europe
		Bromus valdivianus	High rainfall, very palatable		
North America	Pacific coast states (cool Mediterranean)	Perennial *Trifolium* spp.	Rhizomatous habit	Victoria; Tasmania	South-west Europe
		Annual *Trifolium* spp.	Acid soil tolerance		
		Lotus purshianus	Acid soil tolerance		
		Lotus scoparius	Acid soil tolerance		
		Bromus marginatus	Palatable and variable		
	North-east Mexico	*Desmanthus* spp.	Semi-arid climate	South-east Qld; northern and central slopes of NSW	South Africa
		Leucaena retusa	Vertisols		
		Stylosanthes spp.			
South Asia	Himalayan valleys (high altitude)	*Bromus inermis*	Known species, summer active, winter-dormant	Southern NSW; Victoria; Tasmania	Temperate Andes
		Dactylis glomerata			
		Festuca ovina			
		Trifolium repens			
		Medicago falcata			
	Low altitude	*Dactylis glomerata*	Heat tolerance	South-east Qld; northern NSW	Subtropical Andes; south-east Brazil
		Cajanus elongatus	Palatable		
		Pueraria thompsonii	Productive		
		Vigna spp.	Persistent		
	Central Burma (subhumid)	*Cajanus* spp.	Drought-tolerant	North Qld; NT	
		Alysicarpus vaginalis	Acid soil		
		Desmodium heterocarpon	Acid soil		

In recent years, pastoralists in much of the world have had to contend with the gradual loss of grasslands, as they are converted to cropland. The highest loss of grazing lands is occurring probably in the semi-arid zones of Sub-Saharan Africa, but also in South America, especially northern Argentina and southern Brazil. In many, stock numbers have not decreased in the remaining lands and this has resulted in a pronounced increase in overgrazing, soil erosion and loss of plant diversity.

China provides an example of both the pressures on grazing lands and the opportunities for pasture improvement. The World Bank classifies approximately 55% of the total agricultural land in China as range and pasture. The majority of the grazing lands occur in the northern and southern zones where soil erosion, overgrazing and plant cover deterioration is seemingly ubiquitous. In southern China, which contains more than 40% of the livestock, the grazing lands are in ecologically better condition, but animal production tends to be low because of poor soil fertility and the low nutrient value of the native forage.

Chinese pasture scientists estimate the cultivated pasture area will have to expand to at least 20% of the total grazing lands if China is to develop its livestock industry fully. This will, of necessity, create a demand for pasture cultivars that are adapted to a range of environmental conditions and commercial practices. Much of this pasture expansion will occur in southern China where, depending on altitude, tropical, subtropical and warm temperate climates prevail. There are 52 Mha of grasslands in the region that are capable of improvement, potentially using germplasm developed in eastern Australia (Zhu 1993).

Conclusion

Australia has come a long way in a relatively short time in the development of forage genetic resources, and pasture plant introduction will almost certainly continue to be the main source of germplasm for the foreseeable future. The collection process, while focusing on high-potential germplasm, should also maintain a broad-brush approach as there is no way of telling what tomorrow's needs may be and what species may be required to fill them. The Australasian Forage Genetic Resource Centres are repositories of germplasm which has the potential to make a major contribution to the sustainability of global agriculture

Many useful pasture plants are still to be discovered if the evidence of the last 30 years is any indication, but forage germplasm collections are all too often just ahead of the land clearers, and in some cases, a long way behind.

References

AKUNDABWENI, L.M.S. (1985) Forage potential of some native annual *Trifolium* species in the Ethiopian Highlands. In: Haque, I., Jutzi, S. and Neate, P.J.H. (eds) *Potentials of Forage Legumes in Farming Systems of Sub-Saharan Africa*. (ILCA: Addis Ababa, Ethiopia).

AURICHT, G. (1994) Scope and availability of alternative pasture legume germplasm. *Proceedings of the Second National Alternative Pasture Legumes Workshop. Technical Report No. 219, Primary Industries, South Australia.*

BOGDAN, A.V. (1956) Indigenous clovers of Kenya. *East African Agricultural Journal*, **22**, 40–45.

CHEN, W., HILL, M.J. and BLAIR, G.J. (1993) African clovers and miscellaneous legumes on the Northern Tablelands of NSW. *Australian Plant Introduction Review*, **24**, 1–9.

FAO (1994) *Production Year Book 1993*. (FAO: Rome).

IBPGR (1991) *Annual Report 1990*. (IBPGR: Rome).

IBRAHIM, K.M. (1989) *An Illustrated Manual of Kenya Legumes*. (FAO: Rome).

KAHURANANGA, J. (1987) The screening of perennial *Trifolium* species mainly from the Ethiopian Highlands and their potential for use in pasture. In: Dzowela, B.H. (ed.) *African Forage Plant Genetic Resources, Evaluation of Forage Germplasm and Extensive Livestock Production System.* pp. 120–126. (ILCA: Addis Ababa).

LEISTNER, O.A. (1967) The plant ecology of the southern Kalahari. *Botanical Survey of South Africa. Memoir No. 38.*

MANNETJE, L.'t (1964) The use of some African clovers as pasture legumes in Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **4**, 22–25.

MOSS, H. (1991) *Wild Species Collecting in Lesotho*. (IBPGR: Rome).

REID, R. (1994) The role of introduced grasses other than *Lolium perenne, Dactylis glomerata, Phalaris aquatica* and *Festuca arundinacea*, in the pastoral systems of temperate Australia. *New Zealand Journal of Agricultural Research*, **37**, 399–404.

REID, R., BETTENCOURT, E. and TIBBITS, S. (1994) Genetic resources for temperate perennial grass improvement programmes in Australia. *New Zealand Journal of Agricultural Research,*, **37**, 439–444.

SACKVILLE-HAMILTON, N.R. and CHARLTON, K.H. (1995) Collecting vegetative material of forage grasses and legumes. In: Guarino, L., Ramanatha Rao and Reid, R. (eds) *Collecting Plant Genetic Diversity: Technical Guidelines.* (CAB International: Wallingford).

SIMPSON, C.E. (1990) Collecting wild *Arachis* in South America, past and future. In: *Report of a Workshop on the Genetic Resources of Wild* Arachis *Species. IBPGR International Crop Network Series,* **2**, Appendix 4. pp.10–17. (IBPGR/ICRISAT: Rome).

WILLIAMS, R.J. (1962) The search for new pasture legumes. *Plant Introduction Review*, **2**, 10–17.

ZHU, B. (1993) Problems and suggestions on developing Southern China grassland. *Proceedings of Conference on Grazing Industry in Southern China*. (Gansu Grassland Ecological Research Institute).